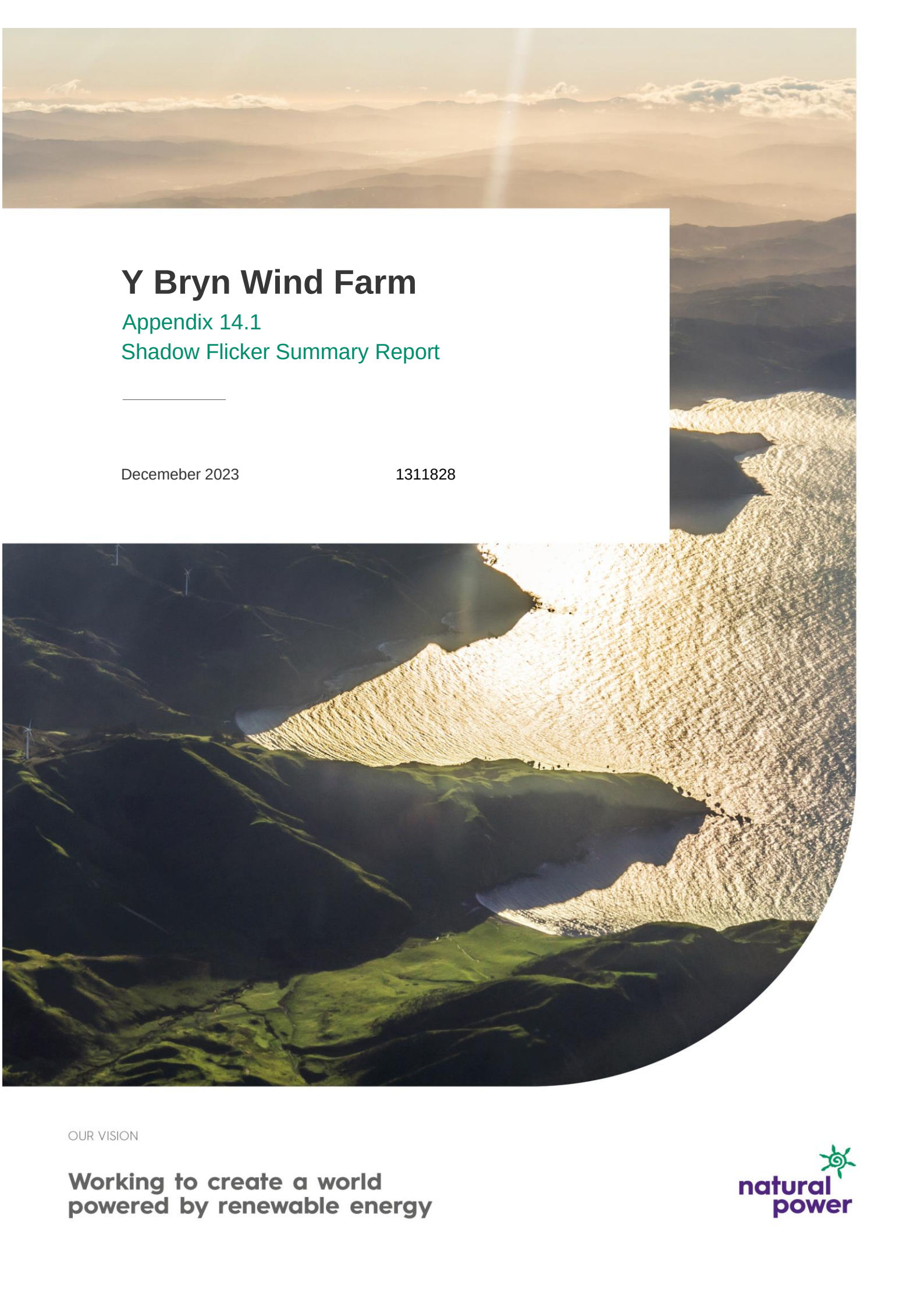




Y Bryn Wind Farm

Appendix 14.1

Shadow Flicker Summary Report

Decemeber 2023

1311828

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1. Introduction

The Natural Power Consultants, Limited ('Natural Power') was commissioned by Y Bryn Wind Farm Ltd. ('Client'), to conduct a shadow flicker assessment of the proposed Y Bryn Wind Farm.

This work is to determine the extent of the real-case shadow flicker effects on nearby residential or commercial properties, including cumulative effects with a neighbouring wind farm.

