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Introduction

15.1 This Chapter assesses the potential effects of the Proposed Development in relation to:

- Shadow Flicker.
- Climate and Carbon Balance.
- Glint and Glare.
- Risk of Accidents and Other Disasters.
- Population and Human Health.
- Air Quality.
- Eskdalemuir Seismic Array.
- Telecommunications and Other Infrastructure.
- Waste and Environmental Management.

15.2 Elements relating to major accidents and disasters have also been addressed in the individual technical discipline chapters where relevant.

15.3 Impacts on population and human health have also been addressed in the individual technical discipline chapters where relevant.

15.4 This assessment has been undertaken by SLR Consulting.

15.5 The chapter is supported by figures 15.1 and 15.2, and Technical Appendices 15.1 and 15.2, which are referenced in the text where appropriate.

Shadow Flicker

Introduction

15.6 This section of the chapter summarises the potential effect of shadow flicker associated with the Proposed Development.

15.7 Under certain combinations of geographical position and time of day, when the sun passes behind the rotors of a wind turbine and casts a shadow over neighbouring properties, as the blades rotate, the shadow may appear to flick on and off, when viewed through a narrow aperture such as a window. The phenomenon occurs only within buildings where shadows are cast across a window aperture, and the effects are typically considered to occur up to a maximum distance of 10 times the rotor diameter from each wind turbine. This effect is known as shadow flicker.

Policy and Guidelines

15.8 The following policy and guidance documents have been referred to in undertaking the assessment:

- Scottish Government - National Planning Framework 4 (2023).
- Scottish Government - Onshore wind policy statement 2022 (and its predecessor Onshore wind turbines: planning advice, now withdrawn).

- Dumfries and Galloway Council□s (D&GC□s) Local Development Plan 2 (2019) and associated Supplementary Guidance □Wind Energy Development: Development Management Considerations□, including Appendix C: Wind Energy Landscape Sensitivity Study.
- Northern Ireland, Planning Policy Statement 18: Renewable Energy (2009).
- Department of Energy & Climate Change (DECC) - Update of UK Shadow Flicker evidence base (2011).

15.9 The report on shadow flicker from the DECC (2011) indicates a general rule of ten rotor diameters should be used for separation distance from a wind turbine position to a dwelling. Scottish Government guidance Onshore wind turbines: planning advice advocates that beyond this distance there should be no adverse impact from shadow flicker. This document has now been withdrawn but is referenced as there is no other Scottish Guidance on the assessment of Shadow Flicker available.

Consultation

15.10 Consultation was undertaken through the EIA Scoping Report. No further consultation has been undertaken. There were no specific requests relating to the shadow flicker assessment provided in the scoping opinion, so it has been assumed that the proposed approach is acceptable to all consultees.

Assessment Methodology and Significance Criteria

Study Area

15.11 The update to Shadow Flicker Evidence Base (2011), published by the then DECC states that assessing shadow flicker effects within ten times the rotor diameter of wind turbines has been widely accepted across different European countries and is deemed to be an appropriate area. It also states that shadow flicker effects on receptors in the UK are generally restricted to 130 degrees either side of north of the turbine, based on a review of policy and guidance in place at the time the document was written.

15.12 The Scottish Government's withdrawn Onshore wind turbines: planning advice (2014) document states that:

15.13 *"Under certain combinations of geographical position, time of day and time of year, the sun may pass behind the rotor and cast a shadow over neighbouring properties. When the blades rotate, the shadow flicks on and off; the effect is known as 'shadow flicker'. It occurs only within buildings where the flicker appears through a narrow window opening. The seasonal duration of this effect can be calculated from the geometry of the machine and the latitude of the potential site.*

15.14 *Where this could be a problem, developers should provide calculations to quantify the effect. In most cases however, where separation is provided between wind turbines and nearby dwellings (as a general rule, 10 rotor diameters), 'shadow flicker' should not be a problem. However, there is scope to vary layout/reduce the height of turbines in extreme cases".*

15.15 Neither National Planning Framework 4 (NPF4) (2023) or the Scottish Government's Onshore Wind Policy Statement (2022) contain technical details regarding the assessment of shadow flicker.

15.16 Supplementary Guidance ‘Wind Energy Development: Development Management Considerations’ to the D&GCLDP2 states that *“Maintaining a separation distance of at least 10 times the turbine rotor blade diameter from sensitive uses/receptors can help reduce the effects but this may need to be extended depending on specific locational circumstances.”*

15.17 The assessment was therefore carried out based on a study area of 10 rotor diameters for the candidate turbine V162 (plus 50m micrositing) giving an overall study area of 1,670m from the proposed turbines[1] (See Figure 15.1).

15.18 Shadow flicker effects are only considered during the operational phase of a wind farm development, and do not occur if the turbines are not rotating or if the sun is not shining.

Assessment Methodology

15.19 The shadow flicker assessment comprises numerical modelling of the proposed turbines and receptors within the defined study area. It is noted that whilst there are a number of computer models available, the DECC study (2011) confirms that there are limited differences between outputs of the various packages. For shadow flicker assessments, SLR Consulting use one of the industry standard software packages, ReSoft Wind Farm software (version 5.1.2.1).

15.20 The calculations from this assessment process assumes a worst-case scenario based on the sun shining during all daylight hours over the course of a year, no obscuring features (such as trees, hedges, other buildings) being present, the face of the rotor always being aligned towards the dwelling, and that the rotor is always turning (i.e. the wind is always blowing between 4m/s and 25m/s, and no account is taken of shut down periods for maintenance). This methodology yields a theoretical maximum indication of potential shadow flicker incidence, together with the times of day, and dates during the year when potential incidence may occur.

15.21 The levels of shadow flicker at each receptor have been calculated based on a ‘greenhouse’ modelling approach, where the full length of each façade of a building is modelled as a window (and is therefore sensitive to shadow flicker). Each modelled window is assumed to have a mid-point height of 3m. This approach has been taken in order to present a worst-case estimate of shadow flicker, in the absence of any detailed window location data. In reality, only the glazed area of each façade would be sensitive to shadow flicker effects, therefore modelling the full façade will result in higher predicted levels than will actually be possible.

15.22 The software performs calculations to determine the position of the sun throughout the year, and thus during what times of day it will theoretically cast a shadow across the windows of nearby houses within the defined study area (plus 50m micrositing). Data input into the model where shadow flicker assessment is required is as follows:

- The locations of all properties within 1,670m of the turbine locations.
- The dimensions and orientations of windows facing the Proposed Development □ for the purpose of this model the full length of each fa|ade of a building is modelled as a window (and is therefore sensitive to shadow flicker). Each modelled window is assumed to have a mid-point height of 3m.

[1] Candidate turbine’s rotor diameter is 162m, 10*162 = 1,620m, plus 50m micrositing = 1,670m.

- The surrounding topography (Ordnance Survey Digital Terrain Model).
- The locations and dimensions of the turbines.

15.23 The following sources of information, outlined in **Table 15-1**, were used to inform this assessment.

Table 15-1: Sources of Information

Topic	Sources of Information
Residential Properties Location in relation to the Proposed Development.	Ordnance Survey (OS) 1:25,000 Mapping AddressBase data.
Topography Height data	OS 5m Digital Terrain Model (DTM) data

15.24 In practice, it is likely that shadow flicker effects would occur for considerably less time than the worst-case predictions, for the following reasons:

- In the UK, sunshine typically occurs for approximately 30% of daylight hours. At other times, the wind turbines are unlikely to cast shadows sufficiently pronounced to cause shadow flicker effects to occur.
- At times when the wind turbine rotor is not oriented directly towards the property, the duration of shadow flicker effects would be reduced due to the elliptical shape of the shadow cast.
- The assessment has been undertaken assuming a worst-case scenario which does not take into consideration the screening effect of anything located between the wind turbines (e.g., intervening structures or vegetation) and the property. The assessment also assumes that the property does have windows facing the wind turbines, which may not always be the case.

15.25 A "likely-case" scenario of shadow flicker effects has therefore also been included in the results section, based on the average sunshine hours experienced at the Proposed Development location.

15.26 Only those properties within 1,670m of the proposed turbines have been included in the calculations. The model has been run using OS terrain 5m DTM data which is the most accurate digital terrain data available for the Site.

Limitations to Assessment

15.27 There are several additional factors that can influence the amount of shadow flicker actually experienced and these cannot be readily included in a computer-based assessment.

