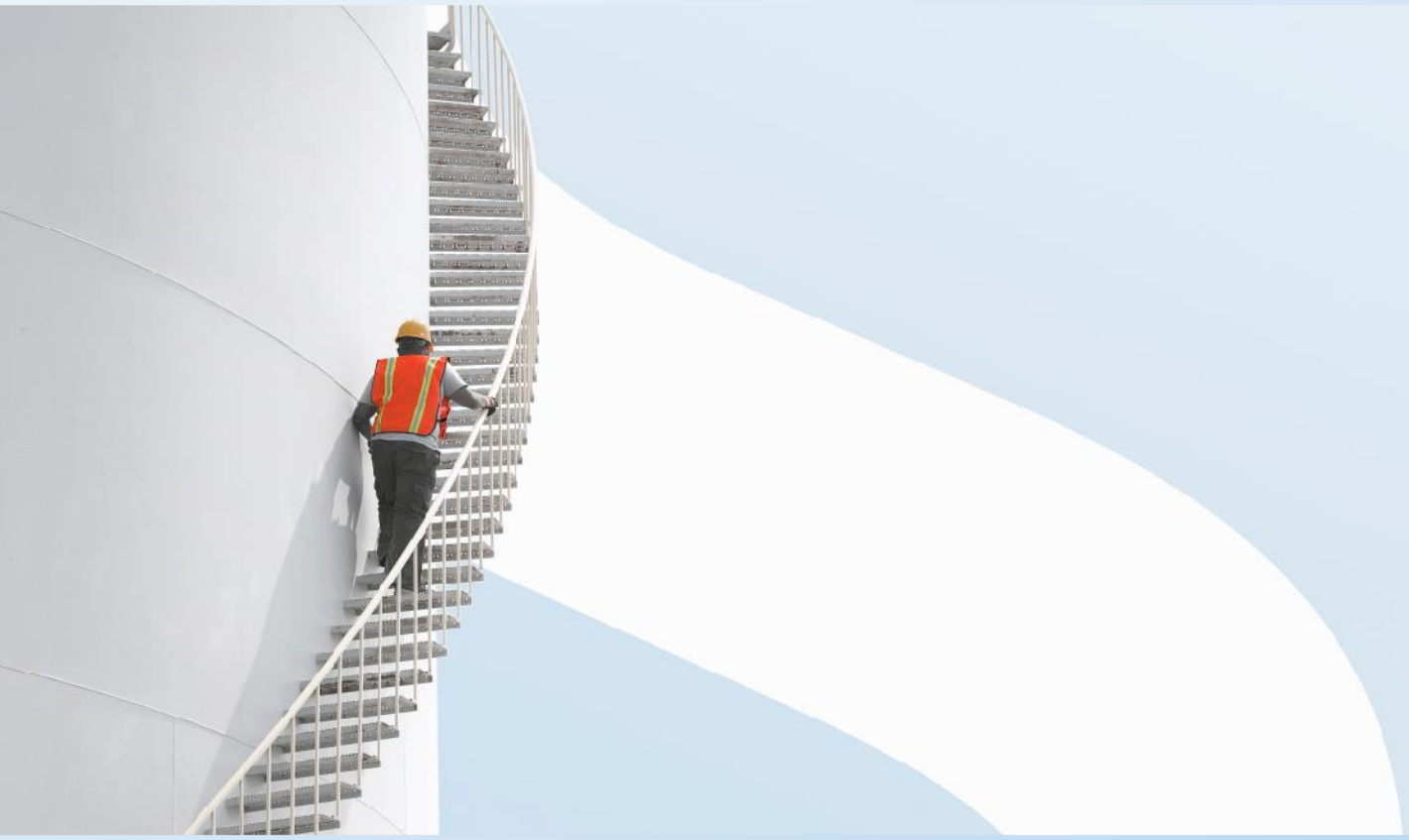
Total Energies

MIRNY 1GW WIND POWER PROJECT - KAZAKHSTAN

ESBS Appendix E: Bird Collision Risk Modelling Report



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ESBS Appendix E: Bird Collision Risk Modelling Report

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APPENDICES

1 INTRODUCTION

This Technical Appendix was commissioned by Total Energies (hereafter, the 'Client') and has been prepared to accompany **Chapter 06: Baseline conditions, Biological and biodiversity resources** of the Mirny 1GW Wind Farm Project (hereafter, the 'Proposed Development') Environmental and Social Baseline Study report.

The Site of the Proposed Development covers approximately 205.7km². This area is defined by the perimeter formed by connecting the outermost turbine rotors. To account for potential observer inaccuracies during bird flight activity surveys, a 500m buffer is added around this perimeter. The total area, including this buffer, is referred to as the Collision Risk Zone (CRZ), which covers approximately 251.47km².

1.1 COLLISION RISK MODEL

The risk of birds colliding with turbine rotors has been assessed using a model ('Band model') developed by William Band, which estimates the number of bird collisions with the turbine rotors during a specified time period (Band *et al.*, 2007; Band, 2024; NatureScot, 2024a). The model requires input data based on species biometrics and flight characteristics, turbine specification and flights observed within the CRZ. The amount of time that a species may be active within the CRZ in any given season is also required for the model and must therefore be estimated.

The original 'Band model' used 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.

An updated guidance released by NatureScot in 2024 (Band, 2024; NatureScot, 2024a) builds on the original 'Band model' and standardises all stages of the Collision Risk Model (CRM) calculations with an updated CRM spreadsheet for running the analysis. The updated model estimates the number of potential collisions through a five-stage process:

- **Stage A** uses bird survey data to establish the density of flying birds in the vicinity of the turbines, and the proportion flying at risk height, between the lowest and highest points of the rotors.
- **Stage B** provides an estimate, of the potential number of bird passages through rotors in the period in question, based on the bird density and proportion at risk height.
- **Stage C** calculates the probability of collision during a single bird rotor transit.
- **Stage D** estimates the potential collision rate for a bird species, assuming current levels of bird use of the site, allowing for the proportion of time that turbines are not operational.
- **Stage E** takes account of the proportion of birds likely to avoid the wind farm or its turbines, either because they have been displaced from the site, take evasive action or are attracted to the wind farm, e.g. in response to changing habitats.

This Technical Appendix uses the updated NatureScot guidance and CRM spreadsheet for its calculations.

The results of the modelling provide an estimate of the number of collisions that can be expected over a specific season, year, or for the lifetime of the wind farm.

1.2 SURVEY DESIGN (JUNE 2023 TO NOVEMBER 2024)

To assess baseline bird biodiversity - including bird density and flight activity - vantage point (VP) surveys have been conducted by Association for the Conservation of Biodiversity of Kazakhstan (ACBK) since summer 2023.

As the Proposed Development has undergone multiple turbine layout revisions based on the findings of various studies, the bird survey design has been adjusted accordingly. This has resulted in some VPs being discontinued and new ones introduced between survey seasons, to ensure alignment with each revised layout. Following ESIA study and the subsequent layout update, a viewshed analysis was conducted in August 2024 to optimise VP placement. This ensured at least 75% coverage of turbine locations with the optimum number of VPs, considering the Site's large size, challenging terrain, weather, and resource constraints. Additional VPs identified through this analysis were incorporated into the autumn 2024 survey.

For each season surveyed, the number of VPs and total survey effort were as follows:

- Summer (June, July, August) 2023: 40 VPs; total survey effort of 480 hours
- Autumn (September, October, November) 2023: 40 VPs; total survey effort of 480 hours
- Spring (March, April, May) 2024: 32 VPs; total survey effort of 384 hours
- Autumn (September, October, November) 2024: 30 VPs; total survey effort of 438 hours
- Winter (December, January, February) 2024-25: 16 VPs; total survey effort of 46 hours
- Spring (March, April, May) 2025: 30 VPs; total survey effort of 378 hours
- Summer (June, July, August) 2025: 30 VPs; total survey effort of 540 hours

Based on the viewshed analysis results and the range of species being recorded i.e. large raptors, it was determined that some VP viewsheds could reasonably be set to 2.5km, rather than the standard 2km. This adjustment helped maximise coverage of proposed turbine locations.

The final layout of turbines was provided by the Client in January 2025. At this stage, VP viewsheds were re-evaluated to determine which of them remained relevant to the CRM. Only data from these selected VPs were used for the CRM calculations. Table 1-1 below lists the VPs that were retained for the CRM analysis and the corresponding survey effort across different survey seasons. These VPs and their viewsheds are shown in Annex A with the final wind farm layout.

Table 1-1 VPs retained for CRM analysis and the survey effort (hours)

Relevant VP	Summer 2023 (hr)	Autumn 2023 (hr)	Spring 2024 (hr)	Autumn 2024 (hr)	Winter 2024-25 (hr)	Spring 2025 (hr)	Summer 2025 (hr)
S01 / M19	12	12	12	12	3	12	18
S04 / M17	12	12	12	12	3	12	18
S05 / M15	12	12	12	18	3	12	18
S09 / M08	12	12	12	18	3	12	18

Relevant VP	Summer 2023 (hr)	Autumn 2023 (hr)	Spring 2024 (hr)	Autumn 2024 (hr)	Winter 2024-25 (hr)	Spring 2025 (hr)	Summer 2025 (hr)
S10 / M10	12	12	12	15		12	18
S12 / M32	12	12	12	15		12	18
S13 / M06	12	12	12	18	3	12	18
S16 / M04	12	12	12	18	3	12	18
S18 / M03	12	12	12	15		12	18
S20 / M01	12	12	12	15		12	18
S11 / M07	12	12		15	2	12	18
M02			12	18		12	18
M05			12	18	3	12	18
M09			12	15	3	12	18
M11			12	18	3	12	18
M12			12	15	3	12	18
M13			12	18	2	12	18
M14			12	12	3	12	18
M16			12	15		12	18
M21			12	18		12	18
P02				12		12	18
P24				12		12	18
P17				12		12	18
X04				12		12	18
X05				12		12	18
P06				12		12	18
No. of relevant VPs	**11**	**11**	**19**	**26**	**13**	**26**	**26**
Total effective survey effort per season	**132**	**132**	**228**	**342**	**37**	**312**	**468**

1.3 BIRD SPECIES SELECTED FOR CRM

This analysis is based on field data collected from summer 2023 to summer 2025 from the VPs that remain relevant to the final Site layout.