This report details the inputs and assumptions made when undertaking the analysis and presents the results and findings.

1.1. Site Description

The proposed Y Bryn Wind Farm is composed of 18 turbines located approximately 3 km east of Port Talbot, in Glamorgan, South Wales. The proposed development is generally uphill from several potential shadow receptors in all directions. Maps illustrating the site layout and the project location with respect to the surrounding region are shown in Appendix A. The surrounding areas consist of forested land and villages surrounded by agricultural areas. The Bristol Channel lies approximately 7 km south-west of the site.

The turbine layout presented in Table 1.1 was considered in the assessment.

Table 1.1: Turbine layout considered for the proposed Y Bryn Wind Farm.

Scenario	Easting	Northing	Hub height (m)	Maximum tip height (m)	Rotor diameter (m)	Elevation (m ASL ¹)
T01	282978	193397	120	206	172	319
T02	283552	193600	120	206	172	314
T03	282921	192990	120	206	172	313
T04	283805	193313	120	206	172	342
T05	283594	192814	120	206	172	339
T06	282453	190558	144	230	172	291
T07	281978	190586	144	230	172	276
T08	282300	189991	164	250	172	275
T09	282490	189646	164	250	172	291
T10	282783	189343	164	250	172	310
T11	283107	188997	120	206	172	336
T12	280945	189877	120	206	172	280
T13	281299	189545	164	250	172	284
T14	281770	189376	120	206	172	308
T15	282166	189165	120	206	172	322
T16	282459	188852	120	206	172	344
T17	280888	189123	120	206	172	313
T18	281227	188966	120	206	172	324

Note that coordinates are in British National Grid.

1. Above Sea Level.

The proposed development is surrounded by a number of settlements which could potentially be impacted by shadow flicker. Natural Power have selected a reference point for each settlement, within a range of 1.7 km (approximately 10 rotor diameters) of the site, which is the closest to the proposed development and modelled this as a receptor location in this analysis, with 28 locations ultimately selected. Receptor locations were selected to represent a worst-case scenario for the settlements near the proposed development. The locations of the 28 receptors are presented in Table A.1 and the layout of the 18 turbines and 28 receptors are illustrated in Figure C.1. A real-case flicker map detailing the areas potentially impacted by shadow flicker, represented as propagation patterns from each turbine at the Y Bryn site (only), is presented in Figure C.2. Cumulative shadow flicker effects from the neighbouring proposed section 73 Foel Trawsnant Wind Farm, composed of eight turbines, a mix of three Nordex N117/2400 with a hub height of 86.5 m and of five Nordex N133/4.8 with a hub height of 78.5 m, have been considered in the analysis. The layout for Foel Trawsnant Wind Farm is presented in Table B.1. The cumulative real-case flicker map, considering both Y Bryn and Foel Trawsnant wind farms, is shown in Figure C.3.

2. Shadow Model

Shadow flicker may occur under certain combinations of geographical position and time of day when the sun passes behind the blades of a wind turbine and casts a shadow over the neighbouring properties. As the blades rotate, a dynamic shadow effect occurs, known as shadow flicker. The effect occurs inside buildings where the flicker appears, generally through a narrow window opening. The likelihood and duration of the effect depends upon several variable factors:

- Location of the property relative to the turbine. Please note that Natural Power's shadow flicker assessment does not take into consideration the orientation of properties or the presence of windows/openings and therefore each receptor is modelled as a worst-case (glasshouse) scenario. Equally the model assumes no sheltering from vegetation or other obstacles is present between the turbine and the receptor;
- Distance from turbine. The further an observer is from the turbine, the less pronounced the effect will be;
- Wind speed and direction. The wind speed at the turbine will need to be greater than the cut-in wind speed of the turbine (typically 3 m/s), and below the cut-out wind speed, in order for the blades to be rotating. Furthermore, the shape of the shadow will be determined by the position of the sun relative to the blades, which will be yawed to face the wind;
- Turbine height and rotor diameter;
- Time of year and day as this determines the height of the sun in the sky; and
- Weather conditions at the time – direct sunshine is required to create the flicker effect and therefore cloud cover reduces the risk of shadow flicker.

While all these factors impact the prevalence of shadow flicker effect occurring at a site, not all factors can be effectively modelled, and a number of assumptions need to be made as part of the modelling process.