15.28 Climatic conditions dictate that the sun is not always shining. The closest Met Office location is Carlisle, located approximately 18km from the Proposed Development. Historic Met Office data (over the period 1991 - 2020) gives actual sunshine hours for the Carlisle Met Station to be on average 32.4%[2] of total daylight hours. Cloud cover during other times may obscure the sun and prevent shadow flicker occurrence. While some shadows

[2] Average sunshine hours of 1,420.87 / total number of daylight hours 4,380 = 32.4%. Data from Met Office Climate Averages site available at: https://www.metoffice.gov.uk/research/climate/maps-and-data/location-specific-long-term-averages/gcvbs87js

may be cast under slightly overcast conditions, no shadow at all would be cast when heavy cloud cover prevails.

15.29 During calm periods, or very high winds, the wind turbine blades would not rotate, and shadow flicker would not occur. Turbines would also be periodically shut down for maintenance or repair work.

15.30 Wind turbines automatically orientate themselves to face the prevailing wind direction. This means that the turbine rotors would not always face directly towards the occupied buildings. Under some wind conditions, the proposed turbines would face ‘side-on’ to properties, and in these conditions only a very small area of blade movement would be visible.

15.31 Any screening provided by vegetation or structures has not been incorporated as the analysis has been run on bare ground terrain data as a worst-case scenario.

Assessment of Potential Effect Significance

15.32 Whilst the time and duration of shadow flicker events can be predicted accurately, the level of the effect is difficult to quantify as this would depend on the location of windows within a property, the use of the rooms affected, the level of shading surrounding the property and how susceptible the receptor is to light flicker.

15.33 As confirmed by the DECC study (2011), there is no standard Scottish or UK guidance relating to a limit for shadow flicker, and this remains the case. The only guidance providing additional recommendations is the Northern Irish PPS 18 (2009) guidance which recommends that for properties within 500m of the turbines, shadow flicker should not exceed 30 hours per year.

15.34 The assessment has therefore adopted a criterion of 30 hours of shadow flicker (under the likely-case assessment scenario outlined in paragraph 15.23) in one year as a significance threshold. Where less than 30 hours of shadow flicker is predicted to occur in one year at a particular property, this is considered to be not significant.

15.35 Whilst the distance between turbine and property does not affect the calculated shadow flicker exposure times, it does mean that the actual effect (i.e. the total exposure time and flicker intensity combined) of the Proposed Development would, in reality, be less than that calculated as a worst-case as a result of a reduction in shadow flicker intensity as the distance increases between a turbine and a receptor.

Requirements for Mitigation

15.36 Mitigation will be proposed to minimise or remove predicted effects, if levels of shadow flicker are deemed to be significant in practice in line with the Northern Irish PPS 18 (2009) guidance.

Cumulative Assessment

15.37 There are no existing, or in planning wind farms located in the local area such that potential cumulative shadow flicker effects would be experienced. Therefore, cumulative effects relating to shadow flicker are not considered further.

Baseline Conditions

15.38 175 residential properties have been identified which fall within the 1,670m study area. These properties could theoretically be affected by shadow flicker from the Proposed

Development (Figure 15.1). Details of the properties are shown in Table 15-2. Due to limitations in available information, indicative receptor locations have been used to estimate the shadow flicker effect at several additional properties where precise building locations could not be confirmed. The Westlands Country Park holiday lodges (located in the north west of the study area, are represented by receptor nine, which is positioned in the approximate centre of the park. In addition, there are 74 proposed residential properties with planning consent located in the south west of the study area, represented by receptors 45 to 49. Three of these five locations represent the outermost corners of the consented scheme. The other two receptors have been situated in the centre of the scheme, where the model shows that shadow flicker effects are more likely to be experienced.

Table 15-2: Receptors within the study area

Property ID	Receptor Name	Easting	Northing	Distance to Nearest Turbine (m)
1	Rowan Cottage	326972	569564	1,544
2	Pinewood Cottage	326990	569560	1,541
3	Croft End	327003	569570	1,552
4	Woodside Cottage	327006	569575	1,557
5	Longmeadow Cottage	327023	569591	1,575
6	Lamar Cottage	327036	569605	1,590
7	Larchfield	327043	569610	1,596
8	Broats	325182	569033	1,606
9*	Holiday Lodges	325629	568778	1,115
10	Flosh	326243	569146	1,234
11	Nutberry Farm	326688	568985	976
12	Cleughside	326639	569192	1,188
13	High Nutberry Farm	326826	569218	1,194
14	High Nutberry House	326863	569208	1,183
15	Caravan High Nutberry Farm	327050	569187	1,178
16	Hillhead Cottage	327470	569133	1,265
17	Calvertsholm Farm	328196	568914	1,604
18	Hillhead	327435	569022	1,151
19	Hillhead Cottage 2	327481	568639	873
20	Rigg Heads	328327	568395	1,512
21	Todholes 1	325103	567926	1,232
22	Todholes Cottage	325123	568009	1,216
23	Todholes 2	325247	568095	1,103
24	Todholes 4	325304	568013	1,036
25	**West Scales Farm**	**327512**	**567618**	**646**
26	**West Scales Bungalow**	**327658**	**567602**	**784**

Property ID	Receptor Name	Easting	Northing	Distance to Nearest Turbine (m)
27	**Redwood House**	**327616**	**567455**	**725**
28	4 Irvington	325677	566877	1,049
29	1 Adelaide Place	325212	566470	1,664
30	3 Adelaide Place	325235	566472	1,645
31	5 Adelaide Place	325253	566473	1,630
32	7 Adelaide Place	325273	566475	1,613
33	9 Adelaide Place	325295	566477	1,594
34	11 Adelaide Place	325314	566478	1,579
35	17 Adelaide Place	325331	566478	1,566
36	15 Adelaide Place	325331	566477	1,566
37	25 Calgary Grove	325370	566481	1,534
38	27 Calgary Grove	325388	566474	1,524
39	29 Calgary Grove	325441	566460	1,494
40	31 Calgary Grove	325462	566453	1,483
41	35 Calgary Grove	325488	566465	1,456
42	33 Calgary Grove	325488	566447	1,469
43	37 Calgary Grove	325507	566442	1,459
44	39 Calgary Grove	325525	566434	1,451
45*	New Build Corner 1	325535	566507	1,393
46*	New Build Corner 2	325812	566531	1,189
47*	New Build Corner 3	325913	566541	1,121
48*	New Build Corner 4	325863	566300	1,352
49*	New Build Corner 5	325631	566377	1,422
50	2 Adelaide Place	325240	566439	1,661
51	4 Adelaide Place	325258	566443	1,644
52	6 Adelaide Place	325276	566443	1,630
53	8 Adelaide Place	325297	566446	1,612
54	10 Adelaide Place	325322	566449	1,591
55	11 Calgary Grove	325320	566422	1,610
56	9 Calgary Grove	325319	566401	1,624
57	6 Calgary Grove	325316	566375	1,644
58	8 Calgary Grove	325314	566356	1,658
59	10 Calgary Grove	325312	566340	1,670
60	18 Edmonton Drive	325294	566364	1,668
61	4a Calgary Grove	325282	566376	1,669
62	1 Calgary Grove	325247	566416	1,670

Property ID	Receptor Name	Easting	Northing	Distance to Nearest Turbine (m)
63	3 Calgary Grove	325259	566418	1,659
64	5 Calgary Grove	325280	566418	1,643
65	7 Calgary Grove	325296	566419	1,630
66	17 Calgary Grove	325360	566440	1,568
67	15 Calgary Grove	325356	566425	1,581
68	13 Calgary Grove	325357	566408	1,591
69	19 Calgary Grove	325375	566411	1,576
70	21 Calgary Grove	325391	566411	1,564
71	23 Calgary Grove	325393	566431	1,549
72	14 Calgary Grove	325395	566379	1,583
73	12 Calgary Grove	325387	566379	1,589
74	8 Kingston Court	325367	566380	1,603
75	6 Kingston Court	325367	566361	1,616
76	5 Kingston Court	325368	566354	1,620
77	1 Wellington Walk	325385	566352	1,609
78	3 Wellington Walk	325393	566352	1,603
79	7 Kingston Court	325368	566347	1,625
80	4 Kingston Court	325367	566340	1,630
81	3 Kingston Court	325367	566333	1,635
82	2 Kingston Court	325366	566322	1,643
83	1 Kingston Court	325365	566315	1,649
84	16 Valetta Gardens	325371	566279	1,670
85	20 Valetta Gardens	325391	566272	1,661
86	18 Valetta Gardens	325392	566279	1,655
87	7 Valetta Gardens	325398	566301	1,635
88	2 Wellington Walk	325400	566321	1,620
89	4 Wellington Walk	325425	566329	1,597
90	6 Wellington Walk	325422	566350	1,584
91	10 Wellington Walk	325417	566364	1,577
92	8 Wellington Walk	325424	566389	1,555
93	16 Calgary Grove	325428	566393	1,549
94	18 Calgary Grove	325432	566411	1,534
95	4 Darwin Crescent	325454	566416	1,515
96	3 Darwin Crescent	325463	566413	1,510
97	2 Darwin Crescent	325476	566408	1,505
98	1 Darwin Crescent	325483	566406	1,501