Thirty-six species were observed flying at Potential Collision Height (PCH) (defined in Section 2.4.3 further) within the CRZ. For CRM, only species with at least five flights recorded across the entire survey effort were considered. Based on this criterion, 13 species were taken forward for the assessment, which are as follows:

- Black bellied Sandgrouse *Pterocles orientalis*;
- Black Kite *Milvus migrans*;
- Common Kestrel *Falco tinnunculus*;
- Eurasian Hobby *Falco subbuteo;*
- Eurasian Sparrowhawk *Accipiter nisus*;
- Golden Eagle *Aquila chrysaetos*;
- Lesser Kestrel *Falco naumanni*;
- Little Bustard *Tetrax tetrax*;
- Long legged Buzzard *Buteo rufinus*;
- Rough Legged Buzzard *Buteo lagopus*;
- Short Toed Snake Eagle *Circaetus gallicus*;
- Steppe Eagle *Aquila nipalensis*; and
- White tailed Eagle *Haliaeetus albicilla*.

2 CRM METHODOLOGY

2.1 WIND FARM SPECIFICS

The Proposed Development will consist of 150 turbines of two different models, the details of which are given in Table 2-1 below.

Table 2-1 Windfarm specifications

Parameter	Model 1 – Envision EN182 6.5MW	Model 2 – Sany 7.7MW
Number of turbines	124	26
Number of blades	3	3
Hub height (m)	110	120
Rotor radius (m)	90.55	97.5
Maximum height to blade tip (m)	200	217.5
Minimum height to blade tip (m)	20	22.5
PCH (m)	20 - 200	22.5 - 217.5
Mean rotor speed (rpm)	9.5	9.88
Mean pitch (degrees)	47.5	42.5
Maximum chord (m)	5.08	4.5

The collision risk for each species was calculated for both turbine models individually, due to differences in model parameters.

2.2 BIRD BIOMETRICS

Morphometric measurements for bird species (Table 2-2) were taken from BTO Facts (BTO, n.d.) with flight speeds from Alerstam *et al.* (2007) or, where required, from Bruderer and Boldt (2001). Flight type for each species was decided based on expert judgement.

Table 2-2 Bird biometrics

Species	Bird length (m)	Wingspan length (m)	Flight speed (m/s)	Flight type
Black bellied Sandgrouse	0.34	0.71	17	Flapping
Black Kite	0.6	1.5	15.7	Gliding

Species	Bird length (m)	Wingspan length (m)	Flight speed (m/s)	Flight type
Common Kestrel	0.35	0.75	8	Flapping
Eurasian Hobby	0.33	0.87	11.3	Flapping
Eurasian Sparrowhawk	0.32	0.65	13.8	Flapping
Golden Eagle	0.81	2.12	15	Gliding
Lesser Kestrel	0.3	0.68	8	Flapping
Little Bustard	0.5	1.12	17	Flapping
Long legged Buzzard	0.6	1.37	14.6	Gliding
Rough Legged Buzzard	0.55	1.35	11.5	Gliding
Short Toed Snake Eagle	0.67	1.86	11	Gliding
Steppe Eagle	0.81	2.02	10	Gliding
White tailed Eagle	0.8	2.2	12	Gliding

2.3 DIRECTIONAL OR NON-DIRECTIONAL MODEL

The Stage A and B calculation varies depending on whether flight activity follows a regular directional pattern or is non-directional.

The modelling method for birds with directional flight activity is used for birds such as geese following a regular migration route or travelling from a winter roost to a regular feeding area. Directional approach or ‘Birds on migration’ requires the input of number of birds that cross a baseline perpendicular to the main flight direction.

The modelling method for birds with non-directional or ‘normal’ flight activity, such as raptors and waders, requires the calculation of the amount of time birds were observed flying per unit of area surveyed. This level of flight activity is then applied to the Proposed Development in subsequent calculations of the collision risk.

The flight activity surveys identified nine of the eleven species selected for CRM as migratory. Therefore, their collision risk assessment followed the directional or 'birds on migration' approach. For the remaining two species (Common Kestrel and Golden Eagle), which are local to the Site, the non-directional or 'normal' approach was applied.

2.4 STAGE A: FLIGHT ACTIVITY

2.4.1. DIRECTIONAL FLIGHT: MIGRATION PASSES

For species following a directional or 'birds on migration' flight pattern, the total number of birds traveling through the migration corridor— i.e., the Site— is entered into the 'Migrant Collision Risk' sheet of the CRM

spreadsheet. Data from each seasonal survey is recorded as a representative month per season. Table 2-3 below gives the data entered for bird passages for each species.

The width of the migration corridor has been measured as the total horizontal extent of the Site, spanning 28.34 km.

Table 2-3 Migration passages as entered for species following directional flights

Species	January (winter survey season)	April (spring survey season)	July (summer survey season)	September (autumn survey season)	Migration passes per annum
Black bellied Sandgrouse	0	98	260	268	**626**
Black Kite	0	43	0	2	**45**
Eurasian Hobby	0	6	0	0	**6**
Eurasian Sparrowhawk	0	66	0	12	**78**
Lesser Kestrel	0	15	0	4	**19**
Little Bustard	0	9	0	0	**9**
Long legged Buzzard	0	68	20	30	**118**
Rough Legged Buzzard	1	2	0	3	**6**
Short Toed Snake Eagle	0	18	5	4	**27**
Steppe Eagle	0	13	6	109	**128**
White tailed Eagle	3	7	0	33	**43**

2.4.2. DIRECTIONAL FLIGHT: AREAL BIRD DENSITY

Areal bird density is defined as the number of birds per unit area, in flight at any height at a given point in time.

For species following non-directional or 'normal' flight pattern, flying time was divided by the period of the watch (in seconds) and the area watched (in km^2) to give the average density of birds in flight per square kilometre. Bird data for each species was grouped by survey season (summer, autumn, and spring). The areal bird density for each species was calculated for each VP and season. Due to the significant differences in survey effort and areas observed across seasons, this density was then weighted based on the number of turbines within each VP. The turbine-weighted annual average bird density was entered for each month in the CRM spreadsheet.

Table 2-4 below shows the average bird density for each species, as entered in the CRM spreadsheet.

Table 2-4 Average annual areal bird density for each species following non-directional flights

Species	Average annual areal bird density (birds/km^2)
Common Kestrel	0.0005
Golden Eagle	0.0003

2.4.3. PROPORTION FLYING AT RISK HEIGHT

The Proposed Development will have turbines of two different models. For the purpose of CRM, PCH is calculated by using the lowest blade sweep height and highest blade sweep height for each individual model, resulting in following PCH values:

- Model 1: PCH 20 - 200m
- Model 2: PCH 22.5 - 217.5m

The flight activity surveys recorded the flight heights of birds using height bands of 0 - 20m, 20 - 200m, and >200m. Ideally, the proportion of birds flying at PCH for each turbine model should be calculated to account for model-specific differences, however, since the difference in PCH between the models is minimal, only flights within the height band 20 - 200m were considered to simplify the assessment without significantly affecting the results. Consequently, the proportion of birds flying at risk height was entered as 100% for all species (both directional and non-directional flights).

2.4.4. WINDFARM LATITUDE

The windfarm latitude is 45°06'. This is expressed in decimals as 45.06° in Sheet 3 of CRM spreadsheet – 'Daylight and night hours' to determine the total daylight hours for which the previously calculated bird densities may be expected to persist.

2.4.5. NOCTURNAL ACTIVITY FACTOR

No night-time surveys of the Site were conducted. Instead, likely levels of nocturnal activity for all species were determined through expert assessment and literature review. As nocturnal activities of all species are believed to be low and therefore, a score of one on the one to five scale used in the spreadsheet (nocturnal activity = 0% of daytime activity) has therefore been attributed.

2.5 STAGE B: ESTIMATING NUMBER OF FLIGHTS THROUGH ROTORS

The total number of bird transits expected through rotors is proportional to the number and cross-sectional area of the rotors and to the number of migration passages/density of birds in the airspace at risk height (given in Table 2-4). Additional information is required on flight speed of the species being observed.

2.5.1. OUTPUT FROM STAGE B

The output from Stage B is shown in the 'Collision risk' sheet as the potential number of bird transits through the rotors, per month and per annum. The output from this stage for both turbine models is given in Table 2-5 below.

Table 2-5 Output from Stage B

	Species	Model 1	Model 2
Total rotor frontal area (m^2)		3,194,100	776,484
Projected number of rotor transits per annum (directional flights)	Black bellied Sandgrouse	390	88
	Black Kite	28	6
	Eurasian Hobby	4	1
	Eurasian Sparrowhawk	49	11
	Lesser Kestrel	12	3
	Little Bustard	4	1
	Long legged Buzzard	73	17
	Rough Legged Buzzard	4	1
	Short Toed Snake Eagle	14	4
	Steppe Eagle	80	18
	White tailed Eagle	27	6
Projected number of rotor transits per annum (non-directional flights)	Common Kestrel	1134	256
	Golden Eagle	1275	288

It is worth noting that at this stage, non-operational time for the turbines has not yet been factored in.

2.6 STAGE C: PROBABILITY OF COLLISION FOR A SINGLE ROTOR TRANSIT

This stage uses information on the size and speed of the turbines and physical details on the size, speed and flight type of the bird to compute the risk of collision for a bird flying through a rotating rotor.

The orientation of the wind turbines is expected to be distributed across many directions, according to the wind rose for the Site. It has been assumed that flights of all species are equally split as between upwind and downwind.

2.6.1. OUTPUT FROM STAGE C

The CRM spreadsheet calculated the risk of collision during a single transit. The result is expressed as a percentage risk for upwind and downwind flight respectively, with the weighted mean value being used in calculating collision risk. The outputs are detailed in Table 2-6 below.