2.1. Assessment Methodology

When assessing the impact of shadow flicker at a site, two possible conditions can be considered:

- Worst-case – this determines the maximum number theoretical hours of shadow flicker that can occur, not accounting for the likelihood of direct sunshine occurring in the region, coinciding with periods where shadow flicker is possible. This is a geometric-based calculation, dependant on the location of the sun with respect to the turbine blade, and alignment with the receptor of interest. Outside of these periods, irrespective of the cloud cover and sunshine status, flicker cannot physically occur. The outcome of this process is the maximum number of hours (per annum) at which flicker could, in theory, occur; and
- Real-case – this takes the worst-case scenario, and then adjusts the duration of the total potential flicker events by the likelihood that direct sunshine occurs in a region. Typically, this utilises sunshine data from a ground-based meteorological station to apply monthly scaling factors to the worst-case scenario results. This results in a more accurate representation of the number of hours per year, that a receptor location may experience shadow flicker. The turbines are still modelled as though they are always yawed perpendicularly to the line between the receptor and the sun, inducing maximum shadow effect. The real-case does not take into account wind direction and the influence on this to the shadows.

The scope of this assessment is to determine the real-case, and the model makes the following assumptions:

- The turbines are always rotating;
- The sun can be represented as a single point;
- The turbine rotor is modelled as a sphere around the hub to account for all possible turbine yaw directions relative to the line of sight with the position of the sun;
- Terrain effects are considered although this is assumed to be bare terrain and therefore surface effects from cover such as forestry or other buildings are not considered;
- The calculation is purely geometric and does not account for the sensitivity of perception of the observer;

- The likelihood of wind direction and speed is not taken into account;
- Shadow flicker is calculated for a height of 2 m Above Ground Level (AGL) to represent an observer at a ground floor window;
- The shadow receptors are simulated as mounted vertical plates always facing directly at each turbine simultaneously, representing the worst-case scenario (glass-house) while real windows would be facing towards a particular, selective direction;
- The simulations have been carried out with a resolution of 1 minute; and
- The shadow flicker effects have been calculated for the area within 1788 m from the centre of each turbine. This area is based on a calculated length the shadows are likely to persist. This is calculated from average thickness of turbine blades from turbines of matching rotor diameter from the WindPRO turbine specifications database. It is noted that if the turbine specifications differ from those assessed, it is recommended that the assessment is updated.

2.2. Results

The results for the worst-case and real-case shadow flicker assessment are detailed in Table C.1. In addition, the number of days per year where any shadow flicker could occur, and the turbines which contribute to the flicker effect, are also shown in the table. This does not account for wind direction. The cumulative effects with neighbouring turbines are shown in Table C.2.

The results indicate that across affected receptors, the worst-case impact is between 6.8 and 205.1 hours per annum, which when adjusted to reflect proportion of direct sunshine, reduces to between 1.2 and 62.1 hours of shadow flicker per annum. Once final shadow flicker receptors are defined, and the final turbine layout consented, Natural Power can update the assessment.

It was found that two receptors (R10 and R13: highlighted in red in Table C.1) had shadow flicker beyond the guidance 30 hours/year for the real-case scenario. Several receptors were also found to be above the threshold for maximum 30 minutes/day of flicker. It is recommended that the locations of these receptors are visited to establish if there is a direct line of sight between any windows at the receptors and the turbines causing shadow flicker before a shadow flicker curtailment scheme is derived.

The cumulative shadow flicker assessment found that three of the receptors identified (R1, R2, and R28) had shadow flicker effects from the neighbouring wind farm. R1 had an increase in real-case flicker of 0.0 to 26.1 hours per annum, therefore all the flicker effects are from the neighbouring Foel Trawsnant Wind Farm. Receptor R2 had an increase from 1.2 to 47.2 hours per annum, hence the majority of this is attributable to Foel Trawsnant. Receptor R28 had an increase from 3.2 to 5.5 hours per annum, which is below the guidance threshold.