Property ID	Receptor Name	Easting	Northing	Distance to Nearest Turbine (m)
99	15 Darwin Street	325504	566404	1,488
100	13 Darwin Street	325502	566398	1,493
101	5 Darwin Crescent	325458	566392	1,529
102	6 Darwin Crescent	325457	566385	1,534
103	7 Darwin Crescent	325455	566374	1,543
104	8 Darwin Crescent	325454	566365	1,551
105	9 Darwin Crescent	325453	566351	1,561
106	10 Darwin Crescent	325452	566343	1,568
107	11 Darwin Crescent	325450	566331	1,578
108	12 Darwin Crescent	325450	566322	1,584
109	9 Valetta Gardens	325419	566303	1,619
110	8 Darwin Close	325438	566303	1,606
111	7 Darwin Close	325445	566301	1,603
112	6 Darwin Close	325456	566300	1,596
113	5 Darwin Close	325461	566299	1,593
114	4 Darwin Close	325469	566298	1,589
115	3 Darwin Close	325476	566298	1,584
116	2 Darwin Close	325487	566297	1,577
117	1 Darwin Close	325493	566296	1,574
118	9 Darwin Close	325455	566274	1,616
119	10 Darwin Close	325455	566268	1,620
120	11 Darwin Close	325454	566259	1,628
121	12 Darwin Close	325452	566253	1,633
122	13 Darwin Close	325441	566244	1,647
123	14 Darwin Close	325433	566245	1,652
124	2 Darwin Terrace	325435	566218	1,671
125	3 Darwin Terrace	325447	566216	1,664
126	4 Darwin Terrace	325454	566215	1,661
127	5 Darwin Terrace	325465	566213	1,655
128	6 Darwin Terrace	325472	566213	1,650
129	1 Darwin Street	325475	566232	1,634
130	3 Darwin Street	325475	566239	1,629
131	5 Darwin Street	325479	566251	1,617
132	7 Darwin Street	325480	566256	1,613
133	9 Darwin Street	325482	566266	1,604
134	11 Darwin Street	325483	566272	1,599

Property ID	Receptor Name	Easting	Northing	Distance to Nearest Turbine (m)
135	2 Darwin Street	325504	566228	1,618
136	4 Darwin Street	325504	566235	1,613
137	6 Darwin Street	325513	566259	1,589
138	8 Darwin Street	325514	566268	1,581
139	10 Darwin Street	325518	566283	1,567
140	12 Darwin Street	325519	566292	1,560
141	14 Darwin Street	325522	566306	1,547
142	16 Darwin Street	325523	566312	1,542
143	1 Darwin Grove	325524	566328	1,529
144	2 Darwin Grove	325530	566328	1,525
145	3 Darwin Grove	325550	566324	1,515
146	4 Darwin Grove	325549	566316	1,522
147	5 Darwin Grove	325548	566302	1,533
148	6 Darwin Grove	325548	566297	1,537
149	7 Darwin Grove	325546	566288	1,545
150	8 Darwin Grove	325546	566282	1,550
151	9 Darwin Grove	325544	566276	1,556
152	10 Darwin Place	325561	566254	1,562
153	8 Darwin Place	325555	566255	1,565
154	6 Darwin Place	325542	566258	1,571
155	4 Darwin Place	325537	566258	1,574
156	2 Darwin Place	325531	566259	1,577
157	1 Darwin Place	325521	566232	1,604
158	3 Darwin Place	325526	566230	1,603
159	5 Darwin Place	325535	566229	1,598
160	7 Darwin Place	325541	566228	1,595
161	9 Darwin Place	325550	566227	1,590
162	11 Darwin Place	325555	566226	1,587
163	7 Darwin Terrace	325502	566207	1,636
164	8 Darwin Terrace	325508	566207	1,632
165	9 Darwin Terrace	325520	566204	1,626
166	10 Darwin Terrace	325526	566203	1,624
167	11 Darwin Terrace	325539	566202	1,616
168	12 Darwin Terrace	325545	566202	1,612
169	Elmside	325798	566153	1,511
170	Bridgend Farm	326045	566191	1,371

Property ID	Receptor Name	Easting	Northing	Distance to Nearest Turbine (m)
171	Bridgend Bungalow	326070	566194	1,359
172	4 Woodfield	326534	566170	1,297
173	Cloverdale	326581	566150	1,318
174	Woodfield	326564	566058	1,410
175	1 The Green	327290	566338	1,172
176	2 The Green	327297	566337	1,176
177	Newtonlea	327469	566343	1,240
178	3 Green Holdings	327480	566342	1,246
179	2 Mount Pleasant	327892	566308	1,512
180	1 Mount Pleasant	327888	566325	1,496
181	Hazeldean	327804	566819	1,105
*Receptor represents indicative location of a number of properties as set out in paragraph 15.35				
Properties in **bold** (25,26 and 27) are financially involved with the Proposed Development.				

Receptors Brought Forward for Assessment

15.39 All properties within the study area and identified in Table 15-2 have been brought forward for assessment.

Potential Effects

Construction and Decommissioning

15.40 Shadow flicker is an operational effect and hence not considered during the construction or decommissioning phases.

Operation

15.41 Figure 15.2 shows the results of the shadow flicker modelling. The results, set out in Table 15-3 below, show both the ‘worst-case scenario’, which assumes that the sun is always shining during daylight hours, the wind is always blowing, makes no allowance for any screening by vegetation, and includes the potential for micrositing leading to turbines being moved 50m closer to these properties, and the likely case scenario, whereby the worst-case results are adjusted for likely annual sunshine hours.

15.42 Based on the predictive modelling technique outlined above, there is predicted to be the greatest shadow flicker effects of up to 172.7 hour per year at 2 West Scales Cottages (receptor 25, shown in Table 15-3), assuming the worst-case scenario whereby the sun is always shining during daylight hours, the turbines are always turning, and there is no screening from vegetation. Of the 181 receptors in the study area, 47 receptors could potentially experience shadow flicker effects but of fewer hours, and 133 receptors are not predicted to experience any shadow flicker effects arising as a result of the Proposed Development. The last two columns of Table 15-3 provide an indication of the “likely” scenario, which takes into account the long-term average sunshine hours per year (32.4%) recorded at the nearest Met Office weather station. Under the likely case scenario, the predicted shadow flicker effects at 2 West Scales Cottages would be up to 56 hours per year.

Table 15-3: Shadow Flicker Assessment Outputs from Computer Model

ID	Receptor Name	Total Theoretical Days Per Year	Turbine(s) Causing Effect	Maximum Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely Maximum Minutes Per Day	Likely Hours Per Year
1	Rowan Cottage	0	/	0	0	0.0	0.0
2	Pinewood Cottage	0	/	0	0	0.0	0.0
3	Croft End	0	/	0	0	0.0	0.0
4	Woodside Cottage	0	/	0	0	0.0	0.0
5	Longmeadow Cottage	0	/	0	0	0.0	0.0
6	Lamar Cottage	0	/	0	0	0.0	0.0
7	Larchfield	0	/	0	0	0.0	0.0
8	Broats	66	4	28.8	22.4	9.3	7.3
9	Holiday Lodges	129	1,3,4	46.2	77.7	15.0	25.2
10	Flosh	45	1	31.8	19.7	10.3	6.4
11	Nutberry Farm	19	1	27.6	5.7	8.9	1.8
12	Cleughside	0	/	0	0	0.0	0.0
13	High Nutberry Farm	0	/	0	0	0.0	0.0
14	High Nutberry House	0	/	0	0	0.0	0.0
15	Caravan High Nutberry Farm	21	4	16.2	4.6	5.2	1.5
16	Hillhead Cottage	71	1,4	53.4	44.3	17.3	14.4
17	Calvertsholm Farm	44	1	27.6	15.5	8.9	5.0
18	Hillhead	80	1,4	58.2	55.8	18.9	18.1
19	**Hillhead Cottage 2**	**126**	**1,2,3,4**	**76.2**	**109.4**	**24.7**	**35.4**
20	Rigg Heads	38	1	28.2	13.1	9.1	4.2
21	Todholes 1	80	3,4	34.2	33.1	11.1	10.7
22	Todholes Cottage	80	3,4	34.8	33.5	11.3	10.9
23	Todholes 2	93	1,3,4	57.6	49.8	18.7	16.1
24	Todholes 4	93	1,3,4	57.6	53.7	18.7	17.4
25	**West Scales Farm**	**218**	**1,2,3,4**	**82.2**	**172.7**	**26.6**	**56.0**