Table 2-6 Output from Stage C - Single transit risk

Species	Model	Single transit risk upwind (%)	Single transit risk downwind (%)	Single transit risk weighted mean (%)
Black bellied sandgrouse	Model 1	9.05%	4.73%	6.24%
	Model 2	7.94%	4.10%	5.44%
Black Kite	Model 1	10.40%	6.04%	7.56%
	Model 2	9.25%	5.37%	6.73%
Common Kestrel	Model 1	16.44%	11.88%	14.16%
	Model 2	14.41%	10.32%	12.36%
Eurasian Hobby	Model 1	12.33%	7.85%	9.41%
	Model 2	10.80%	6.80%	8.20%
Eurasian Sparrowhawk	Model 1	10.46%	6.05%	7.60%
	Model 2	9.17%	5.23%	6.61%
Golden Eagle	Model 1	11.49%	7.11%	9.30%
	Model 2	10.32%	6.42%	8.37%
Lesser Kestrel	Model 1	16.14%	11.58%	13.17%
	Model 2	14.10%	10.01%	11.44%
Little Bustard	Model 1	9.58%	5.27%	6.78%
	Model 2	8.48%	4.64%	5.98%
Long legged Buzzard	Model 1	10.96%	6.56%	8.10%
	Model 2	9.75%	5.83%	7.21%
Rough Legged Buzzard	Model 1	13.02	8.55%	10.12%
	Model 2	11.56%	7.56%	8.96%
Short Toed Snake Eagle	Model 1	14.07%	9.58%	11.15%
	Model 2	12.56%	8.55%	9.96%

Species	Model	Single transit risk upwind (%)	Single transit risk downwind (%)	Single transit risk weighted mean (%)
Steppe Eagle	Model 1	15.87%	11.35%	12.93%
	Model 2	14.27%	10.23%	11.65%
White tailed Eagle	Model 1	13.66%	9.20%	10.76%
	Model 2	12.27%	8.28%	9.68%

2.7 STAGE D: MULTIPLYING TO YIELD EXPECTED COLLISIONS PER YEAR

This stage multiplies the outputs from Stage B and Stage C to yield the projected number of bird collisions per month or year. This includes a factor to allow for proportion of time that rotors are not operational.

It has been assumed that turbines will be non-operational for 15% of the time (e.g., during periods when wind speed is too low or too high to operate, or during maintenance).

2.7.1. OUTPUT FROM STAGE D

The output from Stage D, given in Table 2-7, is the expected number of collisions assuming no avoidance by birds.

Table 2-7 Output from Stage D - Expected collisions per annum assuming no avoidance

Species	Model 1	Model 2	Species	Model 1	Model 2
Black bellied Sandgrouse	21	4	Little Bustard	0	0
Black Kite	2	0	Long legged Buzzard	5	1
Common Kestrel	136	27	Rough Legged Buzzard	0	0
Eurasian Hobby	0	0	Short Toed Snake Eagle	2	0
Eurasian Sparrowhawk	3	1	Steppe Eagle	9	2
Golden Eagle	101	20	White tailed Eagle	2	0
Lesser Kestrel	1	0			

2.8 STAGE E: APPLYING THE AVOIDANCE RATE

2.8.1. AVOIDANCE RATES AND ATTRACTION

The avoidance rates for all species are based on the current NatureScot guidance. Collision risks have been calculated for avoidance rates of 95%, 98%, 99%, and 99.5%. However, the central result is determined according to the guidance for each species.

2.8.2. LARGE ARRAY CORRECTION

The 'Large array correction factor' sheet has calculated the correction factor which should be applied to take account of any depletion of bird density because of collisions. For all both turbine models, the setting 'Allow for large array correction?' in the Collision risk sheet was set to 'Yes' to factor in the correction factor into the calculations.

2.8.3. OUTPUT FROM STAGE E: CRM RESULTS

The results of the CRM for all species modelled are summarised in Table 2-8. Full model calculations are provided in Annex B.

Table 2-8 CRM results - Potential collisions per annum

Species	Avoidance rate	Modelled collisions per year			Years per collision using weighted mean (approximate)	Modelled collisions per 40 years using weighted mean (approximate)
		Model 1	Model 2	**Weighted mean**		
Black bellied Sandgrouse	98%	0.4	0.1	**0.25**	4	10
Black Kite	99%	0.0	0.0	**0.0**	0	0
Common Kestrel	98%	2.7	0.5	**1.6**	0.6	64
Eurasian Hobby	98%	0.0	0.0	**0.0**	0	0
Eurasian Sparrowhawk	98%	0.1	0.0	**0.05**	20	2
Golden Eagle	99%	1	0.2	**0.6**	1.7	24
Lesser Kestrel	95%	0.1	0.0	**0.05**	20	2
Little Bustard	98%	0.0	0.0	**0.0**	0	0
Long legged Buzzard	98%	0.1	0.0	**0.05**	20	2
Rough Legged Buzzard	98%	0.0	0.0	**0.0**	0	0
Short Toed Snake Eagle	98%	0.0	0.0	**0.0**	0	0

Species	Avoidance rate	Modelled collisions per year			Years per collision using weighted mean (approximate)	Modelled collisions per 40 years using weighted mean (approximate)
		Model 1	Model 2	**Weighted mean**		
Steppe Eagle	98%	0.2	0.0	**0.1**	10	4
White tailed Eagle	95%	0.1	0.0	**0.05**	20	2

*All estimates are rounded to the nearest decimal place

2.9 STAGE F: EXPRESSING UNCERTAINTY

In a collision risk estimate, there are many sources of variability or uncertainty at multiple stages. These must be combined to give an understanding of the uncertainty (and hence the likely accuracy) of the estimated collision risk.

Each error or uncertainty is first expressed as a relative error, i.e. expressed as a percentage of the value to which it refers. All the errors here are based on seeking 95% certainty.

The errors are assessed as follows:

- Migration passes (E1) for species following directional flight pattern: Survey effort varied throughout the year, meaning the recorded migration flux does not fully represent the actual annual migration flux. Additionally, there is inherent uncertainty and year-to-year variation in both the number of migrating birds and the precise flight corridor used. Considering these factors, an uncertainty margin of ±75% is deemed a reasonable estimate. Therefore, E1 = 0.75 for species exhibiting directional flight.
- Bird density (E2) for Common Kestrel and Golden Eagle: Bird density measures showed variability between survey seasons. Error is estimated by calculating 1.96 * annual standard deviation (SD) from the mean. Since the average annual bird density was calculated by using turbine-weighted mean, the standard deviation will also be turbine-weighted. The error estimate E2 for both species is given below in Table 2-9.

Table 2-9 Error E2 estimate

Species	Turbine-weighted Standard deviation (SD)	Standard error (E2) = 1.96*SD
Common Kestrel	0.0005	0.0022
Golden Eagle	0.0003	0.0011

- Nocturnal flight activity (E3): Nocturnal activity for all species has been assumed as 0% of the daytime activity, but it has been judged it might be in the range of 0-10%. This results in an uncertainty of ± 5%. Therefore E2 = 0.05 for all species.

- Proportion at risk height (E4): If the visual estimate out by ±5m, it is estimated that the proportion of birds flying above 20m would vary by around ±25%. Therefore E3 = 0.25 for all species.
- Collision model (E5): The model involves a number of simplifications, such as shape of bird, use of average pitch, etc. Based on the NatureScot guidelines, an uncertainty of ±20% is considered a reasonable estimate. Therefore, E4 = 0.20 for all species.

All these errors (E1 to E5) arise independently so in combining errors, the root mean square is taken to allow for the likelihood that some errors will offset others, i.e.

$$E = \sqrt{\{(E1 \text{ or } E2)^2 + E3^2 + E4^2 + E5^2)\}}$$

, which calculates combined uncertainty. Combined uncertainty for each species is given in Table 2-10 below.

Table 2-10 Uncertainty estimate

Species	Combined error (E)	Combined error (E) as %
Black bellied Sandgrouse	± 0.8170	± 82%
Black Kite	± 0.8170	± 82%
Common Kestrel	± 0.3240	± 32%
Eurasian Hobby	± 0.8170	± 82%
Eurasian Sparrowhawk	± 0.8170	± 82%
Golden Eagle	± 0.3240	± 32%
Lesser Kestrel	± 0.8170	± 82%
Little Bustard	± 0.8170	± 82%
Long legged Buzzard	± 0.8170	± 82%
Rough Legged Buzzard	± 0.8170	± 82%
Short Toed Snake Eagle	± 0.8170	± 82%
Steppe Eagle	± 0.8170	± 82%
White tailed Eagle	± 0.8170	± 82%

3 CRM RESULTS

The best estimate of annual collision risk, with considering avoidance rates outlined in Section 2.8 and uncertainties outlined in Section 2.9, is given below in Table 3-1 for all species for which collision risk was modelled.

Table 3-1 Best estimate of annual collision risk

Species	Avoidance rate (%)	Annual collision estimate	Best estimate range
Black bellied Sandgrouse	98%	0.25 ± 82%	0 – 1.1
Black Kite	99%	0 ± 82%	0 – 0.8
Common Kestrel	98%	1.6 ± 32%	1.3 – 1.9
Eurasian Hobby	98%	0 ± 82%	0 – 0.8
Eurasian Sparrowhawk	98%	0.05 ± 82%	0 – 0.9
Golden Eagle	99%	0.6 ± 32%	0.3 – 0.9
Lesser Kestrel	95%	0.05 ± 82%	0 – 0.9
Little Bustard	98%	0 ± 82%	0 – 0.8
Long legged Buzzard	98%	0.05 ± 82%	0 – 0.9
Rough Legged Buzzard	98%	0 ± 82%	0 – 0.8
Short Toed Snake Eagle	98%	0 ± 82%	0 – 0.8
Steppe Eagle	98%	0.1 ± 82%	0 – 0.9
White tailed Eagle	95%	0.05 ± 82%	0 – 0.9

4 REFERENCES

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Annex A

FIGURE

Figure 1 – Vantage point visibility, January 2025 layout

Date Modified: 2/13/2025

Drawn By: AP

File: \\uk.wspgroup.com\central data\Discipline Management\Environmental\1. Service Lines\Ecology\1. Office specific\Noida\New folder (2)\Shrishti\Aparna\Mirny Windfarm CRM\mxd\Final layout\Figures\Complete site old+new 2025 jan..mxd

Legend

- Optimised viewsheds
- Vantage Points (26)
- Visible turbine rotors (119)
- Hidden turbine rotors (31)