3. Conclusion and Recommendations

The Client is advised of the following conclusions and recommendations:

- For the basis of the assessment Natural Power have selected a point in each settlement which is closest to the proposed Y Bryn Wind Farm and modelled this as a receptor location in this analysis, with 28 locations ultimately selected. Receptor locations were selected to represent a worst-case scenario for the settlements near the proposed development. It is recommended that the Client carries out a full and thorough survey to confirm all potential receptors. Cumulative effects including the proposed Foel Trawsnant Wind Farm were also considered.
- The shadow model makes a number of assumptions with respect to the shadow receptors, including the assumption that they have windows directly facing the wind farm, that the direction of the wind is always aligned with the line between the receptor and the sun, and that there is no screening from vegetation or buildings which would otherwise mitigate the potential shadow flicker effect. It is recommended that, if specific dwellings are modelled, affected dwellings are visited to confirm the conditions for shadow flicker are present, and if not, then these receptors are removed from inclusion in the curtailment calculation. For this assessment, the closest point to the proposed development in the nearest settlement have been modelled as receptors.
- Two of the receptors identified exceeded the shadow flicker guidance threshold of 30 hours per year and other receptors were also found to be above the threshold for guidance 30 minutes per day on the worst affected day, considering Y Bryn Wind Farm alone. It is recommended that the locations of the receptors are visited to establish if there is a direct line of sight between the windows at the receptors and the turbines causing shadow flicker before a shadow flicker curtailment scheme is derived. It may be the case that the presence and/or orientation of windows and intervening structures partially mitigates from the results derived in this report, however, analysis of this factor is out of the scope of this work.
- The ability to implement shutdown of turbines to mitigate potential shadow flicker effects, requires the appropriate shadow module / sunshine sensors to be installed on the turbine and programmed into the turbine SCADA. As such, it is recommended that this equipment is installed on turbines which have been predicted to cause an impact.
- Responsibility for flicker mitigation through curtailment must be established between wind farms before a curtailment scheme can be designed.

Appendices

A. Receptor Locations

Table A.1: Shadow receptor locations

Receptor ID	Easting	Northing	Elevation (m)
R1	282501	194997	186
R2	282861	195086	183
R3	281849	192538	165
R4	281886	192344	167
R5	281964	191860	159
R6	281101	191693	129
R7	280750	191271	188
R8	280327	191060	141
R9	280202	190604	110
R10	280153	189842	186
R11	284324	188656	240
R12	284160	189012	244
R13	283357	190159	249
R14	283891	190216	214
R15	283736	190876	208
R16	283998	190564	183
R17	283950	191563	230
R18	284368	191838	202
R19	284699	192478	200
R20	284807	192863	198
R21	284988	193580	236
R22	285038	193310	199
R23	285172	194023	201
R24	281523	192295	147
R25	285061	192386	152
R26	285282	192733	150
R27	285330	193123	159
R28	285437	193521	166

Note that coordinates are in British National Grid.

B. Neighbouring Wind Farm Layout

Table B.1: Foel Trawsnant Wind Farm Layout

Receptor ID	Easting	Northing	Elevation (m)
T1	283979	193530	246
T2	283853	193719	354
T5	283096	194329	326
T6	282868	194591	301
T8	283996	194025	371
T9	283748	194174	357
T10	283726	194429	340
T11	283512	194698	320

Note that coordinates are in British National Grid.

C. Shadow Flicker Results

Table C.1: Results of shadow flicker assessment at each receptor for Y Bryn turbines

ID	No. of days with shadow flicker occurrences	Worst-case maximum shadow flicker (mins/day)	Worst-case shadow flicker (hrs / annum)	Real-case shadow flicker (hrs/annum)
R1	0	0	0.0	0.0
R2	28	18	6.8	1.2
R3	90	34	36.2	14.2
R4	0	0	0.0	0.0
R5	50	43	23.5	4.4
R6	73	43	31.0	7.3
R7	0	0	0.0	0.0
R8	68	32	32.2	6.3
R9	116	38	51.1	12.1
R10	196	58	116.4	39.4
R11	97	48	44.8	18.2
R12	113	37	49.1	18.7
R13	324	67	205.1	62.1
R14	213	30	79.9	22.2
R15	0	0	0.0	0.0
R16	113	25	35.2	10.1
R17	0	0	0.0	0.0
R18	0	0	0.0	0.0
R19	0	0	0.0	0.0
R20	0	0	0.0	0.0
R21	0	0	0.0	0.0
R22	44	32	18.2	7.1
R23	0	0	0.0	0.0
R24	41	23	12.7	4.9
R25	53	27	18.3	7.5
R26	115	27	38.9	15.4
R27	66	26	21.2	7.8
R28	30	24	9.6	3.2

Note that coordinates are in British National Grid.