ID	Receptor Name	Total Theoretical Days Per Year	Turbine(s) Causing Effect	Maximum Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely Maximum Minutes Per Day	Likely Hours Per Year
26	**West Scales Bungalow**	**213**	**1,2,3,4**	**66**	**146.3**	**21.4**	**47.4**
27	**Redwood House**	**175**	**1,2,3,4**	**59.4**	**114.7**	**19.2**	**37.2**
28	4 Irvington	105	2,3,4	55.8	69.4	18.1	22.5
29	1 Adelaide Place	53	3	28.2	20.7	9.1	6.7
30	3 Adelaide Place	51	3	27.6	19.3	8.9	6.3
31	5 Adelaide Place	49	3	27	18	8.7	5.8
32	7 Adelaide Place	47	3	26.4	16.5	8.6	5.3
33	9 Adelaide Place	43	3	25.2	14.8	8.2	4.8
34	11 Adelaide Place	41	3	24	13	7.8	4.2
35	17 Adelaide Place	37	3	22.8	11.2	7.4	3.6
36	15 Adelaide Place	37	3	22.8	11.1	7.4	3.6
37	25 Calgary Grove	29	3	18.6	7.3	6.0	2.4
38	27 Calgary Grove	23	3	14.4	4.4	4.7	1.4
39	29 Calgary Grove	0	/	0	0	0.0	0.0
40	31 Calgary Grove	0	/	0	0	0.0	0.0
41	35 Calgary Grove	0	/	0	0	0.0	0.0
42	33 Calgary Grove	0	/	0	0	0.0	0.0
43	37 Calgary Grove	0	/	0	0	0.0	0.0
44	39 Calgary Grove	0	/	0	0	0.0	0.0
45	New Build Corner 1	65	2	29.4	27.7	9.5	9.0
46	New Build Corner 2	29	2	18.6	6.9	6.0	2.2
47	New Build Corner 3	0	/	0	0	0.0	0.0
48	New Build Corner 4	0	/	0	0	0.0	0.0

ID	Receptor Name	Total Theoretical Days Per Year	Turbine(s) Causing Effect	Maximum Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely Maximum Minutes Per Day	Likely Hours Per Year
49	New Build Corner 5	29	2	18.6	7.1	6.0	2.3
50	2 Adelaide Place	45	3	25.8	15.5	8.4	5.0
51	4 Adelaide Place	43	3	24.6	14.4	8.0	4.7
52	6 Adelaide Place	41	3	24	12.8	7.8	4.1
53	8 Adelaide Place	37	3	22.8	11.1	7.4	3.6
54	10 Adelaide Place	33	3	20.4	8.7	6.6	2.8
55	11 Calgary Grove	27	3	16.2	5.6	5.2	1.8
56	9 Calgary Grove	20	3	12.6	3.2	4.1	1.0
57	6 Calgary Grove	9	3	5.4	0.6	1.7	0.2
58	8 Calgary Grove	0	/	0	0	0.0	0.0
59	10 Calgary Grove	0	/	0	0	0.0	0.0
60	18 Edmonton Drive	15	3	9	1.8	2.9	0.6
61	4a Calgary Grove	23	3	13.8	4.3	4.5	1.4
62	1 Calgary Grove	40	3	23.4	12.3	7.6	4.0
63	3 Calgary Grove	39	3	22.8	11.5	7.4	3.7
64	5 Calgary Grove	35	3	21	9.5	6.8	3.1
65	7 Calgary Grove	31	3	19.2	8	6.2	2.6
66	17 Calgary Grove	19	3	12.6	3.1	4.1	1.0
67	15 Calgary Grove	15	3	9.6	1.8	3.1	0.6
68	13 Calgary Grove	0	/	0	0	0.0	0.0
69	19 Calgary Grove	0	/	0	0	0.0	0.0
70	21 Calgary Grove	0	/	0	0	0.0	0.0
71	23 Calgary Grove	0	/	0	0	0.0	0.0

ID	Receptor Name	Total Theoretical Days Per Year	Turbine(s) Causing Effect	Maximum Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely Maximum Minutes Per Day	Likely Hours Per Year
72	14 Calgary Grove	0	/	0	0	0.0	0.0
73	12 Calgary Grove	0	/	0	0	0.0	0.0
74	8 Kingston Court	0	/	0	0	0.0	0.0
75	6 Kingston Court	0	/	0	0	0.0	0.0
76	5 Kingston Court	0	/	0	0	0.0	0.0
77	1 Wellington Walk	0	/	0	0	0.0	0.0
78	3 Wellington Walk	0	/	0	0	0.0	0.0
79	7 Kingston Court	0	/	0	0	0.0	0.0
80	4 Kingston Court	0	/	0	0	0.0	0.0
81	3 Kingston Court	0	/	0	0	0.0	0.0
82	2 Kingston Court	0	/	0	0	0.0	0.0
83	1 Kingston Court	0	/	0	0	0.0	0.0
84	16 Valetta Gardens	0	/	0	0	0.0	0.0
85	20 Valetta Gardens	0	/	0	0	0.0	0.0
86	18 Valetta Gardens	0	/	0	0	0.0	0.0
87	7 Valetta Gardens	0	/	0	0	0.0	0.0
88	2 Wellington Walk	0	/	0	0	0.0	0.0
89	4 Wellington Walk	0	/	0	0	0.0	0.0
90	6 Wellington Walk	0	/	0	0	0.0	0.0
91	10 Wellington Walk	0	/	0	0	0.0	0.0
92	8 Wellington Walk	0	/	0	0	0.0	0.0
93	16 Calgary Grove	0	/	0	0	0.0	0.0
94	18 Calgary Grove	0	/	0	0	0.0	0.0

ID	Receptor Name	Total Theoretical Days Per Year	Turbine(s) Causing Effect	Maximum Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely Maximum Minutes Per Day	Likely Hours Per Year
95	4 Darwin Crescent	0	/	0	0	0.0	0.0
96	3 Darwin Crescent	0	/	0	0	0.0	0.0
97	2 Darwin Crescent	0	/	0	0	0.0	0.0
98	1 Darwin Crescent	0	/	0	0	0.0	0.0
99	15 Darwin Street	0	/	0	0	0.0	0.0
100	13 Darwin Street	0	/	0	0	0.0	0.0
101	5 Darwin Crescent	0	/	0	0	0.0	0.0
102	6 Darwin Crescent	0	/	0	0	0.0	0.0
103	7 Darwin Crescent	0	/	0	0	0.0	0.0
104	8 Darwin Crescent	0	/	0	0	0.0	0.0
105	9 Darwin Crescent	0	/	0	0	0.0	0.0
106	10 Darwin Crescent	0	/	0	0	0.0	0.0
107	11 Darwin Crescent	0	/	0	0	0.0	0.0
108	12 Darwin Crescent	0	/	0	0	0.0	0.0
109	9 Valetta Gardens	0	/	0	0	0.0	0.0
110	8 Darwin Close	0	/	0	0	0.0	0.0
111	7 Darwin Close	0	/	0	0	0.0	0.0
112	6 Darwin Close	0	/	0	0	0.0	0.0
113	5 Darwin Close	0	/	0	0	0.0	0.0
114	4 Darwin Close	0	/	0	0	0.0	0.0
115	3 Darwin Close	0	/	0	0	0.0	0.0
116	2 Darwin Close	0	/	0	0	0.0	0.0
117	1 Darwin Close	0	/	0	0	0.0	0.0

ID	Receptor Name	Total Theoretical Days Per Year	Turbine(s) Causing Effect	Maximum Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely Maximum Minutes Per Day	Likely Hours Per Year
118	9 Darwin Close	0	/	0	0	0.0	0.0
119	10 Darwin Close	0	/	0	0	0.0	0.0
120	11 Darwin Close	0	/	0	0	0.0	0.0
121	12 Darwin Close	0	/	0	0	0.0	0.0
122	13 Darwin Close	0	/	0	0	0.0	0.0
123	14 Darwin Close	0	/	0	0	0.0	0.0
124	2 Darwin Terrace	0	/	0	0	0.0	0.0
125	3 Darwin Terrace	0	/	0	0	0.0	0.0
126	4 Darwin Terrace	0	/	0	0	0.0	0.0
127	5 Darwin Terrace	0	/	0	0	0.0	0.0
128	6 Darwin Terrace	0	/	0	0	0.0	0.0
129	1 Darwin Street	0	/	0	0	0.0	0.0
130	3 Darwin Street	0	/	0	0	0.0	0.0
131	5 Darwin Street	0	/	0	0	0.0	0.0
132	7 Darwin Street	0	/	0	0	0.0	0.0
133	9 Darwin Street	0	/	0	0	0.0	0.0
134	11 Darwin Street	0	/	0	0	0.0	0.0
135	2 Darwin Street	0	/	0	0	0.0	0.0
136	4 Darwin Street	0	/	0	0	0.0	0.0
137	6 Darwin Street	0	/	0	0	0.0	0.0
138	8 Darwin Street	0	/	0	0	0.0	0.0
139	10 Darwin Street	0	/	0	0	0.0	0.0
140	12 Darwin Street	0	/	0	0	0.0	0.0