M21
M19
P06
M17
M16
M15
M14
X05
M12
M13
M09
M10
M11
X04
M08
M07
P17
M32
P02
M06
P24
M04
M03
M05
M01
M02

0 0.5 1 2 3 4
Kilometres

wsp

Scale:
1:116,110

TITLE:
Mirny Wind Farm Project

FIGURE No:
Vantage Point Visibility January 2025 layout

Annex B

CRM CALCULATIONS

BLACK BELLIED SANDGROUSE – TURBINE MODEL 1

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		**llied sandgrouse**	
Bird length	L	0.34	m
Wingspan	W	0.71	m
Bird flight speed	v	17	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		**Mirny**	
Latitude		45.06	degrees
No of turbines	T	124	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		**EN182 - 6.5MW**	
Hub height		110	m
Rotor radius	R	90.55	m
No of blades	b	3	
Rotation speed	Ω	9.5	rpm
Max blade width	C	5.08	m
Blade pitch	λ	47.5	degrees
Risk height range		19-201	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.0133	0.0133	0.033	0.0528	0.0528	0.0528	0.0528	0.0528	0.0528	0.0133	0.0133	0.0133	0.0347
Proportion at rotor risk height	Q_{RR}	14.50%														
At latitude 45.1		**Daylight hours per month**		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	124															
Rotor radius	R	90.55	m														
		Total rotor frontal ar		3194100													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	17	m s^{-1}														
		Projected number of rotor transits			0.0	0.0	0.0	61.0	0.0	0.0	161.8	0.0	166.8	0.0	0.0	0.0	**390**

Stage C								
No of blades	b	3			Bird length	l	0.34	m
Rotation speed	Ω	9.5	rpm		Wingspan	w	0.71	m
Rotor radius	R	90.55	m		Bird flight speed	v	17	m s^{-1}
Max blade width	C	5.08	m		Flight type		flapping	
Pitch	λ	47.5	degrees	% of flights upwind/downwind			35%	65%
Blade profile		see Blade profile sheet						
		Single transit risk		**upwind**	9.05%			
				downwind	4.73%			
				weighted mean	**6.24%**			

Stage D		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	$Q_{..}$	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.00	0.00	0.00	3.24	0.00	0.00	8.58	0.00	8.85	0.00	0.00	0.00	**21**

Stage E					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
Allow for large array correction?		Yes															
Width of windfarm	w	8.946	km														
			large array correction		**Collision rates allowing for avoidance**												
Avoidance rates modelled		95.00%	99.76%		0.00	0.00	0.00	0.16	0.00	0.00	0.43	0.00	0.44	0.00	0.00	0.00	**1.0**
		98.00%	99.90%		0.00	0.00	0.00	0.06	0.00	0.00	0.17	0.00	0.18	0.00	0.00	0.00	**0.4**
		99.00%	99.95%		0.00	0.00	0.00	0.03	0.00	0.00	0.09	0.00	0.09	0.00	0.00	0.00	**0.2**
		99.50%	99.98%		0.00	0.00	0.00	0.02	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.00	**0.1**

BLACK BELLIED SANDGROUSE – TURBINE MODEL 2

COLLISION RISK MODEL		Required input data is in	orange	boxes
		Calculated output is in	blue	boxes
			green	boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		**llied Sandgrouse**	
Bird length	L	0.34	m
Wingspan	W	0.71	m
Bird flight speed	v	17	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		**Mirny WF**	
Latitude		45.06	degrees
No of turbines	T	26	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		**Sany 7.7MW**	
Hub height		120	m
Rotor radius	R	97.5	m
No of blades	b	3	
Rotation speed	Ω	9.88	rpm
Max blade width	C	4.5	m
Blade pitch	λ	42.5	degrees
Risk height range		23-218	m

birds on migration	Set to 'normal approach' to use survey data on bird density
	Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2	0.00118	0.00118	0.00118	0.00118	0.00118	0.00118	0.00118	0.00118	0.00118	0.00118	0.00118	0.00118	0.0012
Proportion at rotor risk height	Q_{2R}	100.00%														
At latitude 45.1		**Daylight hours per month**		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	26															
Rotor radius	R	97.5	m														
		Total rotor frontal ar		776484													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	17	m s^{-1}														
		Projected number of rotor transits			0.0	0.0	0.0	13.8	0.0	0.0	36.5	0.0	37.7	0.0	0.0	0.0	**88**

Stage C								
No of blades	b	3		Bird length	l	0.34	m	
Rotation speed	Ω	9.88	rpm	Wingspan	w	0.71	m	
Rotor radius	R	97.5	m	Bird flight speed	v	17	m s^{-1}	
Max blade width	C	4.5	m	Flight type		flapping		
Pitch	λ	42.5	degrees	% of flights upwind/downwind		35%	65%	
Blade profile		see Blade profile sheet						
		Single transit risk	**upwind**	7.94%				
			downwind	4.10%				
			weighted mean	**5.44%**				

Stage D			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}		85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance													year total
			0.00	0.00	0.00	0.64	0.00	0.00	1.69	0.00	1.74	0.00	0.00	0.00	**4**

Stage E					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
Allow for large array correction?		Yes															
Width of windfarm	w	8.946	km														
			large array correction	**Collision rates allowing for avoidance**													
Avoidance rates modelled		95.00%	99.96%		0.00	0.00	0.00	0.03	0.00	0.00	0.08	0.00	0.09	0.00	0.00	0.00	**0.2**
		98.00%	99.98%		0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.00	**0.1**
		99.00%	99.99%		0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.00	**0.0**
		99.50%	100.00%		0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	**0.0**

BLACK KITE – TURBINE MODEL 1

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

Bird data		Value	Units	Windfarm data		Value	Units	Turbine data		Value	Units
Species name		Black Kite		Site name		Mirny VF		Model		EN182 - 6.5MW	
Bird length	L	0.6	m	Latitude		45.06	degrees	Hub height		110	m
Wingspan	W	1.5	m	No of turbines	T	124		Rotor radius	R	90.55	m
Bird flight speed	v	15.7	m s^{-1}	Width of windfarm	w	8.946	km	No of blades	b	3	
Flight type, flapping or gliding		gliding						Rotation speed	Ω	9.5	rpm
% of flights upwind/downwind		35%	65%					Max blade width	C	5.08	m
Nocturnal activity ranking 1-5		1						Blade pitch	λ	47.5	degrees
Nocturnal activity factor	f_{night}	0%						Risk height range		19-201	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.0004
Proportion at rotor risk height	Q_{ER}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	124															
Rotor radius	R	90.55	m														
		Total rotor frontal ar		3194100													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	15.7	m s^{-1}		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
		Projected number of rotor transits			0.0	0.0	0.0	26.8	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	**28**

Stage C

No of blades	b	3			Bird length	l	0.6	m
Rotation speed	Ω	9.5	rpm		Wingspan	w	1.5	m
Rotor radius	R	90.55	m		Bird flight speed	v	15.7	m s^{-1}
Max blade width	C	5.08	m		Flight type		gliding	
Pitch	λ	47.5	degrees	% of flights upwind/downwind			35%	65%
Blade profile		see Blade profile sheet						
		Single transit risk	upwind	10.40%				
			downwind	6.04%				
			weighted mean	**7.56%**				

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%

Collision rates before avoidance												year total
0.00	0.00	0.00	1.72	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	**2**

Stage E

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
Allow for large array correction?		Yes														
Width of windfarm	w	8.946	km													
			large array correction	Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	99.71%	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.1**
		98.00%	99.88%	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.00%	99.94%	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.50%	99.97%	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

BLACK KITE – TURBINE MODEL 2

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

Bird data		Value	Units
Species name		Black Kite	
Bird length	L	0.6	m
Wingspan	W	1.5	m
Bird flight speed	v	15.7	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Mirny VF	
Latitude		45.06	degrees
No of turbines	T	26	
Width of windfarm	w	8.946	km

Turbine data		Value	Units
Model		Sany 7.7MW	
Hub height		120	m
Rotor radius	R	97.5	m
No of blades	b	3	
Rotation speed	Ω	9.88	rpm
Max blade width	C	4.5	m
Blade pitch	λ	42.5	degrees
Risk height range		23-218	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.0004
Proportion at rotor risk height	Q_{ZR}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	26															
Rotor radius	R	97.5	m														
		Total rotor frontal ar		776484													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	15.7	m s^{-1}														
		Projected number of rotor transits			0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	**6**

Stage C

No of blades	b	3			Bird length	l	0.6	m
Rotation speed	Ω	9.88	rpm		Wingspan	w	1.5	m
Rotor radius	R	97.5	m		Bird flight speed	v	15.7	m s^{-1}
Max blade width	C	4.5	m		Flight type		gliding	
Pitch	λ	42.5	degrees	% of flights upwind/downwind			35%	65%
Blade profile		see Blade profile sheet						
		Single transit risk		upwind	9.25%			
				downwind	5.37%			
				weighted mean	**6.73%**			

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	**0**

Stage E

Allow for large array correction?		Yes													
Width of windfarm	w	8.946	km												
			large array correction		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
					Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	99.95%		0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		98.00%	99.98%		0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.00%	99.99%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.50%	99.99%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

COMMON KESTREL – TURBINE MODEL 1

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		**Common kestrel**	
Bird length	L	0.35	m
Wingspan	W	0.75	m
Bird flight speed	v	8	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		50%	50%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		**Mirny WF**	
Latitude		45.06	degrees
No of turbines	T	124	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		**EN182 - 6.5MW**	
Hub height		110	m
Rotor radius	R	90.55	m
No of blades	b	3	
Rotation speed	Ω	9.5	rpm
Max blade width	C	5.08	m
Blade pitch	λ	47.5	degrees
Risk height range		19-201	m

normal approach

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Proportion at rotor risk height	Q_{ZR}	100.00%														
At latitude 45.1		**Daylight hours per month**		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	124															
Rotor radius	R	90.55	m														
		Total rotor frontal ar		3194100													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	8	m s^{-1}														
		Projected number of rotor transits			72.4	73.8	93.6	102.6	116.8	118.5	120.1	110.9	95.8	86.7	73.2	69.6	**1134**

Stage C

No of blades	b	3		Bird length	l	0.35	m	
Rotation speed	Ω	9.5	rpm	Wingspan	w	0.75	m	
Rotor radius	R	90.55	m	Bird flight speed	v	8	m s^{-1}	
Max blade width	C	5.08	m	Flight type		flapping		
Pitch	λ	47.5	degrees	% of flights upwind/downwind		50%	50%	
Blade profile		see Blade profile sheet						
		Single transit risk	**upwind**	16.44%				
			downwind	11.88%				
			weighted mean	**14.16%**				

Stage D

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}		85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance													year total
			8.71	8.88	11.26	12.34	14.05	14.26	14.45	13.34	11.53	10.43	8.80	8.37	**136**

