Appendix V12A
Ornithology Collision Risk Modelling Report

1. Executive summary

1.1 Purpose of this report

E.ON Climate & Renewables UK Developments Ltd (E.ON) (the Developer) is seeking to amend the approved wind farm scheme at the consented Enoch Hill Wind Farm. The proposal to increase the maximum height to blade tip (from 130m to 149.9m for all 16 turbines) necessitates the Environmental Impact Assessment (EIA) undertaken for the original scheme and reported in the 2015 ES and 2017 FEI to be updated as the turbine parameters have changed.

This report documents the results of collision risk modelling (CRM) based on the revised turbine parameters and uses the same data collected from vantage point surveys to inform the 2015 ES and 2017 FEI. CRM was carried out for the same species modelled in the 2015 ES and 2017 FEI, golden plover, using the same approach taken in the original ES and FEI, and all data remains the same except for revised turbine parameters.

1.2 Results

The theoretical annual collision rate for golden plover using the turbine parameters of the Variation Development, and assuming the wind farm is operational 75 % of the time and a 98 % avoidance rate (as per the 2015 ES and 2017 FEI), is 8.2 collisions per year (i.e. 246 individuals over 30 years). This compares to a theoretical annual collision rate of 3.7 based on the original turbine parameters as reported in the 2017 FEI (i.e. 111 individuals over 30 years).

2. Introduction

The definition of the terms used in this assessment are as follows:

- Collision Risk Area: This is determined as the boundary around the extremities of the outermost turbines, including blade length and incorporating the proposed micro-siting allowance of 50m;
- Collision Risk Height: Only flight data at collision risk height is used in the Band model; and in this case the worst-case rotor swept heights are between 13.9m and 149.9m on the basis of the largest rotor diameter being considered (136m) on a 81.9m hub height to meet the maximum tip height criteria of 149.9m). During surveys, observed flights of target species were assigned to one of a series of height bands, generally 0-30m, 30-150 and >150m. For the purposes of CRM, all flights at heights of 30-150m and 53.67% of flight time within band 0-30m (i.e. on the basis of the 16.1m 'risk airspace' between 13.9m and 30m being 53.67% of the 0-30m height band) have been included;

- View-shed: The survey area associated with each VP, calculated on the basis of a 180° arc and a 2km-radius applied around each VP location. The area of visibility within each view-shed at collision-risk height is calculated using Zone of Theoretical Visibility software (in this case ReSoft Windfarm Release 4.2.1.7);
- Collision Risk Volume: Defined as the volume of the collision risk height airspace over the collision risk area; and
- The Rotor-Swept Volume: Defined as the volume of air that would actually be swept by all of the rotors in the wind farm. For an individual rotor this is determined by the area swept (πr^2) multiplied by the depth of the rotor blades from front to back.

Bird flight activity over the Development Site was assessed during Vantage-Point watches undertaken to inform the Environmental Impact Assessment (EIA) for the now Consented Development as reported in the 2015 ES. As reported in the 2015 ES, vantage point surveys undertaken across two breeding and three non-breeding seasons confirmed that target species flight activity over the Development Site was very limited.

CRM was therefore undertaken for only the most frequently occurring 'target species' with flight activity at collision risk height that could be analysed using the models developed by W. Band (Band et al, 2007) for birds with 'predictable' and 'less predictable' flights.

The 'Band model' uses a two-stage approach, whereby the number of birds or flights passing through the air space swept by the rotors is determined at Stage 1 and the probability of a bird strike occurring is calculated at Stage 2. The product of Stage 1 and Stage 2 gives a theoretical annual collision mortality rate on the assumption that birds make no attempt to avoid collision. The Band model involves making a number of assumptions, for example that a turbine blade has width and pitch but no thickness and that a bird's flight will be unaffected by a near miss, despite the slipstream around a turbine blade. The amount of time that a species may be active within the site in a year is also required for the model and must therefore be estimated.

Because the Band model assumes that no action is taken to avoid collision, it is recognised that the collision risk figures derived are purely theoretical and represent worst case estimates. Further assumptions about likely levels of active avoidance on the part of birds are therefore applied in order to draw conclusions; and it is widely accepted that avoidance rates for most species/groups are well in excess of 95% and 98-99%+ in most cases (see SNH 2016 and 2017 for example). Further information on CRM is provided in Appendix 12.G of the 2015 ES.