ID	Receptor Name	Total Theoretical Days Per Year	Turbine(s) Causing Effect	Maximum Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely Maximum Minutes Per Day	Likely Hours Per Year
141	14 Darwin Street	0	/	0	0	0.0	0.0
142	16 Darwin Street	0	/	0	0	0.0	0.0
143	1 Darwin Grove	0	/	0	0	0.0	0.0
144	2 Darwin Grove	0	/	0	0	0.0	0.0
145	3 Darwin Grove	0	/	0	0	0.0	0.0
146	4 Darwin Grove	0	/	0	0	0.0	0.0
147	5 Darwin Grove	0	/	0	0	0.0	0.0
148	6 Darwin Grove	0	/	0	0	0.0	0.0
149	7 Darwin Grove	0	/	0	0	0.0	0.0
150	8 Darwin Grove	0	/	0	0	0.0	0.0
151	9 Darwin Grove	0	/	0	0	0.0	0.0
152	10 Darwin Place	0	/	0	0	0.0	0.0
153	8 Darwin Place	0	/	0	0	0.0	0.0
154	6 Darwin Place	0	/	0	0	0.0	0.0
155	4 Darwin Place	0	/	0	0	0.0	0.0
156	2 Darwin Place	0	/	0	0	0.0	0.0
157	1 Darwin Place	0	/	0	0	0.0	0.0
158	3 Darwin Place	0	/	0	0	0.0	0.0
159	5 Darwin Place	0	/	0	0	0.0	0.0
160	7 Darwin Place	0	/	0	0	0.0	0.0
161	9 Darwin Place	0	/	0	0	0.0	0.0
162	11 Darwin Place	0	/	0	0	0.0	0.0
163	7 Darwin Terrace	0	/	0	0	0.0	0.0
164	8 Darwin Terrace	0	/	0	0	0.0	0.0
165	9 Darwin Terrace	0	/	0	0	0.0	0.0
166	10 Darwin Terrace	0	/	0	0	0.0	0.0

ID	Receptor Name	Total Theoretical Days Per Year	Turbine(s) Causing Effect	Maximum Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely Maximum Minutes Per Day	Likely Hours Per Year
167	11 Darwin Terrace	0	/	0	0	0.0	0.0
168	12 Darwin Terrace	0	/	0	0	0.0	0.0
169	Elmside	0	/	0	0	0.0	0.0
170	Bridgend Farm	0	/	0	0	0.0	0.0
171	Bridgend Bungalow	0	/	0	0	0.0	0.0
172	4 Woodfield	0	/	0	0	0.0	0.0
173	Cloverdale	0	/	0	0	0.0	0.0
174	Woodfield	0	/	0	0	0.0	0.0
175	1 The Green	0	/	0	0	0.0	0.0
176	2 The Green	0	/	0	0	0.0	0.0
177	Newtonlea	0	/	0	0	0.0	0.0
178	3 Green Holdings	0	/	0	0	0.0	0.0
179	2 Mount Pleasant	0	/	0	0	0.0	0.0
180	1 Mount Pleasant	0	/	0	0	0.0	0.0
181	Hazeldean	102	2,3	51.6	68.3	16.7	22.1
Properties in **bold** are those predicted to potentially experience more than 30 hours of shadow flicker effect annually, under the likely case scenario, and prior to the implementation of mitigation.							

Analysis of Results

15.43 The results show that 13 of the 181 receptors assessed could potentially experience over 30 hours of shadow flicker effect per annum from the Proposed Development, based on the worst-case assessment criteria. However, only four of these properties (receptors 25, 26, 27 and 19)[3] would experience shadow flicker in excess of 30 hours based on the likely-case assessment criteria.

15.44 Based on the assessment criteria set out previously, the effects on all properties, with the exception of properties 25, 26, 27, and 19, would therefore not be significant.

15.45 These figures are likely to comprise an over-estimate of actual effects. Given the conservative nature of this assessment as set out in the limitations of assessment section, it is likely that in practice actual hours of shadow flicker would be considerably less than this due to the fact that the wind is not always blowing, the sun is not always shining, and other assumptions set out previously.

[3] Properties 25, 26, and 27 are all financially involved with the Proposed Development.

Mitigation

15.46 Based on the significance thresholds outlined previously, significant shadow flicker effects are predicted to occur as a result of the Proposed Development at four properties. The Applicant is committed to promptly investigating any complaints of shadow flicker and taking appropriate action as required, should a substantiated shadow flicker effect from the Proposed Development be confirmed.

15.47 The applicant proposes that prior to the operation of the first turbine, a Wind Farm Shadow Flicker Protocol would be submitted to and approved by D&GC. This would set out the protocol to be followed should a shadow flicker complaint be received from a receptor within the study area, and potential mitigation measures. Should a complaint be received, these mitigation measures would include programming the turbine’s shadow flicker control module to minimise impacts at the receptor(s). Operation of the Proposed Development would be undertaken in accordance with the Wind Farm Shadow Flicker Protocol.

15.48 If a complaint is made regarding shadow flicker, an investigation would take place which considers the weather conditions at the time of the alleged shadow flicker event, to determine which turbines were, or were not, creating the effect and the extent of the shadow flicker created. If the investigation confirms a loss of residential amenity at any location, the technical mitigation measures built into these turbines would be activated.

15.49 Shadow flicker control modules, consisting of light sensors and specialised software, would be installed on the turbines that can prevent operation during periods when shadow flicker can be experienced at nearby properties. The installation of a programmable shadow flicker module would allow the control of turbines in order to eliminate shadow flicker. The correct operation of the installed shadow flicker control measures would ensure that there would be no impact from shadow flicker. The operation and performance of the shadow flicker control measures would be monitored on an ongoing basis.

15.50 The shadow flicker control module consists of bespoke software, a clock, a timer, a switch, a wind direction sensor and a light sensor. The module can control a specific turbine (or turbines) which would be programmed to shut down on specific dates at specific times when the sun is bright enough, there is sufficient wind to rotate the blades and the wind direction is such that nuisance shadow flicker could occur. There is no specific UK guidance regarding what level of light is sufficient to cause a shadow flicker event. However, the actual light level that would trigger a turbine shut down can be manually configured on-site, following installation, to reflect local conditions.

15.51 It is proposed that a planning condition would provide an appropriate form of mitigation to ensure that any complaints would be investigated within a reasonable timescale and that the rectification of any substantiated shadow flicker issue would be implemented promptly and effectively. The DECC guidance (2011) states that *“Mitigation measures which have been employed to operational wind farms such as turbine shut down strategies, have proved very successful, to the extent that shadow flicker cannot be considered to be a major issue in the UK"*.

Residual Effects

15.52 The mitigation commitments made by the applicant would ensure that **no significant** residual effects would occur in relation to shadow flicker on the identified receptors as a result of the Proposed Development.

Summary

15.53 Under conservative assumptions, the Proposed Development is predicted to potentially cause significant shadow flicker effects for 13 properties within the 1,670m study area, under the worst-case scenario; reducing to potentially cause significant shadow flicker effects for four properties under the likely-case scenario.

15.54 Should a shadow flicker complaint be raised, mitigation can be provided, including shutting down individual wind turbines during periods when shadow flicker is modelled to occur and the climatic conditions are such that shadow flicker can be experienced.

15.55 A suitably worded planning condition would provide an appropriate form of mitigation to ensure that any complaints would be investigated within a reasonable timescale and that the rectification of any substantiated shadow flicker issue would be implemented promptly and effectively. The mitigation commitments made by the applicant would ensure that no significant residual effects would occur in relation to shadow flicker on the identified receptors as a result of the Proposed Development.

Climate and Carbon Balance

15.56 This section of the chapter details the calculations to work out carbon dioxide (CO_2) emissions from the wind energy element of the Proposed Development. Consideration of potential lifecycle emissions for onshore renewable energy development in Scotland has tended to focus on wind energy, given that wind farms are often constructed on peatlands or in forestry, resulting in associated carbon emissions from excavation of peat and forestry felling. The Scottish Government's industry-accepted 'Carbon Calculator' tool relates only to onshore wind energy projects, and there is no equivalent for energy storage or solar PV installations, therefore the non-wind aspects of the Proposed Development have not been included within this assessment.