Stage E

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
Allow for large array correction?		No															
Width of windfarm	w	8.946	km														
			large array correctio		**Collision rates allowing for avoidance**												
Avoidance rates modelled		95.00%	100.00%		0.44	0.44	0.56	0.62	0.70	0.71	0.72	0.67	0.58	0.52	0.44	0.42	**6.8**
		98.00%	100.00%		0.17	0.18	0.23	0.25	0.28	0.29	0.29	0.27	0.23	0.21	0.18	0.17	**2.7**
		99.00%	100.00%		0.09	0.09	0.11	0.12	0.14	0.14	0.14	0.13	0.12	0.10	0.09	0.08	**1.4**
		99.50%	100.00%		0.04	0.04	0.06	0.06	0.07	0.07	0.07	0.07	0.06	0.05	0.04	0.04	**0.7**

COMMON KESTREL – TURBINE MODEL 2

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		Common kestrel	
Bird length	L	0.35	m
Wingspan	W	0.75	m
Bird flight speed	v	8	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		50%	50%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	26	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		Sany 7.7MW	
Hub height		120	m
Rotor radius	R	97.5	m
No of blades	b	3	
Rotation speed	Ω	9.88	rpm
Max blade width	C	4.5	m
Blade pitch	λ	42.5	degrees
Risk height range		23-218	m

normal approach

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Proportion at rotor risk height	Q_{ER}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	26															
Rotor radius	R	97.5	m														
		Total rotor frontal ar		776484													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	8	m s^{-1}														
		Projected number of rotor transits			16.3	16.7	21.1	23.2	26.4	26.8	27.1	25.0	21.6	19.6	16.5	15.7	**256**

Stage C

No of blades	b	3		Bird length	l	0.35	m
Rotation speed	Ω	9.88	rpm	Wingspan	w	0.75	m
Rotor radius	R	97.5	m	Bird flight speed	v	8	m s^{-1}
Max blade width	C	4.5	m	Flight type		flapping	
Pitch	λ	42.5	degrees	% of flights upwind/downwind		50%	50%
Blade profile		see Blade profile sheet					
		Single transit risk	upwind	14.41%			
			downwind	10.32%			
			weighted mean	**12.36%**			

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		1.72	1.75	2.22	2.43	2.77	2.81	2.85	2.63	2.27	2.06	1.74	1.65	**27**

Stage E

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
Allow for large array correction?		Yes															
Width of windfarm	w	8.946	km														
			large array correction		Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	99.91%		0.09	0.09	0.11	0.12	0.14	0.14	0.14	0.13	0.11	0.10	0.09	0.08	**1.3**
		98.00%	99.96%		0.03	0.03	0.04	0.05	0.06	0.06	0.06	0.05	0.05	0.04	0.03	0.03	**0.5**
		99.00%	99.98%		0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	**0.3**
		99.50%	99.99%		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	**0.1**

EURASIAN HOBBY - TURBINE MODEL 1

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		**Eurasian Hobby**	
Bird length	L	0.33	m
Wingspan	W	0.87	m
Bird flight speed	v	11.3	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		**Mirny WF**	
Latitude		45.06	degrees
No of turbines	T	124	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		**EN182 - 6.5MW**	
Hub height		110	m
Rotor radius	R	90.55	m
No of blades	b	3	
Rotation speed	Ω	9.5	rpm
Max blade width	C	5.08	m
Blade pitch	λ	47.5	degrees
Risk height range		19-201	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.0004
Proportion at rotor risk height	Q_{ZR}	100.00%														
At latitude 45.1		**Daylight hours per month**		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	124														
Rotor radius	R	90.55	m													
		Total rotor frontal ar	3194100													
Nocturnal activity factor	f_{night}	0%														
Bird flight speed	v	11.3	m s^{-1}													
		Projected number of rotor transits		0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**4**

Stage C

No of blades	b	3		Bird length	l	0.33	m
Rotation speed	Ω	9.5	rpm	Wingspan	w	0.87	m
Rotor radius	R	90.55	m	Bird flight speed	v	11.3	m s^{-1}
Max blade width	C	5.08	m	Flight type		flapping	
Pitch	λ	47.5	degrees	% of flights upwind/downwind		35%	65%
Blade profile		see Blade profile sheet					

Single transit risk	**upwind**	12.33%
	downwind	7.85%
	weighted mean	**9.41%**

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	$Q_{..}$	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
Collision rates before avoidance													
	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0**

Stage E

Allow for large array correction? Yes
Width of windfarm w 8.946 km

Avoidance rates modelled		large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
			Collision rates allowing for avoidance												
	95.00%	99.64%	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
	98.00%	99.86%	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
	99.00%	99.93%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
	99.50%	99.96%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

EURASIAN HOBBY – TURBINE MODEL 2

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

Bird data		Value	Units
Species name		Eurasian Hobby	
Bird length	L	0.33	m
Wingspan	W	0.87	m
Bird flight speed	v	11.3	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	26	
Width of windfarm	w	8.946	km

Turbine data		Value	Units
Model		Sany 7.7MV	
Hub height		120	m
Rotor radius	R	97.5	m
No of blades	b	3	
Rotation speed	Ω	9.88	rpm
Max blade width	C	4.5	m
Blade pitch	λ	42.5	degrees
Risk height range		23-218	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R	birds/km^2	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.0004
Proportion at rotor risk height	Q_{RR}	100.00%													
At latitude 45.1		Daylight hours per month	284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month	459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	26														
Rotor radius	R	97.5	m													
		Total rotor frontal ar	776484													
Nocturnal activity factor	f_{night}	0%														
Bird flight speed	v	11.3	m s^{-1}													
		Projected number of rotor transits		0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1**

Stage C

No of blades	b	3		Bird length	l	0.33	m
Rotation speed	Ω	9.88	rpm	Wingspan	w	0.87	m
Rotor radius	R	97.5	m	Bird flight speed	v	11.3	m s^{-1}
Max blade width	C	4.5	m	Flight type		flapping	
Pitch	λ	42.5	degrees	% of flights upwind/downwind		35%	65%
Blade profile		see Blade profile sheet					

Single transit risk	upwind	10.80%
	downwind	6.80%
	weighted mean	**8.20%**

Stage D		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0**

Stage E

Allow for large array correction? Yes
Width of windfarm w 8.946 km

Avoidance rates modelled		large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
			Collision rates allowing for avoidance												
95.00%		99.94%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
98.00%		99.98%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
99.00%		99.99%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
99.50%		99.99%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

EURASIAN SPARROWHAWK – TURBINE MODEL 1

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

Bird data		Value	Units
Species name		sian sparrowhawk	
Bird length	L	0.32	m
Wingspan	W	0.65	m
Bird flight speed	v	13.8	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	124	
Width of windfarm	w	8.946	km

Turbine data		Value	Units
Model		EN182 - 6.5MW	
Hub height		110	m
Rotor radius	R	90.55	m
No of blades	b	3	
Rotation speed	Ω	9.5	rpm
Max blade width	C	5.08	m
Blade pitch	λ	47.5	degrees
Risk height range		19-201	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.0002
Proportion at rotor risk height	Q_{RR}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	124															
Rotor radius	R	90.55	m														
		Total rotor frontal ar		3194100													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	13.8	m s^{-1}														
		Projected number of rotor transits			0.0	0.0	0.0	41.1	0.0	0.0	0.0	0.0	7.5	0.0	0.0	0.0	**49**

Stage C

No of blades	b	3		Bird length	l	0.32	m	
Rotation speed	Ω	9.5	rpm	Wingspan	w	0.65	m	
Rotor radius	R	90.55	m	Bird flight speed	v	13.8	m s^{-1}	
Max blade width	C	5.08	m	Flight type		flapping		
Pitch	λ	47.5	degrees	% of flights upwind/downwind		35%		65%
Blade profile		see Blade profile sheet						
		Single transit risk	upwind	10.46%				
			downwind	6.05%				
			weighted mean	**7.60%**				

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.00	0.00	0.00	2.65	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	**3**

Stage E

Allow for large array correction?		Yes														
Width of windfarm	w	8.946	km													
			large array correction	Collision rates allowing for avoidance	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
Avoidance rates modelled		95.00%	99.71%		0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	**0.2**
		98.00%	99.88%		0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	**0.1**
		99.00%	99.94%		0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.50%	99.97%		0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

EURASIAN SPARROWHAWK – TURBINE MODEL 2

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		sian sparrowhawk	
Bird length	L	0.32	m
Wingspan	W	0.65	m
Bird flight speed	v	13.8	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	26	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		Sany 7.7MV	
Hub height		120	m
Rotor radius	R	97.5	m
No of blades	b	3	
Rotation speed	Ω	9.88	rpm
Max blade width	C	4.5	m
Blade pitch	λ	42.5	degrees
Risk height range		23-218	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.00016	0.0002
Proportion at rotor risk height	Q_{ER}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	26															
Rotor radius	R	97.5	m														
		Total rotor frontal ar		776484													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	13.8	m s^{-1}														
		Projected number of rotor transits			0.0	0.0	0.0	9.3	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	**11**

Stage C								
No of blades	b	3		Bird length	l	0.32	m	
Rotation speed	Ω	9.88	rpm	Wingspan	w	0.65	m	
Rotor radius	R	97.5	m	Bird flight speed	v	13.8	m s^{-1}	
Max blade width	C	4.5	m	Flight type		flapping		
Pitch	λ	42.5	degrees	% of flights upwind/downwind		35%	65%	
Blade profile		see Blade profile sheet						
		Single transit risk	upwind	9.17%				
			downwind	5.23%				
			weighted mean	**6.61%**				

Stage D		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	**1**

Stage E					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
Allow for large array correction?		Yes															
Width of windfarm	w	8.946	km														
			large array correction		Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	99.95%		0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		98.00%	99.98%		0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.00%	99.99%		0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.50%	99.99%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