Table C.2: Results of cumulative shadow flicker assessment at each receptor Y Bryn and Foel Trawsnant Wind Farm

ID	Worst-case maximum shadow flicker (mins/day)		Real-case shadow flicker (hours/annum)		Comment
	Total	Increase relative to Y Brun only	Total	Increase relative to Y Bryn only	
R1	74	74	26.1	26.1	Entirely flicker from neighbour
R2	109	91	47.2	46.0	Majority flicker from neighbour
R3	34	0	14.2	0.0	Entirely flicker from Y Bryn
R4	0	0	0.0	0.0	No Flicker
R5	43	0	4.4	0.0	Entirely flicker from Y Bryn
R6	43	0	7.3	0.0	Entirely flicker from Y Bryn
R7	0	0	0.0	0.0	No Flicker
R8	32	0	6.3	0.0	Entirely flicker from Y Bryn
R9	38	0	12.1	0.0	Entirely flicker from Y Bryn
R10	58	0	39.4	0.0	Entirely flicker from Y Bryn
R11	48	0	18.2	0.0	Entirely flicker from Y Bryn
R12	37	0	18.7	0.0	Entirely flicker from Y Bryn
R13	67	0	62.1	0.0	Entirely flicker from Y Bryn
R14	30	0	22.2	0.0	Entirely flicker from Y Bryn
R15	0	0	0.0	0.0	No Flicker
R16	25	0	10.1	0.0	Entirely flicker from Y Bryn
R17	0	0	0.0	0.0	No Flicker
R18	0	0	0.0	0.0	No Flicker
R19	0	0	0.0	0.0	No Flicker
R20	0	0	0.0	0.0	No Flicker
R21	0	0	0.0	0.0	No Flicker
R22	32	0	7.1	0.0	Entirely flicker from Y Bryn

ID	Worst-case maximum shadow flicker (mins/day)		Real-case shadow flicker (hours/annum)		Comment
	Total	Increase relative to Y Brun only	Total	Increase relative to Y Bryn only	
R23	0	0	0.0	0.0	No Flicker
R24	23	0	4.9	0.0	Entirely flicker from Y Bryn
R25	27	0	7.5	0.0	Entirely flicker from Y Bryn
R26	27	0	15.4	0.0	Entirely flicker from Y Bryn
R27	26	0	7.8	0.0	Entirely flicker from Y Bryn
R28	24	0	5.5	2.3	Flicker from each farm. Below thresholds

Note that coordinates are in British National Grid.