15.57 In addition to generating electricity, the Scottish Government sees wind farms as an important mechanism for reducing the UK's CO_2 emissions. This section estimates the CO_2 emissions associated with the manufacture and construction of the Proposed Development as well as estimating the contribution the Proposed Development would make to reducing CO_2 emissions, to give an estimate of the whole life carbon balance of the Proposed Development. The assessment is based on a detailed baseline description of the Proposed Development and its location. All calculations are based on site specific data, where available. Where site specific data is not available approved national/regional information has been used.

15.58 A standalone assessment on the vulnerability of the Proposed Development to climate change has not been included, as it is considered that none of the identified climate change trends would affect the Proposed Development, with the possible exception of increased windstorms. Mitigation with regards to extreme weather events, is detailed in paragraphs 15.101 - 15.104. The effects of climate change on environmental receptors has been considered in each of the relevant environmental topic chapters of this EIA Report **(Chapters 7 to 14).**

15.59 Each unit of wind generated electricity would displace a unit of conventionally generated electricity, therefore, saving power station emissions. **Table 15-4** provides a breakdown of the estimated emissions displaced per annum and over the assumed lifespan of 40 years for the Proposed Development.

Carbon and Peatland

15.60 Wind farms in upland areas tend to be sited on peatlands which hold stocks of carbon and so have the potential to release carbon into the atmosphere in the form of CO_2 if disturbed. The Proposed Development Site comprises mainly agricultural fields, however sits adjacent to former peat extraction sites, therefore appropriate consideration of the carbon balance is required.

15.61 In order to minimise the requirement for the extraction of peat, the site design process (described in **Chapter 2: Site Description and Design Evolution**) has avoided areas of deeper peat. Peat probing was carried out on site and peat depth mapped, as shown in **Figure 10.1.1** of **Technical Appendix 10.1: Peat Survey Data**. This enabled wind turbines and associated infrastructure to be located in areas of shallower peat.

15.62 Paragraphs 15.73 to 15.78 detail how the whole life carbon balance assessment for wind farms on peatlands is calculated, including the input of emissions due to liberation of CO_2 from carbon stored in peat as a result of construction.

Effects of Carbon Emissions from Construction

15.63 Emissions arising from the fabrication of the turbines and the associated components are based on a full life analysis of a typical turbine and include CO_2 emissions resulting from transportation, erection, operation, dismantling and removal of turbines and foundations and transmission grid connection equipment from the existing electricity grid system.

15.64 With respect to turbines, emissions from material production are the dominant source of CO_2. Emissions arising from construction (including transportation of components, quarrying, building foundations, access tracks and hard standings) and commissioning are also included in the calculations. The assessment has used Nayak et al (2008) default values for 'turbine life' emissions, calculated with respect to installed capacity (**Technical Appendix 15.1: Carbon Calculator)**.

15.65 The Proposed Development is seeking consent for an operational lifespan of 40 years.

Characteristics of Peatland

15.66 The loss of carbon from the carbon fixing potential from plants and vegetation on peat land is small, but is calculated for the area from which peat is removed and the area affected by drainage. The carbon stored in the peat itself represents a much larger potential source of carbon loss.

15.67 When flooded, peat soils emit less carbon dioxide but more methane than when they are drained. In flooded soils, carbon emissions are usually exceeded by plant fixation, so the net exchange of carbon with the atmosphere is negative and soil stocks increase. When soils are aerated, carbon emissions usually exceed plant fixation, so the net exchange of carbon with the atmosphere is positive.

15.68 To calculate the carbon emissions attributable to the removal or drainage of the peat, emissions occurring if the soil had remained in situ and undrained are subtracted from the emissions occurring after removal or drainage.

15.69 The indirect loss of CO_2 uptake (fixation) by plants originally on the surface of the site, but eliminated by construction activity including the destruction of active bog plants on wet sites and felling, is calculated on site specific data collected as part of the EIA process and based on blanket bog.

15.70 Emissions due to the indirect, long term liberation of CO_2 from carbon stored in peat due to drying and oxidation processes caused by construction of the site, can also be calculated from site specific data for the proposed development. This figure is a worst-case scenario, as the peat would be reused onsite to minimise carbon losses.

15.71 Data from turbine manufacturers and the construction related activity is included as part of the assessment to address payback periods, however the two previous sources (from peat and the losses from loss of plant uptake) are a much more significant contributor to CO_2 emissions and the overall CO_2 debt where peat is disturbed onsite.

Methodology

15.72 In Scotland, applications submitted under Section 36 of the Electricity Act 1989 are required to undertake the carbon balance assessment using the Scottish Government's carbon calculator tool. Whilst the Proposed Development is not a Section 36 development, and therefore a carbon balance assessment is not a statutory requirement, the tool is still useful to determine the overall payback time and emissions savings due to the wind element of the Proposed Development. The Scottish Government's carbon calculator tool is currently offline (as of the finalisation of this chapter in April 2026). In the absence of the online Carbon Calculator Tool this assessment has been undertaken in accordance with the associated guidance using the offline version spreadsheet provided by the Energy Consents Unit. The methodology to calculate carbon emissions generated in the construction, operation and decommissioning of a wind farm is based on 'Calculating carbon savings from windfarms on Scottish peat lands - A New Approach' (Nayak et al, 2008), prepared for the Scottish Government Science, Policy and Co-ordination Division. This was superseded in 2011 by the document 'Calculating Carbon Savings from Wind Farms on Scottish Peatlands - A New Approach', (Nayak et al, 2008 and 2010) and (Smith et al, 2011). In terms of carbon footprint, the aforementioned 'carbon calculator' is the Scottish Government's tool provided to support the process of determining the carbon impact of wind farm developments in Scotland.

Significance of Effects

15.73 The assessment of the significance of effects of the Proposed Development in relation to climate and carbon balance uses professional judgement to analyse the results from the Carbon Calculator to determine any likely significant effects.

Input Parameters

15.74 To undertake this assessment the following parameters were considered, which encompass a full life cycle analysis of the wind elements of the Proposed Development. These parameters include:

- emissions arising from fabrication of wind turbines and associated components;
- emissions arising from construction, (including transportation of components; quarrying; building foundations, access tracks and hard standings; and commissioning);
- the indirect loss of CO_2 uptake (fixation) by plants originally on surface of the Site but eliminated by construction activity (including the destruction of active bog plants on wet sites) and felling;
- emissions due to the indirect, long term liberation of CO_2 from carbon stored in peat due to drying and oxidation processes caused by construction; and

- loss of carbon due to drainage.

15.75 The offline spreadsheet version of the Scottish Government's carbon calculator tool provides generic values for CO_2 emissions associated with some components (such as turbine manufacture) and requires site specific information for other components (such as habitat type, extent of peat disturbance and ground water levels). The calculation evaluates the balance of total carbon savings and carbon losses over the life of the proposed development. The potential carbon savings and carbon costs associated with wind farms are as follows:

- carbon emission savings due to generation (based on displacing emissions from different power sources);
- lifetime costs associated with manufacture of turbines and construction;
- loss of carbon from backup power generation;
- loss of carbon-fixing potential of peatland;
- loss and/or saving of carbon stored in peatland (by peat removal or changes in drainage); and
- carbon gains due to proposed habitat improvements such as bog restoration.

15.76 This assessment draws on information detailed in the EIA Report, **Chapter 8: Ecology** and **Chapter 10: Hydrology, Hydrogeology and Geology**. For the purpose of this assessment, it is assumed that all the embedded good practice measures outlined in **Chapter 8: Ecology**, and **Chapter 10: Hydrology, Hydrogeology and Geology**, would be employed.

15.77 The final wind turbine choice is not yet known, but is anticipated to be approximately a 6.2MW machine, and the Proposed Development would consist of four turbines. The greenhouse gas savings and carbon payback are based on these input parameters. Figures are based on currently available turbines and assume a consistent supplier for all turbine locations (i.e. turbine types are chosen by manufacturer). Note that, within the calculation spreadsheet, the expected, maximum and minimum values have been adjusted to suit the input parameter.

15.78 The site specific capacity factor used in the calculation spreadsheet is 40%, based on site-specific lidar measurements and yield assessment.

15.79 The input parameters for the Scottish Government calculation spreadsheet are detailed in **Technical Appendix 15.1: Carbon Calculator**. The choice of methodology for calculating the emission factors uses the 'Site Specific methodology' defined within the calculation spreadsheet.

Results

15.80 This section presents a summary of the carbon assessment which has been undertaken in respect of the Proposed Development. The purpose of the 'carbon calculator' is to assess, in a comprehensive and consistent way, the carbon impact of wind energy developments. This is undertaken by comparing the carbon costs of manufacture and construction with the carbon savings attributable to a development through operation. An assessment has been undertaken to calculate the carbon emissions which would be generated in the construction, operation and possible decommissioning of the Proposed Development after an illustrative 40 years. Where peaty soils are present on intensive grassland (the majority of land use onsite) the predicted baseline emissions are expected to be 22 t CO2 eq ha^{-1}.