GOLDEN EAGLE – TURBINE MODEL 1

COLLISION RISK MODEL		Required input data is in	orange	boxes													
		Calculated output is in	blue	boxes													
			green	boxes are for information only, to show variables used at each stage													
		Value	Units				Value	Units						Value	Units		
Bird data				**Windfarm data**								**Turbine data**					
Species name		**Golden eagle**		Site name			**Mirny VF**					Model		**EN182 - 6.5MW**			
Bird length	L	0.81	m	Latitude			45.06	degrees				Hub height		110	m		
Wingspan	W	2.12	m	No of turbines	T		124					Rotor radius	R	90.55	m		
Bird flight speed	v	15	m s^{-1}	Width of windfarm	w		8.946	km				No of blades	b	3			
Flight type, flapping or gliding		gliding										Rotation speed	Ω	9.5	rpm		
% of flights upwind/downwind		50%	50%									Max blade width	C	5.08	m		
Nocturnal activity ranking 1-5		1										Blade pitch	λ	47.5	degrees		
Nocturnal activity factor	f_{night}	0%										Risk height range		19-201	m		
normal approach		Set to 'normal approach' to use survey data on bird density															
		Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A															
Stage A					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2		0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Proportion at rotor risk height	Q_{ER}	100.00%															
At latitude 45.1		**Daylight hours per month**			284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month			459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1
Stage B																	
No of turbines	T	124															
Rotor radius	R	90.55	m														
		Total rotor frontal ar	3194100														
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	15	m s^{-1}		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
		Projected number of rotor transits			81.4	83.0	105.3	115.4	131.3	133.3	135.1	124.8	107.8	97.5	82.3	78.3	**1275**
Stage C																	
No of blades	b	3				Bird length	l	0.81	m								
Rotation speed	Ω	9.5	rpm			Wingspan	w	2.12	m								
Rotor radius	R	90.55	m			Bird flight speed	v	15	m s^{-1}								
Max blade width	C	5.08	m			Flight type		gliding									
Pitch	λ	47.5	degrees	% of flights upwind/downwind				50%	50%								
Blade profile		see Blade profile sheet															
		Single transit risk	**upwind**	11.49%													
			downwind	7.11%													
			weighted mean	**9.30%**													
Stage D					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}				85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
				Collision rates before avoidance													year total
					6.43	6.56	8.32	9.12	10.38	10.54	10.68	9.86	8.52	7.71	6.51	6.19	**101**
Stage E																	
Allow for large array correction?		Yes															
Width of windfarm	w	8.946	km														
			large array correctio		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
				Collision rates allowing for avoidance													
Avoidance rates modelled		95.00%	99.65%		0.32	0.33	0.41	0.45	0.52	0.53	0.53	0.49	0.42	0.38	0.32	0.31	**5.0**
		98.00%	99.86%		0.13	0.13	0.17	0.18	0.21	0.21	0.21	0.20	0.17	0.15	0.13	0.12	**2.0**
		99.00%	99.93%		0.06	0.07	0.08	0.09	0.10	0.11	0.11	0.10	0.09	0.08	0.07	0.06	**1.0**
		99.50%	99.96%		0.03	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.03	0.03	**0.5**

GOLDEN EAGLE – TURBINE MODEL 2

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		**Golden eagle**	
Bird length	L	0.81	m
Wingspan	W	2.12	m
Bird flight speed	v	15	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		50%	50%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		**Mirny WF**	
Latitude		45.06	degrees
No of turbines	T	26	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		**Sany 7.7MV**	
Hub height		120	m
Rotor radius	R	97.5	m
No of blades	b	3	
Rotation speed	Ω	9.88	rpm
Max blade width	C	4.5	m
Blade pitch	λ	42.5	degrees
Risk height range		23-218	m

normal approach

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Proportion at rotor risk height	Q_{ER}	100.00%														
At latitude 45.1		**Daylight hours per month**		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

No of turbines	T	26														
Rotor radius	R	97.5	m													
		Total rotor frontal ar	776484													
Nocturnal activity factor	f_{night}	0%														
Bird flight speed	v	15	m s^{-1}	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
		Projected number of rotor transits		18.4	18.7	23.8	26.1	29.7	30.1	30.5	28.2	24.3	22.0	18.6	17.7	**288**

Stage C

No of blades	b	3		Bird length	l	0.81	m
Rotation speed	Ω	9.88	rpm	Wingspan	w	2.12	m
Rotor radius	R	97.5	m	Bird flight speed	v	15	m s^{-1}
Max blade width	C	4.5	m	Flight type		gliding	
Pitch	λ	42.5	degrees	% of flights upwind/downwind		50%	50%
Blade profile		see Blade profile sheet					

Single transit risk	**upwind**	10.32%
	downwind	6.42%
	weighted mean	**8.37%**

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		1.31	1.33	1.69	1.85	2.11	2.14	2.17	2.00	1.73	1.57	1.32	1.26	**20**

Stage E

Allow for large array correction?		Yes														
Width of windfarm	w	8.946	km													
			large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
				Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	99.94%	0.07	0.07	0.08	0.09	0.11	0.11	0.11	0.10	0.09	0.08	0.07	0.06	**1.0**
		98.00%	99.97%	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	**0.4**
		99.00%	99.99%	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	**0.2**
		99.50%	99.99%	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	**0.1**

LESSER KESTREL – TURBINE MODEL 1

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

Bird data		Value	Units
Species name		Lesser kestrel	
Bird length	L	0.3	m
Wingspan	W	0.68	m
Bird flight speed	v	8	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	124	
Width of windfarm	w	8.946	km

Turbine data		Value	Units
Model		EN182 - 6.5MV	
Hub height		110	m
Rotor radius	R	90.55	m
No of blades	b	3	
Rotation speed	Ω	9.5	rpm
Max blade width	C	5.08	m
Blade pitch	λ	47.5	degrees
Risk height range		19-201	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_a		birds/km^2	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Proportion at rotor risk height	Q_{ER}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	124															
Rotor radius	R	90.55	m														
		Total rotor frontal ar		3194100													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	8	m s^{-1}														
		Projected number of rotor transits			0.0	0.0	0.0	9.3	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	**12**

Stage C

No of blades	b	3		Bird length	l	0.3	m
Rotation speed	Ω	9.5	rpm	Wingspan	w	0.68	m
Rotor radius	R	90.55	m	Bird flight speed	v	8	m s^{-1}
Max blade width	C	5.08	m	Flight type		flapping	
Pitch	λ	47.5	degrees	% of flights upwind/downwind		35%	65%
Blade profile		see Blade profile sheet					
		Single transit risk	upwind	16.14%			
			downwind	11.58%			
			weighted mean	**13.17%**			

Stage D

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}		85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance													year total
			0.00	0.00	0.00	1.05	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	**1**

Stage E

Allow for large array correction? Yes
Width of windfarm w 8.946 km

Avoidance rates modelled		large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
			Collision rates allowing for avoidance												
95.00%	99.50%		0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	**0.1**
98.00%	99.80%		0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	**0.0**
99.00%	99.90%		0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
99.50%	99.95%		0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

LESSER KESTREL – TURBINE MODEL 2

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

Bird data		Value	Units
Species name		Lesser kestrel	
Bird length	L	0.3	m
Wingspan	W	0.68	m
Bird flight speed	v	8	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	26	
Width of windfarm	w	8.946	km

Turbine data		Value	Units
Model		Sany 7.7MW	
Hub height		120	m
Rotor radius	R	97.5	m
No of blades	b	3	
Rotation speed	Ω	9.88	rpm
Max blade width	C	4.5	m
Blade pitch	λ	42.5	degrees
Risk height range		23-218	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Proportion at rotor risk height	Q_{ER}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	26														
Rotor radius	R	97.5	m													
		Total rotor frontal ar	776484													
Nocturnal activity factor	f_{night}	0%														
Bird flight speed	v	8	m s^{-1}													
		Projected number of rotor transits		0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	**3**

Stage C

No of blades	b	3		Bird length	l	0.3	m
Rotation speed	Ω	9.88	rpm	Wingspan	w	0.68	m
Rotor radius	R	97.5	m	Bird flight speed	v	8	m s^{-1}
Max blade width	C	4.5	m	Flight type		flapping	
Pitch	λ	42.5	degrees	% of flights upwind/downwind		35%	65%
Blade profile		see Blade profile sheet					

Single transit risk	upwind	14.10%
	downwind	10.01%
	weighted mean	**11.44%**

Stage D		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%

Collision rates before avoidance													year total
0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00		**0**

Stage E

Allow for large array correction? Yes
Width of windfarm w 8.946 km

Avoidance rates modelled		large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
			Collision rates allowing for avoidance												
95.00%		99.91%	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
98.00%		99.97%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
99.00%		99.98%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
99.50%		99.99%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

LITTLE BUSTARD - TURBINE MODEL 1

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		**Little Bustard**	
Bird length	L	0.5	m
Wingspan	W	1.12	m
Bird flight speed	v	17	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		**Mirny WF**	
Latitude		45.06	degrees
No of turbines	T	124	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		**EN182 - 6.5MV**	
Hub height		110	m
Rotor radius	R	90.55	m
No of blades	b	3	
Rotation speed	Ω	9.5	rpm
Max blade width	C	5.08	m
Blade pitch	λ	47.5	degrees
Risk height range		19-201	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_a		birds/km^2	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.0004
Proportion at rotor risk height	Q_{ZR}	100.00%														
At latitude 45.1		**Daylight hours per month**		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	124															
Rotor radius	R	90.55	m														
		Total rotor frontal ar		3194100													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	17	m s^{-1}		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
		Projected number of rotor transits			0.0	0.0	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**6**

Stage C

No of blades	b	3			Bird length	l	0.5	m
Rotation speed	Ω	9.5	rpm		Wingspan	w	1.12	m
Rotor radius	R	90.55	m		Bird flight speed	v	17	m s^{-1}
Max blade width	C	5.08	m		Flight type		flapping	
Pitch	λ	47.5	degrees	% of flights upwind/downwind			35%	65%
Blade profile		see Blade profile sheet						
		Single transit risk		**upwind**	9.58%			
				downwind	5.27%			
				weighted mean	**6.78%**			

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
Collision rates before avoidance													
	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0**

Stage E

Allow for large array correction?		Yes														
Width of windfarm	w	8.946	km													
			large array correction		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
				Collision rates allowing for avoidance													
Avoidance rates modelled		95.00%	99.74%		0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		98.00%	99.90%		0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.00%	99.95%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.50%	99.97%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

LITTLE BUSTARD – TURBINE MODEL 2

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		Little Bustard	
Bird length	L	0.5	m
Wingspan	W	1.12	m
Bird flight speed	v	17	m s^{-1}
Flight type, flapping or gliding		flapping	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	26	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		Sany 7.7MW	
Hub height		120	m
Rotor radius	R	97.5	m
No of blades	b	3	
Rotation speed	Ω	9.88	rpm
Max blade width	C	4.5	m
Blade pitch	λ	42.5	degrees
Risk height range		23-218	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.00041	0.0004
Proportion at rotor risk height	Q_{ER}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	26															
Rotor radius	R	97.5	m														
		Total rotor frontal ar		776484													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	17	m s^{-1}														
		Projected number of rotor transits			0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1**