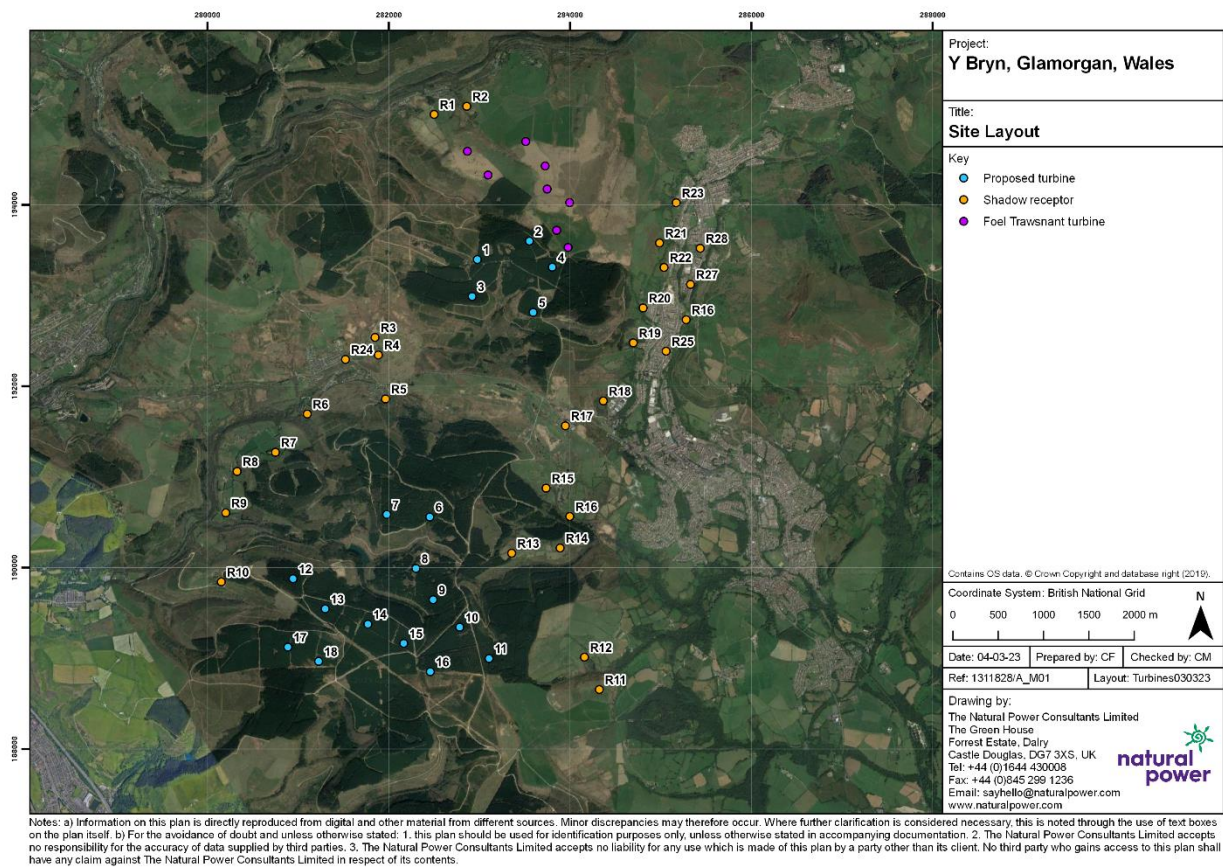


Figure C.1: Y Bryn Wind Farm 18 turbine site layout (T1-T18) with receptors (R1-R28)