15.81 The calculations spreadsheet is provided in **Technical Appendix 13.1: Carbon Calculator.** A summary of the anticipated carbon emissions and carbon payback of the Proposed Development relative to the current Department for Energy Security and Net Zero figures is provided in **Table 15.4.**

Table 15-4: CO2 Emissions and Payback Time

Results	Exp.	Min.	Max.
Net emissions of carbon dioxide (t $CO_{2\ eq}$) (carbon losses minus carbon gains) per annum.	39,719	36,871	41,343
Carbon Payback Time			
…coal-fired electricity generation (years)	0.5	0.45	0.5
…grid-mix of electricity generation (years)	2.2	2.0	2.3
…fossil fuel – mix of electricity generation (years)	1.1	1.0	1.1
Ratio of $CO_{2\ eq}$. emissions to power generation (g/kWh) (Target ratio by 2030 (electricity generation)	11	11	12

15.82 The calculations of total carbon dioxide emission savings and payback time for the Proposed Development indicates the overall payback period of a development with 4 wind turbines with an average (expected) installed capacity of around 6.2MW each would be approximately 1.1 years (13 months), when compared to the fossil fuel mix of electricity generation.

15.83 This means that the Proposed Development is expected to take around 13 months to repay the carbon exchange to the atmosphere (the CO_2 debt) through construction of the wind turbines; the Proposed Development would in effect be in a net gain situation following this time period and would contribute to national CO_2 reduction targets.

15.84 The potential savings in CO_2 emissions[4] due to the Proposed Development replacing other electricity sources over the lifetime of the wind turbines (assumed to be 40 years for the purpose of the carbon calculator) are approximately:

- 82,120 tonnes of CO_2 per year over coal-fired electricity;
- 17,994 tonnes of CO_2 per year over a grid-mix of electricity;
- 36,845 tonnes of CO_2 per year over a fossil fuel mix of electricity.

15.85 Chapter 4 – Renewable Energy and Planning Policy provides details on the current renewable energy targets, such as the Scottish Government target of reaching net zero emissions by 2045. The potential savings in CO_2 emissions due to the Proposed Development would help in reaching this, and other, targets.

[4] It should be noted that the Scottish Government is seeking to decarbonise other CO2 generating activities through electrification or electric plant and equipment. The displacement of CO2 emissions from these activities over the course of the lifetime of the Proposed Development is not captured by the carbon calculations.

Significance

15.86 Based on the results from the Carbon Calculator (**Technical Appendix 15.1**), and using professional judgement, it is concluded that the potential savings in CO_2 emissions of between 17,994 and 82,120 tonnes per year, would result in a **significant** positive impact.

Glint and Glare

15.87 Solar Photovoltaic (PV) modules have the potential to produce glint and glare effects. As the Proposed Development will include a solar PV component, a glint and glare assessment has been undertaken (see **Technical Appendix 15.2**). Glint is defined as a momentary flash of bright light, whilst glare is a more continuous source of bright light. Dazzle is an effect caused by intense glint and glare, which can cause distraction, and if strong enough, can reduce the ability of the receptor (pilot driver, or otherwise) to distinguish details and objects.

15.88 The assessment categorises potential glare under a traffic light system, as 'green glare', 'yellow glare' and 'red glare'. This is explained in **Table 15-5** below.

Table 15-5: Types of glares

Name	Description
Green glare	'Green glare' is glare with low potential to cause an after-image* (flash blindness) when observed prior to a typical blink response time.
Yellow glare	'Yellow glare' is glare with potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.
Red glare	'Red glare' has potential to cause retinal burn (permanent eye damage). Retinal burn is typically not possible for PV glare since the reflected light is not focused on a concentrated point.
*Temporary after-image is the phenomenon whereby an image remains momentarily visible on the retina after looking away from a bright light source.	

15.89 Th conclusions of the glint and glare assessment found that of the receptors assessed, only one fixed ground receptor and two route receptors (the A75 and the railway line) are predicted to potentially experience glint and glare. In all cases, the predicted effects are limited to green glare only, with no occurrence of yellow glare.

15.90 For the fixed ground receptor, modelling indicates potential green glare; however, the presence of surrounding farm buildings would obstruct direct views towards the PV arrays. When these physical constraints are taken into account, no perceptible glint or glare effects are expected under real-world conditions, and the residual impact is considered negligible, and **not significant**.

15.91 For the two route receptors, potential effects are limited to the A75 and the railway line and are predicted to occur over very short periods of time only. No glint or glare effects are predicted for the rural road. The modelling incorporates existing and proposed screening vegetation.

15.92 It should be noted that the assessment is limited, as the modelling used assumes clear-sky conditions throughout the year, representing a worst-case scenario. As demonstrated by local climate data for Gretna, such conditions do not occur consistently in practice, with cloud cover present for a substantial proportion of the year. The high frequency of overcast and partly cloudy conditions is expected to significantly reduce the likelihood and frequency of glare occurrences compared to the modelled outputs. As a result, actual glint and glare effects under real-world operating conditions are anticipated to be materially lower than those predicted by the clear-sky assessment, further supporting the conclusion that the residual impact of the Proposed Development is negligible.

15.93 Overall, the Proposed Development is therefore assessed as having a **negligible and not significant** glint and glare impact on surrounding receptors, based on the assessment criteria outlined in **Technical Appendix 15.2**.

Risk of Accidents and Other Disasters

15.94 The vulnerability of the Proposed Development to major accidents and natural disasters, such as flooding, sea level rise, or earthquakes, is considered to be low due to its geographical location and the fact that its purpose is to ameliorate some of these issues.

15.95 In addition, the nature of the proposals and remoteness of the Site means there would be negligible risks on the factors identified by the EIA Regulations. For example:

- population and human health - the Site is away from major population centres, with low population density, and the required safety clearances around turbines has been a key consideration throughout the design process;
- biodiversity - receptors and resources would be unaffected as there would be little risk of polluting substances released or loss of habitat in a turbine failure scenario (highly unlikely);
- land, soil, water, air and climate - there would be little risk of polluting substances released or loss of habitat in a turbine failure scenario (highly unlikely); and
- material assets, cultural heritage and the landscape - there would be no adverse effects on these features in a turbine failure scenario (highly unlikely).

15.96 In conclusion, the Proposed Development would not result in any significant impacts due to the risk of accidents and other disasters.

Battery Energy Storage System Fire Safety

15.97 A Battery Safety Statement has been produced for the Proposed Development (see Technical Appendix 3.2).

15.98 To summarise, The Battery Energy Storage System (BESS) that forms part of the Proposed Development would contribute to a more integrated renewable energy system (wind and solar). By utilising proven Li Ion technology with comprehensive risk mitigations, the adherence to national and international standards, and proactive safety management, the BESS would contribute not only in terms of dispatchability of the renewable energy scheme but as well contribute to the grid stability, energy security, and decarbonisation.

15.99 The BESS design should prioritise the safety aspect through layered protections, early detection systems and comprehensive emergency response planning. A close consultation with key stakeholders, such as the local FRS, along with strict compliance with national and international standards, is essential to enhance BESS safety and effectively mitigate risks.

Public Safety and Access

15.100 The Renewable UK Onshore Wind Health and Safety Guidelines (2015) note that wind farm development and operation can give rise to a range of risks to public safety, including:

- traffic (especially lorries during construction, and abnormal loads for the transport of wind turbine components; including beyond the Site boundary);
- construction site hazards (particularly to any people entering the Site without the knowledge or consent of the site management);
- effects of catastrophic wind turbine failures, which may on rare occasions result in blade throw, tower topple or fire; and
- ice throw, if the wind turbine is operated with ice build-up on the blades.

15.101 The RenewableUK guidance (2015) states that *"Developers should ensure that risks to public safety are considered and managed effectively over the project lifecycle, and should be prepared to share their plans for managing these risks with stakeholders and regulators; effective engagement can both build trust, and help to reduce the level of public safety risk by taking account of local knowledge".*

15.102 Site security and access during the construction period would be governed under Health and Safety at Work Act 1974 and associated legislation. No public access would be permitted along new access tracks to the Site during construction. However, the Land Reform (Scotland) Act 2003 which came into effect in February 2005 establishes statutory rights of responsible access on and over most land. The legislation offers a general framework of responsible conduct for both those exercising rights of access and for landowners. Once the construction period and commissioning of the Proposed Development is complete, no special restrictions on access are proposed.

15.103 Appropriate warning signs would be installed concerning restricted areas such as the substation compound, switchgear and metering systems. All onsite electrical cables would be buried underground with relevant signage. Follow implementation of the required measures, the risk to public safety is concluded to **not result in a significant effect**.