Stage C								
No of blades	b	3			Bird length	l	0.5	m
Rotation speed	Ω	9.88	rpm		Wingspan	w	1.12	m
Rotor radius	R	97.5	m		Bird flight speed	v	17	m s^{-1}
Max blade width	C	4.5	m		Flight type		flapping	
Pitch	λ	42.5	degrees	% of flights upwind/downwind			35%	65%
Blade profile		see Blade profile sheet						
		Single transit risk		upwind	8.48%			
				downwind	4.64%			
				weighted mean	**5.98%**			

Stage D		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{ii}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0**

Stage E															
Allow for large array correction?		Yes													
Width of windfarm	w	8.946	km												
			large array correction		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
					Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	99.95%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		98.00%	99.98%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.00%	99.99%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.50%	100.00%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

LONG LEGGED BUZZARD – TURBINE MODEL 1

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		**ng legged buzzard**	
Bird length	L	0.6	m
Wingspan	W	1.37	m
Bird flight speed	v	14.6	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		**Mirny WF**	
Latitude		45.06	degrees
No of turbines	T	124	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		**EN182 - 6.5MW**	
Hub height		110	m
Rotor radius	R	90.55	m
No of blades	b	3	
Rotation speed	Ω	9.5	rpm
Max blade width	C	5.08	m
Blade pitch	λ	47.5	degrees
Risk height range		19-201	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.0020
Proportion at rotor risk height	Q_{ZR}	100.00%														
At latitude 45.1		**Daylight hours per month**		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	124															
Rotor radius	R	90.55	m														
		Total rotor frontal ar		3194100													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	14.6	m s^{-1}														
		Projected number of rotor transits			0.0	0.0	0.0	42.3	0.0	0.0	12.4	0.0	18.7	0.0	0.0	0.0	**73**

Stage C

No of blades	b	3		Bird length	l	0.6	m	
Rotation speed	Ω	9.5	rpm	Wingspan	w	1.37	m	
Rotor radius	R	90.55	m	Bird flight speed	v	14.6	m s^{-1}	
Max blade width	C	5.08	m	Flight type		gliding		
Pitch	λ	47.5	degrees	% of flights upwind/downwind		35%	65%	
Blade profile		see Blade profile sheet						
		Single transit risk	**upwind**	10.96%				
			downwind	6.56%				
			weighted mean	**8.10%**				

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Stage D														
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.00	0.00	0.00	2.91	0.00	0.00	0.86	0.00	1.29	0.00	0.00	0.00	**5**

Stage E

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
Allow for large array correction?		Yes															
Width of windfarm	w	8.946	km														
			large array correction		**Collision rates allowing for avoidance**												
Avoidance rates modelled		95.00%	99.69%		0.00	0.00	0.00	0.15	0.00	0.00	0.04	0.00	0.06	0.00	0.00	0.00	**0.3**
		98.00%	99.88%		0.00	0.00	0.00	0.06	0.00	0.00	0.02	0.00	0.03	0.00	0.00	0.00	**0.1**
		99.00%	99.94%		0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	**0.1**
		99.50%	99.97%		0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	**0.0**

LONG LEGGED BUZZARD – TURBINE MODEL 2

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

Bird data		Value	Units
Species name		ng legged buzzard	
Bird length	L	0.6	m
Wingspan	W	1.37	m
Bird flight speed	v	14.6	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	26	
Width of windfarm	w	8.946	km

Turbine data		Value	Units
Model		Sany 7.7MW	
Hub height		120	m
Rotor radius	R	97.5	m
No of blades	b	3	
Rotation speed	Ω	9.88	rpm
Max blade width	C	4.5	m
Blade pitch	λ	42.5	degrees
Risk height range		23-218	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.00199	0.0020
Proportion at rotor risk height	Q_{ZR}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	26															
Rotor radius	R	97.5	m														
		Total rotor frontal ar		776484													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	14.6	m s^{-1}														
		Projected number of rotor transits			0.0	0.0	0.0	9.6	0.0	0.0	2.8	0.0	4.2	0.0	0.0	0.0	**17**

Stage C

No of blades	b	3		Bird length	l	0.6	m	
Rotation speed	Ω	9.88	rpm	Wingspan	w	1.37	m	
Rotor radius	R	97.5	m	Bird flight speed	v	14.6	m s^{-1}	
Max blade width	C	4.5	m	Flight type		gliding		
Pitch	λ	42.5	degrees	% of flights upwind/downwind		35%	65%	
Blade profile		see Blade profile sheet						
		Single transit risk	upwind	9.75%				
			downwind	5.83%				
			weighted mean	**7.21%**				

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.00	0.00	0.00	0.59	0.00	0.00	0.17	0.00	0.26	0.00	0.00	0.00	**1**

Stage E

Allow for large array correction? Yes
Width of windfarm w 8.946 km

Avoidance rates modelled		large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
			Collision rates allowing for avoidance												
95.00%	99.95%		0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	**0.1**
98.00%	99.98%		0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	**0.0**
99.00%	99.99%		0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
99.50%	99.99%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

ROUGH LEGGED BUZZARD – TURBINE MODEL 1

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

Bird data		Value	Units
Species name		gh legged buzzard	
Bird length	L	0.55	m
Wingspan	W	1.35	m
Bird flight speed	v	11.5	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	124	
Width of windfarm	w	8.946	km

Turbine data		Value	Units
Model		EN182 - 6.5MW	
Hub height		110	m
Rotor radius	R	90.55	m
No of blades	b	3	
Rotation speed	Ω	9.5	rpm
Max blade width	C	5.08	m
Blade pitch	λ	47.5	degrees
Risk height range		19-201	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.0002
Proportion at rotor risk height	Q_{RR}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	124															
Rotor radius	R	90.55	m														
		Total rotor frontal ar		3194100													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	11.5	m s^{-1}														
		Projected number of rotor transits			0.6	0.0	0.0	1.2	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	**4**

Stage C

No of blades	b	3		Bird length	l	0.55	m
Rotation speed	Ω	9.5	rpm	Wingspan	w	1.35	m
Rotor radius	R	90.55	m	Bird flight speed	v	11.5	m s^{-1}
Max blade width	C	5.08	m	Flight type		gliding	
Pitch	λ	47.5	degrees	% of flights upwind/downwind		35%	65%
Blade profile		see Blade profile sheet					

Single transit risk	upwind	13.02%
	downwind	8.55%
	weighted mean	**10.12%**

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	$Q_{..}$	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.05	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	**0**

Stage E

Allow for large array correction? Yes
Width of windfarm w 8.946 km

Avoidance rates modelled	large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
		Collision rates allowing for avoidance												
95.00%	99.62%	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	**0.0**
98.00%	99.85%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
99.00%	99.92%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
99.50%	99.96%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

ROUGH LEGGED BUZZARD – TURBINE MODEL 2

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		jh legged buzzard	
Bird length	L	0.55	m
Wingspan	W	1.35	m
Bird flight speed	v	11.5	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	26	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		Sany 7.7MW	
Hub height		120	m
Rotor radius	R	97.5	m
No of blades	b	3	
Rotation speed	Ω	9.88	rpm
Max blade width	C	4.5	m
Blade pitch	λ	42.5	degrees
Risk height range		23-218	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.00019	0.0002
Proportion at rotor risk height	Q_{RR}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	26															
Rotor radius	R	97.5	m														
		Total rotor frontal ar		776484													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	11.5	m s^{-1}														
		Projected number of rotor transits			0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	1

Stage C

No of blades	b	3		Bird length	l	0.55	m
Rotation speed	Ω	9.88	rpm	Wingspan	w	1.35	m
Rotor radius	R	97.5	m	Bird flight speed	v	11.5	m s^{-1}
Max blade width	C	4.5	m	Flight type		gliding	
Pitch	λ	42.5	degrees	% of flights upwind/downwind		35%	65%
Blade profile		see Blade profile sheet					
		Single transit risk	upwind	11.56%			
			downwind	7.56%			
			weighted mean	8.96%			

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0

Stage E

Allow for large array correction? Yes
Width of windfarm w 8.946 km

		large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
			Collision rates alloving for avoidance												
Avoidance rates modelled	95.00%	99.93%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
	98.00%	99.97%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
	99.00%	99.99%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
	99.50%	99.99%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

SHORT TOED SNAKE EAGLE – TURBINE MODEL 1

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		toed snake eagle	
Bird length	L	0.67	m
Wingspan	W	1.86	m
Bird flight speed	v	11	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	124	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		EN182 - 6.5MW	
Hub height		110	m
Rotor radius	R	90.55	m
No of blades	b	3	
Rotation speed	Ω	9.5	rpm
Max blade width	C	5.08	m
Blade pitch	λ	47.5	degrees
Risk height range		19-201	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.0003
Proportion at rotor risk height	Q_{RR}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	124															
Rotor radius	R	90.55	m														
		Total rotor frontal ar		3194100													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	11	m s^{-1}														
		Projected number of rotor transits			0.0	0.0	0.0	11.2	0.0	0.0	3.1	0.0	2.5	0.0	0.0	0.0	**17**

Stage C								
No of blades	b	3			Bird length	l	0.67	m
Rotation speed	Ω	9.5	rpm		Wingspan	w	1.86	m
Rotor radius	R	90.55	m		Bird flight speed	v	11	m s^{-1}
Max blade width	C	5.08	m		Flight type		gliding	
Pitch	λ	47.5	degrees	% of flights upwind/downwind			35%	65%
Blade profile		see Blade profile sheet						
		Single transit risk	upwind	14.07%				
			downwind	9.58%				
			weighted mean	**11.15%**				

Stage D		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.00	0.00	0.00	1.06	0.00	0.00	0.29	0.00	0.24	0.00	0.00	0.00	**2**

Stage E															
Allow for large array correction?		Yes													
Width of windfarm	w	8.946	km												
			large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
				Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	99.58%	0.00	0.00	0.00	0.05	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	**0.1**
		98.00%	99.83%	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.00%	99.91%	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.50%	99.96%	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