The Applicant is seeking to vary the Consented Development, the proposal of relevance to the CRM being to increase the maximum height to blade tip (from 130 m to 149.9 m for all 16 turbines). As the Variation Development primarily relates to increasing rotor diameter and blade tip height of turbines and operational period from 25-30 years) with all ground level infrastructure, construction/decommissioning methods and programme remaining unchanged (and therefore, no changes in respect of disturbance and habitat loss etc.), the only potential issue scoped into the assessment is the risk of collisions with turbines. Due to the very limited bird interest recorded previously and the limited potential for additional impacts on birds resulting from the proposed variation to the Consented Development, the assessment is based on the bird flight data of golden plover only as presented in the 2015 ES. This approach also allows the difference between the collision risk associated with the Consented Development and the Variation Development to be assessed.

Of the three non-breeding seasons during which VP surveys were undertaken at Enoch Hill, golden plover activity appeared to be at its greatest during winter 2013/14 in terms of peak flock size and the cumulative amount of flight time. Collision risk has therefore been modelled using golden plover flight data for winter 2013/14 only, as this represents a worst case scenario.

3. Methods

The data and parameters used for the CRM presented within this document are the same as those applied in the 2017 FEI except for changes to turbine parameters to reflect the increase in maximum turbine tip height and rotor diameter. The turbine technical parameters reported in the 2017 FEI and those of the Variation Development are provided in **Table 3.1** and golden plover biometric data is presented in **Table 3.2**.

Table 3.1 Turbine Technical Parameters

Parameter	2017 FEI	2020 Variation	Unit
Number of turbines	16	16	
Number of blades	3	3	
Maximum hub height	77	8~~1~~92	m
Approximate rotor diameter	106	136	m
Maximum height to blade tip	130	149.9	m
Minimum height to blade tip	24	13.9	m
Pitch	6	16	Degrees
Chord	4	4.1	m
Rotation period	4.6	5.45	m/s

Table 3.2 Golden plover biometric data

Parameter	Biometrics
Wingspan	0.72m
Body length	0.28m
Flight speed	13.7m/s

In respect of bird biometric data, this has been obtained from the British Trust for Ornithology (BTO) website , while information on average flight speed has been obtained from Alerstam *et al*., 2007.

CRM for golden plover has been carried out using the cumulative survey data from VPs 2, 3 and 5 during winter 2013/14. The entire turbine envelope lies within these three view-sheds and the main activity area for golden plover[1] (Enoch Hill, High Chang Hill, Barbey's Hill and Benty Cowan Hill) lies within these. The mean flock size across the 2013/14 winter season was of 28 individuals (a total of 25 flocks comprising 702 individuals in total, with the peak flock size of 220 birds in March).

Table 3.3 details those flights that meet the criteria detailed above and which have therefore been included in the CRM. It should be noted that the amount of time at collision risk height has been derived as a product of flight duration and the number of individuals in the flock. Furthermore, given the apparent random nature of golden plover flights, all of those observed within each view-shed at collision-risk height have been

[1] Only two flights, each of two individuals, was recorded from VP1 and from VP4.

included in the CRM, including flights out-with the collision-risk area. As such, the results of the CRM are likely to over-estimate the theoretical collision risk of golden plover.

Table 3.3 Golden Plover (GP) Flights from Winter 2013/14 included in the CRM

Unique Identification Code (UID)	Time (secs) at collision risk within viewshed (30-150m)	Time (secs) at collision risk within viewshed (13.9-30m)
Vantage Point 2		
EH_038_A	n/a	21.5
EH_038_B	140	n/a
EH_038_C	n/a	10.7
EH_052	n/a	13.4
EH_057	n/a	4.3
EH_058	n/a	16.1
EH_059	66,000	n/a
EH_065	n/a	3.2
EH_066	n/a	161,010
Vantage Point 3		
EH_030	252	n/a
EH_031	n/a	29
EH_041	n/a	81.6
EH_042	n/a	5.4
EH_053	n/a	1.6
EH_061	n/a	75.1
EH_064	79,200	n/a
Vantage Point 5		
EH_028	n/a	153.5
EH_029	n/a	6.4
EH_036	n/a	3.8
EH_043	n/a	15.0
EH_048	n/a	4.8
EH_049	n/a	21.5
EH_051	n/a	1.6

Unique Identification Code (UID)	Time (secs) at collision risk within viewshed (30-150m)	Time (secs) at collision risk within viewshed (13.9-30m)
EH_054	n/a	2.1
EH_055	n/a	8.6
Total	145,592	161,480.7

For the purposes of CRM, it has been assumed that turbines will be non-operational for 25 % of the time (e.g. during periods when wind speed is too low or too high to operate, or during maintenance) as per the CRM presented in the 2017 FEI.