Traffic

15.104 Accident data for roads within the Traffic and Transport study area has been reviewed, and the requirement for an assessment of the potential effects on road safety has been undertaken and is presented in **Chapter 12: Traffic and Transport**. In summary, the increase in vehicle movements during the busiest months would be of a level that would create no discernible environmental impact and are therefore considered not to warrant further assessment on the matters of road safety and driver delay.

Construction

15.105 With regard to risks and accidents during the construction phase, the construction works for the Proposed Development would be undertaken in accordance with primary health and safety legislation, including the Health and Safety at Work Act 1974 and the Construction (Design and Management) (CDM) Regulations 2015 which will include a requirement to produce emergency procedures in a Construction Phase (Health & Safety) Plan in accordance with the Regulations.

15.106 Nonetheless, the risk of accidents and other disasters is covered where relevant in individual topic chapters, for instance, the potential for environmental incidents and accidents such as spillages are considered in **Chapter 8: Ecology**, **Chapter 9: Ornithology** and **Chapter 10: Hydrology, Hydrogeology and Geology**. Flood risk is also assessed with **Chapter 10**. The level of effect is considered **not significant**, following the implementation of a health and safety requirements.

Extreme Weather

15.107 As far as the risk of turbine failure during high winds is concerned, the turbines would cut-out and automatically stop as a safety precaution in wind speeds over 50m/s.

15.108 Wind turbines can be susceptible to lightning strike due to their height and appropriate measures are taken into account in the design of turbines to conduct lightning strikes down to earth and minimise the risk of damage to turbines. Occasionally however, lightning can strike and damage a wind turbine blade. Modern wind turbine blades are manufactured from a glass-fibre or wood-epoxy composite in a mould, such that the reinforcement runs predominantly along the length of the blade. This means that blades will usually stay attached to the turbine if damaged by lightning and in all cases turbines will automatically shut down if damaged by lightning.

15.109 Ice build-up on blade surfaces occurs in cold weather conditions. Wind turbines can continue to operate with a very thin accumulation of snow or ice, but will shut down automatically as soon as there is a sufficient build up to cause aerodynamic or physical imbalance of the rotor assembly. Potential icing conditions affecting turbines can be expected two to seven days per year (light icing) in Scotland (WECO, 1999). The potential for ice throw to occur after start up following a turbine shut down during conditions suitable for ice formation is high. There are monitoring systems and protocols in place to ensure that turbines that have been stationary during icing conditions are restarted in a controlled manner to ensure public safety. The risk to public safety is considered to be very low due to the few likely occurrences of these conditions along with the particular circumstances that can cause ice throw.

15.110 The risk to the environment and the public, from the proposed development, as a result of extreme weather is considered **not significant**.

Seismic Activity

15.111 There are no records of any earthquakes occurring in the vicinity of the site within the last 25 years (Earthquake Track). Earthquakes in Scotland are typically no greater than 4 on the Richter Scale and, therefore, slight and unlikely to cause significant damage to buildings and infrastructure.

15.112 It is very unlikely that an earthquake would occur in the vicinity of the site resulting in any damage to the Proposed Development. Should a wind turbine be damaged, the risk to public safety is considered to be negligible due to the relatively remote location and careful design layout of the infrastructure. Therefore, the risk to the environment and the public, from the Proposed Development, as a result of seismic activity is considered **not significant.**

Population and Human Health

15.113 **Chapter 7: Landscape and Visual, Chapter 10: Hydrology, Hydrogeology and Geology, Chapter 12: Traffic and Transport,** and **Chapter 13: Noise** contain assessments which relate to the health and wellbeing of the local population. These chapters assess the effects of the proposed development, both positive and negative, provide an analysis of the significance of these effects and also put forward measures to mitigate against negative effects on people and their health.

15.114 **Chapter 16: Schedule of Commitments**, provides an overview of the mitigation put forward as part of these assessments in order to reduce any negative effects of the Proposed Development to an acceptable level.

15.115 Further to the topics covered in **Chapters 7 – 15**, including this chapter, it is not expected that there will be any other effects from the Proposed Development which would have significant effects on population and human health.

Agricultural Land Classification

15.116 As shown on Figure 15.3, the Proposed Development site contains approximately 37.93 ha of Class 3.1 Agricultural Land. The predicted permanent loss of Class 3.1 Agricultural Land due to the Proposed Development is 8.78 ha, representing 23% of the total area of Class 3.1 Agricultural Land within the Site.

15.117 It should be noted that the farm will continue to operate as a working farm, and that grazing will continue underneath the solar panels. These areas, including 6.02 ha of Class 3.1 Agricultural Land, have been considered as “lost” for the purpose of this assessment. This represents 69% of the total predicted permanent loss of Class 3.1 Agricultural Land due to the Proposed Development.

Air Quality

15.118 Construction activities can result in temporary effects from dust if unmanaged. This can result in nuisance effects such as soiling of buildings and, if present over a long period of time, can affect human health. As the nearest, non-financially involved property, is over 400m away from any substantial construction works (e.g. wind turbines, substation compound, BESS, solar array, borrow pits, new tracks) effects associated with dust or vehicle emissions are considered to be unlikely. In addition to this, it is expected that dust mitigation measures would be included within the full Construction Environment Management Plan for the Proposed Development. Therefore, the effects of dust and vehicle emissions from the construction and operation of the Proposed Development was scoped out of this assessment.

Eskdalemuir Seismic Array

15.119 The Proposed Development is located within the statutory consultation zone of the seismological recording station at Eskdalemuir, an asset that contributes to the Nuclear Test Ban Treaty. Wind turbines can interfere with seismic monitoring and according to the Ministry of Defence’s (MOD) response to the West Scales Energy Park EIA Scoping Report *“in order to ensure the United Kingdom can continue to implement its obligations in maintaining the Comprehensive Nuclear Test Ban Treaty, a finite seismic noise capacity for the 50km radius surrounding the array, based on the findings of research, is managed by the MOD.”*

15.120 The Planning and Infrastructure Act 2025 gives the Secretary of State the power to make regulations about planning permissions or consents relating to wind generating stations that may affect the functioning of a relevant seismic array system, such as Eskdalemuir

Seismic Array. This regulation making power came into force on 18 February 2026. It is anticipated that this will facilitate the introduction of new regulations for managing development on the land surrounding Eskdalemuir Seismic Array, ensuring that its functionality is protected, whilst enabling onshore wind farm developments, so long as they are outwith an agreed exclusion zone (anticipated to be 15km from the Seismic Array).

Telecommunications and Other Infrastructure

15.121 Wind turbines can potentially cause interference to telecommunications links through reflection and shadowing to electro-magnetically propagated signals including terrestrial fixed microwave links managed by telecommunications operators.

15.122 Constraints mapping, using the Ofcom SIS Portal, identified no fixed links running through the site. Fixed links that pass within 250 m of the site have been mapped and are shown on **Figure 15.4**. The following telecommunication consultees were contacted as part of the scoping process with none advising of any telecoms related concerns:

- Joint Radio Company (JRC)
- NATS Safeguarding
- Edinburgh Airport
- Glasgow Prestwick Airport
- Glasgow Airport
- British Telecom (BT)
- Ofcom
- MBNL (EE/Three)
- Vodafone
- Telefonica / O2

15.123 Additionally, wind turbines have the potential to adversely affect analogue television reception through either physical blocking of the transmitted signal or, more commonly, by introducing multi-path interference where some of the signal is reflected through different routes. However, the Proposed Development is located in an area which is now served by a digital transmitter, making such interference unlikely. In the rare event that television signals are affected, reasonable mitigation measures will be considered.

15.124 Consultation has been undertaken which confirms that no fixed telecommunications links should be affected by the Proposed Development. Further to this, television signals are unlikely to be affected by wind turbines, and should unexpected adverse effects on television reception arise, technical solutions are available. Therefore, **no significant** effects are predicted on telecommunications and tv reception.

Waste and Environmental Management

15.125 Where relevant, environmental topic **Chapters 7 to 14** put forward suggestions on how to mitigate any negative impacts from the Proposed Development with regards to waste and environmental management. These are summarised in **Chapter 16: Schedule of Commitments.**

15.126 The outline CEMP (**Technical Appendix 3.1**) provides a general overview on how waste and other environmental issues would be managed during the construction phase. **Technical Appendix 10.1**: Peat Survey Data presents the results of peat probing and coring undertaken across the Site, which inform the approach to avoiding areas of deeper peat. Measures for the control, storage, re-use and reinstatement of any shallow excavated peat are set out within the Outline CEMP

15.127 It is expected that a site specific waste management plan for the control and disposal of waste generated onsite would be required by condition, should the proposed development receive consent. Therefore, it is not considered necessary for waste to be assessed further within this EIA Report and is scoped out for further assessment.

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