SHORT TOED SNAKE EAGLE – TURBINE MODEL 2

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		toed snake eagle	
Bird length	L	0.67	m
Wingspan	W	1.86	m
Bird flight speed	v	11	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	26	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		Sang 7.7MW	
Hub height		120	m
Rotor radius	R	97.5	m
No of blades	b	3	
Rotation speed	Ω	9.88	rpm
Max blade width	C	4.5	m
Blade pitch	λ	42.5	degrees
Risk height range		23-218	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R	birds/km^2	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.00029	0.0003
Proportion at rotor risk height	Q_{ZR}	100.00%													
At latitude 45.1		Daylight hours per month	284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month	459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	26														
Rotor radius	R	97.5	m													
		Total rotor frontal ar	776484													
Nocturnal activity factor	f_{night}	0%														
Bird flight speed	v	11	m s^{-1}													
		Projected number of rotor transits		0.0	0.0	0.0	2.5	0.0	0.0	0.7	0.0	0.6	0.0	0.0	0.0	**4**

Stage C

No of blades	b	3		Bird length	l	0.67	m
Rotation speed	Ω	9.88	rpm	Wingspan	w	1.86	m
Rotor radius	R	97.5	m	Bird flight speed	v	11	m s^{-1}
Max blade width	C	4.5	m	Flight type		gliding	
Pitch	λ	42.5	degrees	% of flights upwind/downwind		35%	65%
Blade profile		see Blade profile sheet					
		Single transit risk	upwind	12.56%			
			downwind	8.55%			
			weighted mean	**9.96%**			

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.00	0.00	0.00	0.21	0.00	0.00	0.06	0.00	0.05	0.00	0.00	0.00	**0**

Stage E

Allow for large array correction? Yes
Width of windfarm w 8.946 km

		large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
			Collision rates allowing for avoidance												
Avoidance rates modelled	95.00%	99.92%	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
	98.00%	99.97%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
	99.00%	99.98%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
	99.50%	99.99%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

STEPPE EAGLE – TURBINE MODEL 1

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		Steppe eagle	
Bird length	L	0.81	m
Wingspan	W	2.02	m
Bird flight speed	v	10	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	124	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		EN182 - 6.5MW	
Hub height		110	m
Rotor radius	R	90.55	m
No of blades	b	3	
Rotation speed	Ω	9.5	rpm
Max blade width	C	5.08	m
Blade pitch	λ	47.5	degrees
Risk height range		19-201	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.0077
Proportion at rotor risk height	Q_{RR}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	124															
Rotor radius	R	90.55	m														
		Total rotor frontal ar		3194100													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	10	m s^{-1}														
		Projected number of rotor transits			0.0	0.0	0.0	8.1	0.0	0.0	3.7	0.0	67.8	0.0	0.0	0.0	**80**

Stage C

No of blades	b	3		Bird length	l	0.81	m	
Rotation speed	Ω	9.5	rpm	Wingspan	w	2.02	m	
Rotor radius	R	90.55	m	Bird flight speed	v	10	m s^{-1}	
Max blade width	C	5.08	m	Flight type		gliding		
Pitch	λ	47.5	degrees	% of flights upwind/downwind		35%	65%	
Blade profile		see Blade profile sheet						
		Single transit risk	upwind	15.87%				
			downwind	11.35%				
			weighted mean	**12.93%**				

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%

	Collision rates before avoidance												year total
	0.00	0.00	0.00	0.89	0.00	0.00	0.41	0.00	7.46	0.00	0.00	0.00	**9**

Stage E

Allow for large array correction? Yes
Width of windfarm w 8.946 km

		large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
			Collision rates allowing for avoidance												
Avoidance rates modelled	95.00%	99.51%	0.00	0.00	0.00	0.04	0.00	0.00	0.02	0.00	0.37	0.00	0.00	0.00	**0.4**
	98.00%	99.80%	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.15	0.00	0.00	0.00	**0.2**
	99.00%	99.90%	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	**0.1**
	99.50%	99.95%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	**0.0**

STEPPE EAGLE – TURBINE MODEL 2

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

Bird data		Value	Units
Species name		Steppe eagle	
Bird length	L	0.81	m
Wingspan	W	2.02	m
Bird flight speed	v	10	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

Windfarm data		Value	Units
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	26	
Width of windfarm	w	8.946	km

Turbine data		Value	Units
Model		Sany 7.7MW	
Hub height		120	m
Rotor radius	R	97.5	m
No of blades	b	3	
Rotation speed	Ω	9.88	rpm
Max blade width	C	4.5	m
Blade pitch	λ	42.5	degrees
Risk height range		23-218	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.00766	0.0077
Proportion at rotor risk height	Q_{ER}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	26															
Rotor radius	R	97.5	m														
		Total rotor frontal ar		776484													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	10	m s^{-1}														
		Projected number of rotor transits			0.0	0.0	0.0	1.8	0.0	0.0	0.8	0.0	15.3	0.0	0.0	0.0	**18**

Stage C

No of blades	b	3		Bird length	l	0.81	m
Rotation speed	Ω	9.88	rpm	Wingspan	w	2.02	m
Rotor radius	R	97.5	m	Bird flight speed	v	10	m s^{-1}
Max blade width	C	4.5	m	Flight type		gliding	
Pitch	λ	42.5	degrees	% of flights upwind/downwind		35%	65%
Blade profile		see Blade profile sheet					

Single transit risk	
upwind	14.27%
downwind	10.23%
weighted mean	**11.65%**

Stage D		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.00	0.00	0.00	0.18	0.00	0.00	0.08	0.00	1.52	0.00	0.00	0.00	**2**

Stage E

Allow for large array correction? Yes
Width of windfarm w 8.946 km

		large array correction	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
			Collision rates allowing for avoidance												
Avoidance rates modelled	95.00%	99.91%	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	**0.1**
	98.00%	99.96%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	**0.0**
	99.00%	99.98%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	**0.0**
	99.50%	99.99%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	**0.0**

WHITE TAILED EAGLE – TURBINE MODEL 1

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		White tailed eagle	
Bird length	L	0.8	m
Wingspan	W	2.2	m
Bird flight speed	v	12	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	124	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		EN182 - 6.5MW	
Hub height		110	m
Rotor radius	R	90.55	m
No of blades	b	3	
Rotation speed	Ω	9.5	rpm
Max blade width	C	5.08	m
Blade pitch	λ	47.5	degrees
Risk height range		19-201	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A

				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_R		birds/km^2	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.0025
Proportion at rotor risk height	Q_{ER}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	124															
Rotor radius	R	90.55	m														
		Total rotor frontal ar		3194100													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	12	m s^{-1}														
		Projected number of rotor transits			1.9	0.0	0.0	4.4	0.0	0.0	0.0	0.0	20.5	0.0	0.0	0.0	**27**

Stage C

No of blades	b	3		Bird length	l	0.8	m	
Rotation speed	Ω	9.5	rpm	Wingspan	w	2.2	m	
Rotor radius	R	90.55	m	Bird flight speed	v	12	m s^{-1}	
Max blade width	C	5.08	m	Flight type		gliding		
Pitch	λ	47.5	degrees	% of flights upwind/downwind		35%		65%
Blade profile		see Blade profile sheet						

Single transit risk	upwind	13.66%
	downwind	9.20%
	weighted mean	**10.76%**

Stage D

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.17	0.00	0.00	0.40	0.00	0.00	0.00	0.00	1.88	0.00	0.00	0.00	**2**

Stage E

					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
Allow for large array correction?		Yes															
Width of windfarm	w	8.946	km														
			large array correction		Collision rates allowing for avoidance												
Avoidance rates modelled		95.00%	99.59%		0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	**0.1**
		98.00%	99.84%		0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	**0.0**
		99.00%	99.92%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	**0.0**
		99.50%	99.96%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	**0.0**

WHITE TAILED EAGLE – TURBINE MODEL 2

COLLISION RISK MODEL

Required input data is in orange boxes
Calculated output is in blue boxes
green boxes are for information only, to show variables used at each stage

		Value	Units
Bird data			
Species name		White tailed eagle	
Bird length	L	0.8	m
Wingspan	W	2.2	m
Bird flight speed	v	12	m s^{-1}
Flight type, flapping or gliding		gliding	
% of flights upwind/downwind		35%	65%
Nocturnal activity ranking 1-5		1	
Nocturnal activity factor	f_{night}	0%	

		Value	Units
Windfarm data			
Site name		Mirny WF	
Latitude		45.06	degrees
No of turbines	T	26	
Width of windfarm	w	8.946	km

		Value	Units
Turbine data			
Model		Sany 7.7MW	
Hub height		120	m
Rotor radius	R	97.5	m
No of blades	b	3	
Rotation speed	Ω	9.88	rpm
Max blade width	C	4.5	m
Blade pitch	λ	42.5	degrees
Risk height range		23-218	m

birds on migration

Set to 'normal approach' to use survey data on bird density
Set to 'birds on migration' to use 'Migrant collision risk' sheet in place of Stage A

Stage A				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Daytime bird density	D_A		birds/km^2	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.00248	0.0025
Proportion at rotor risk height	Q_{ZR}	100.00%														
At latitude 45.1		Daylight hours per month		284.9	290.5	368.4	403.9	459.7	466.7	472.7	436.6	377.4	341.2	288.1	273.9	4463.9
		Nighttime hours per month		459.1	381.5	375.6	316.1	284.3	253.3	271.3	307.4	342.6	402.8	431.9	470.1	4296.1

Stage B					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year total
No of turbines	T	26															
Rotor radius	R	97.5	m														
		Total rotor frontal ar		776484													
Nocturnal activity factor	f_{night}	0%															
Bird flight speed	v	12	m s^{-1}														
		Projected number of rotor transits			0.4	0.0	0.0	1.0	0.0	0.0	0.0	0.0	4.6	0.0	0.0	0.0	**6**

Stage C								
No of blades	b	3		Bird length	l	0.8	m	
Rotation speed	Ω	9.88	rpm	Wingspan	w	2.2	m	
Rotor radius	R	97.5	m	Bird flight speed	v	12	m s^{-1}	
Max blade width	C	4.5	m	Flight type		gliding		
Pitch	λ	42.5	degrees	% of flights upwind/downwind		35%	65%	
Blade profile		see Blade profile sheet						
		Single transit risk	upwind	12.27%				
			downwind	8.28%				
			weighted mean	**9.68%**				

Stage D		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year avge
Proportion of time operational	Q_{op}	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
		Collision rates before avoidance												year total
		0.03	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	**0**

Stage E																
Allow for large array correction?		Yes														
Width of windfarm	w	8.946	km													
			large array correction		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	per year
				Collision rates allowing for avoidance													
Avoidance rates modelled		95.00%	99.93%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	**0.0**
		98.00%	99.97%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	**0.0**
		99.00%	99.99%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
		99.50%	99.99%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**

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