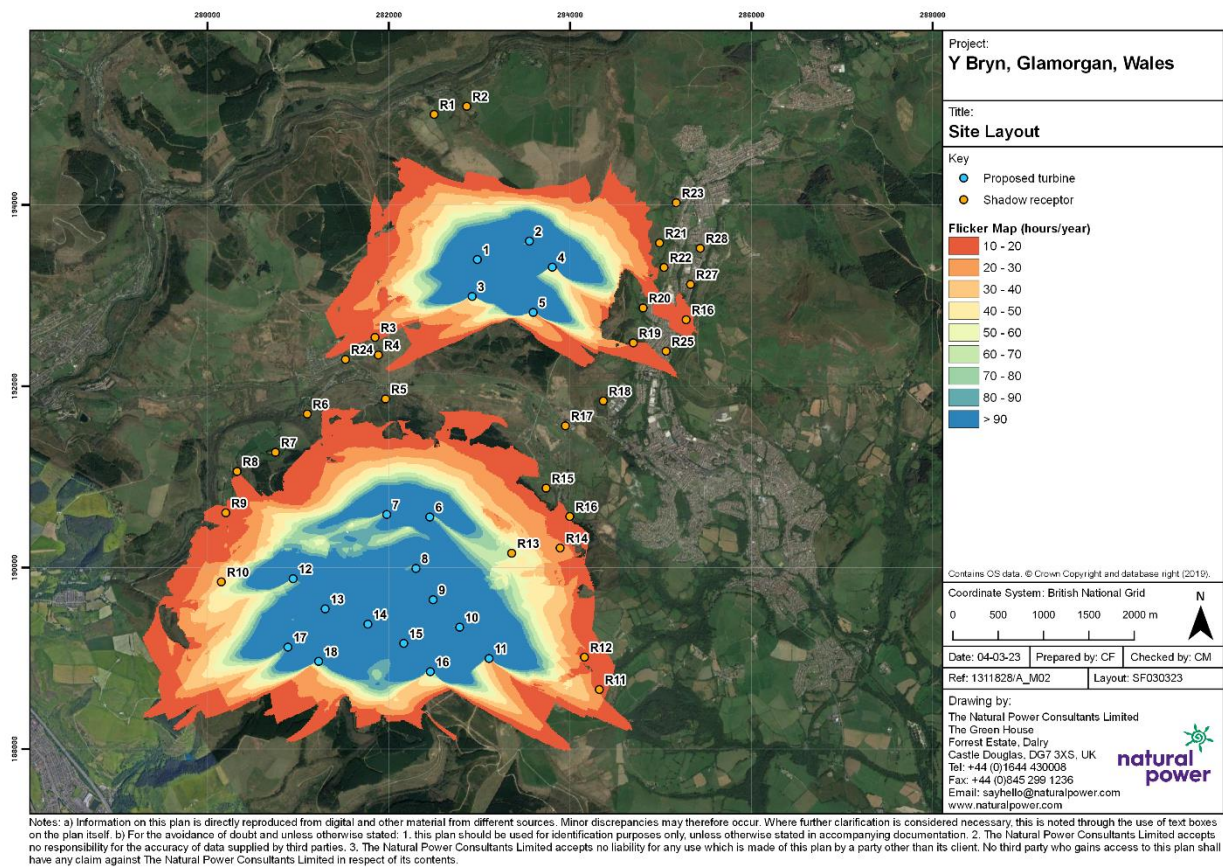


Figure C.2: Y Bryn Wind Farm real-case shadow flicker map

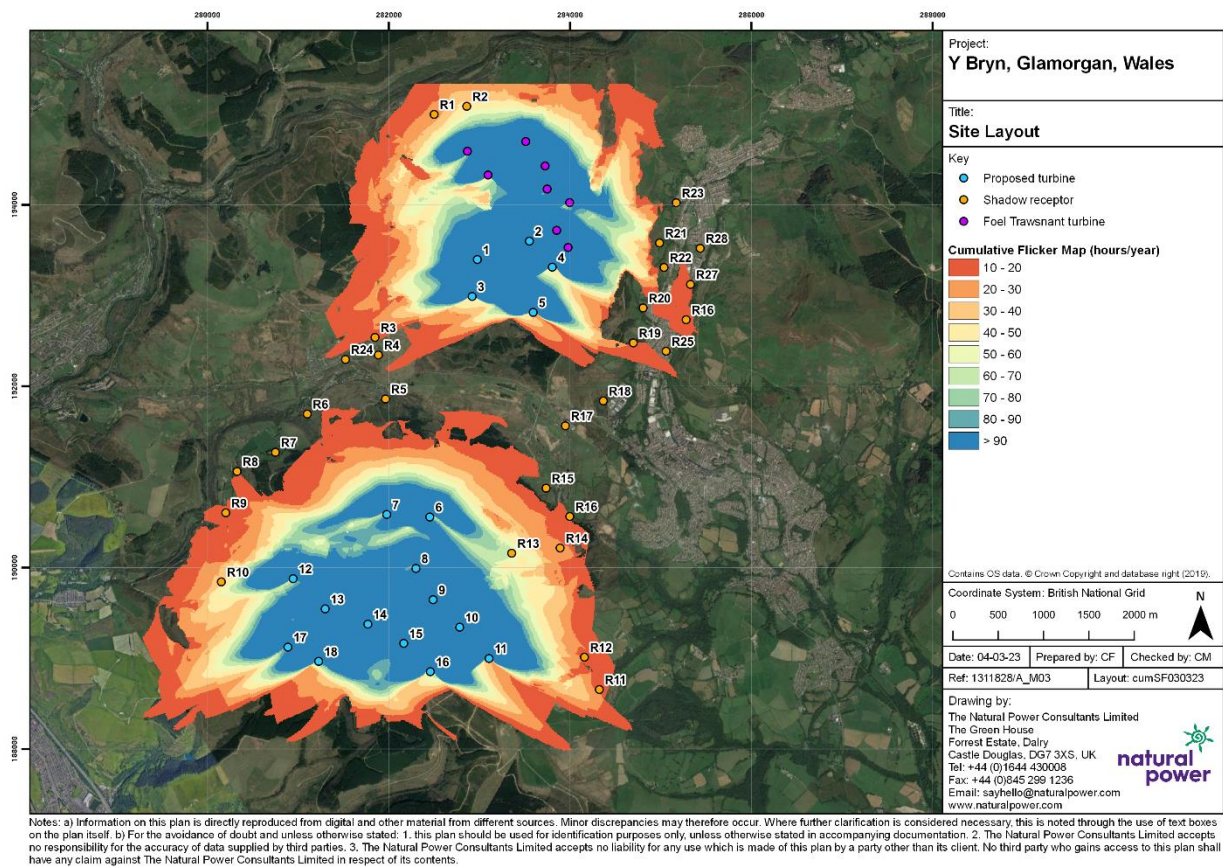


Figure C.3: Y Bryn Wind Farm real-case cumulative shadow flicker map with neighbouring wind farm



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