4. Results

A summary of the CRM results based on a 98% avoidance rate for golden plover are shown in **Table 4.1**. Full details of model calculations are presented in **Annex 1.A**.

Table 4.1 Theoretical Annual Collision Rates for Golden Plover

Species	Annual collision rate based on the Variation Development turbine parameters	Annual collision rate based on the FEI Consented Development turbine parameters
Golden plover	8.2	3.7

* As per the CRM presented in the 2015 ES and 2017 FEI, the collision rate was calculated for golden plover based upon the season with the greatest level of flight activity (winter 2013/14) during the five seasons that Enoch Hill was surveyed (2011-14).

5. References

Alerstam T, Rosén M, Bäckman J, Ericson PGP, Hellgren O (2007) Flight Speeds among Bird Species: Allometric and Phylogenetic Effects. PLoS Biol 5(8): e197. doi:10.1371/journal.pbio.0050197.

Band, W., Madders, M. & Whitfield, D.P. 2007. Developing field and analytical methods to assess avian collision risk at wind farms. In Birds and Wind Farms: Risk Assessment and Mitigation. de Lucas, M., Janss, G., and Ferrer, M. (eds). Lynx Edicions, Barcelona.

Scottish Natural Heritage (2016). Avoidance rates for the onshore SNH Wind Farm Collision Risk Model. SNH guidance. October 2016.

Scottish Natural Heritage (2017). Avoidance Rates for the onshore SNH Wind Farm Collision Risk Model. SNH guidance. July 2017.

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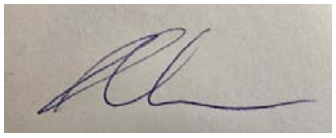

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6. Annex 1.A.

Stage 1

Survey area visible (ha)

1 | 1626

	Survey time (Mins)	Bird obs time@13.9-149.9m (Mins)
Proportion of time between 13.9-149.9m (t)	7560	5117.9

(obs time/survey time)
0.676970899

2 Flight activity per ha (F)
F = t/Survey *area visible*
0.000416341

Flight risk area (ha)
301

3 Proportion of time at 24-130m
F*flight risk area
0.125318721

Hub height (m)	Blade diameter (m)
81.9	136

Maximum rotor height	Minimum rotor height
149.9	13.9

4 Proportion of time in turbine area
((top of rotor-bottom of rotor)/(130-24))*F
0.160786284

days likely present	hours active
212	10

5 Bird occupancy period in windfarm n (hrs)
(days present*hrs active per day)* prop time in turbines
340.8669218

6 Flight risk volume V_w (m^2)
(windfarm area*rotor diameter)
409360000

Number of turbines	piR^2
16	14532.57143

7 Combined volume swept by rotors V_r (m^3)

Blade Depth (m)	Bird Length (m)
2	0.28

530148.2057

8 Occupancy of rotor swept area b (bird seconds)
(n*(Vr/Vw)
1589.202543

n(secs) (used in step 8)
1227120.918

flight speed (m/s)
13.7

9 Time to fly through and clear rotors time
(rotor depth+bird length)/flight speed(m/s)
0.166423358

10 Number of transits through rotors per year
(b/time)
9549.155632

Stage 2 (collision probability)
0.043

Annual theoretical collision rate assuming no avoidance
(Number of transits x stage 2 collision probability)
412.3

Annual theoretical collision rate assuming 98% avoidance:

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA - Golden Plover

K: [1D or [3D] (0 or 1)	**1**		**Calculation of alpha and p(collision) as a function of radius**									
NoBlades	**3**						Upwind:				Downwind:	
MaxChord	**4.1**	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	**16**		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	**0.28**	m	0.025	0.575	6.99	21.52	0.86	0.00108	20.22	0.81	0.00102
Wingspan	**0.72**	m	0.075	0.575	2.33	7.61	0.31	0.00229	6.31	0.25	0.00190
F: Flapping (0) or gliding (+1)	**0**		0.125	0.702	1.40	5.66	0.23	0.00284	4.08	0.16	0.00205
			0.175	0.860	1.00	5.08	0.20	0.00357	3.13	0.13	0.00220
Bird speed	**13.7**	m/sec	0.225	0.994	0.78	4.73	0.19	0.00427	2.48	0.10	0.00224
RotorDiam	**136**	m	0.275	0.947	0.64	3.90	0.16	0.00431	1.76	0.07	0.00194
RotationPeriod	**5.45**	sec	0.325	0.899	0.54	3.31	0.13	0.00432	1.28	0.05	0.00167
			0.375	0.851	0.47	2.86	0.11	0.00431	0.94	0.04	0.00141
			0.425	0.804	0.41	2.51	0.10	0.00428	0.69	0.03	0.00118
			0.475	0.756	0.37	2.23	0.09	0.00426	0.52	0.02	0.00100
Bird aspect ratioo: β	0.39		0.525	0.708	0.33	2.01	0.08	0.00424	0.41	0.02	0.00086
			0.575	0.660	0.30	1.82	0.07	0.00420	0.32	0.01	0.00075
			0.625	0.613	0.28	1.65	0.07	0.00414	0.30	0.01	0.00075
			0.675	0.565	0.26	1.50	0.06	0.00405	0.34	0.01	0.00093
			0.725	0.517	0.24	1.36	0.05	0.00395	0.37	0.01	0.00109
			0.775	0.470	0.23	1.23	0.05	0.00382	0.39	0.02	0.00122
			0.825	0.422	0.21	1.11	0.04	0.00368	0.40	0.02	0.00134
			0.875	0.374	0.20	1.00	0.04	0.00351	0.41	0.02	0.00144
			0.925	0.327	0.19	0.89	0.04	0.00332	0.41	0.02	0.00151
			0.975	0.279	0.18	0.79	0.03	0.00310	0.40	0.02	0.00156

Overall p(collision) = **Upwind** **7.4%** **Downwind** **2.8%**

Average **5.1%**

inc shut-down **4.3%** (turbines assumed inoperative 15% of time)

Flight reference number	VP	Date	Time	No. of birds	Flight time at 0-30m	Flight time at 30-150m	Total flight time at 0-30m	Total flight time at 30-150m	Time (secs) at collision risk within viewshed (13.9-30m)	Time (secs) at collision risk within viewshed
EH_038_A	2	11/10/2013	12:52	4	10		40	0	5.4	21.5
EH_038_B	2	11/10/2013	12:52	4		35	0	140	0.0	0.0
EH_038_C	2	11/10/2013	12:52	4	5		20	0	2.7	10.7
EH_052	2	11/01/2014	13:02	5	5		25	0	2.7	13.4
EH_057	2	19/02/2014	10:10	2	4		8	0	2.1	4.3
EH_058	2	19/02/2014	10:22	10	3		30	0	1.6	16.1
EH_059	2	19/02/2014	13:05	110		600	0	66000	0.0	0.0
EH_065	2	24/03/2014	10:05	1	6		6	0	3.2	3.2
EH_066	2	24/03/2014	11:35	200	1500		300000	0	805.1	161010.0
EH_030	3	13/09/2013	08:08	18		14	0	252	0.0	0.0
EH_031	3	13/09/2013	08:08	18	3		54	0	1.6	29.0
EH_041	3	14/11/2013	11:29	19	8		152	0	4.3	81.6
EH_042	3	26/11/2013	09:13	2	5		10	0	2.7	5.4
EH_053	3	20/01/2014	09:35	1	3		3	0	1.6	1.6
EH_061	3	27/02/2014	10:13	35	4		140	0	2.1	75.1
EH_064	3	23/03/2014	11:03	220		360	0	79200	0.0	0.0
EH_028	5	12/09/2013	13:35	22	13		286	0	7.0	153.5
EH_029	5	12/09/2013	14:22	2	6		12	0	3.2	6.4
EH_036	5	02/10/2013	15:04	1	7		7	0	3.8	3.8
EH_043	5	27/11/2013	09:51	7	4		28	0	2.1	15.0
EH_048	5	09/01/2014	08:33	3	3		9	0	1.6	4.8
EH_049	5	09/01/2014	09:55	8	5		40	0	2.7	21.5
EH_051	5	09/01/2014	14:30	1	3		3	0	1.6	1.6
EH_054	5	27/01/2014	09:30	1	4		4	0	2.1	2.1
EH_055	5	27/01/2014	11:15	8	2		16	0	1.1	8.6
							300877	145592	859.3	161480.7