Chapter 14: Shadow Flicker

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Executive Summary

This chapter provides an assessment of the potential shadow flicker impact on nearby dwellings from the Proposed Varied Development. This shadow flicker assessment has been updated from the previous assessment undertaken as part of the 2018 EIAR, whereby the study area has increased from 1,300m to 1,500m due to an increase in the nominal rotor diameter to 150m.

The total number of shadow flicker hours has been predicted and compared to the previous assessment. Previously, 12 receptors were identified within 1,300m of the Consented Development, however, with the increase in study area the total number of identified receptors has increased to 24. The maximum number of realistic hours, at the worst-case dwelling, is predicted to increase from 15.4 hours (the Consented Development assessment) to 18.4 hours (the Proposed Varied Development assessment). As shadow flicker has been predicted to occur at receptors within 10 rotor diameters of turbines, such effects are potentially **significant** in terms of the EIA Regulations.

The Consented Development's Section 36 ('S.36') consent included a planning condition that required a shadow flicker control scheme to be submitted for the approval of the Local Planning Authority prior to commencement of development. It is anticipated that a similar pre-commencement condition would be attached if consent is granted for the Proposed Varied Development. The Applicant would then apply to discharge the update condition through submission of an updated shadow flicker control scheme.

With mitigation implemented, shadow flicker is unlikely to occur at receptors within a distance of ten rotor diameters of any turbine of the Proposed Varied Development. Mitigated effects are therefore considered to be **not significant** in terms of the EIA Regulations.

14.1. Introduction

14.1.1. A shadow flicker assessment was previously undertaken for the consented Tangy IV Wind Farm ('the Consented Development') in 2018. This assessed a layout consisting of 16 turbines with a maximum tip height of 149.9m.

14.1.2. This chapter considers the potential for the Proposed Varied Development as described in **Chapter 2: Design Iteration and Description of Proposed Varied Development** to result in material changes to the effects identified for the Consented Development.

14.1.3. The assessment is supported by **Figure 14.1** in **Volume 3a** and **Technical Appendix 14.1** in **Volume 4** of this EIA Report.

14.2. Scope of Assessment

14.2.1. The 2025 Scoping Report[1] proposed to update the 2018 EIAR Shadow Flicker assessment with the updated dimensions of the worst-case candidate turbine detailed within the Proposed Varied Development. This will include identifying any additionally affected receptors within an increased study area of 1,500m.

14.3. Consultations

14.3.1. Argyll & Bute Council ('A&BC') provided a scoping response in August 2025, however, at time of writing they were unable to obtain advice from the Council's Environmental Services on shadow flicker. Nevertheless, A&BC agreed with the Scoping Report that an updated assessment should be carried out to identify any additionally affected receptors within an increased study area. A&BC recommended that a planning condition similar to that attached to the Consented Development would likely be required for the Proposed Varied Development.

14.3.2. Planning Condition 14 states "*No development shall commence unless and until a scheme for the avoidance or mitigation of any shadow flicker at residential properties situated at a distance which is the same as ten rotor diameters of any wind turbine forming part of the Development*".

[1] See **Technical Appendix 3.1: Scoping Report**

14.4. Assessment Methodology

14.4.1. Shadow Flicker effects have been predicted using the Applicant's in-house modelling tool, which was developed using the Python programming language.

14.4.2. The tool functions as follows:

- It includes the turbine locations, hub height and rotor diameter, receptor point locations and a digital terrain model ('DTM').
- It first determines the sun's position (azimuth and elevation) as a function of date and time throughout the year, from the perspective of each receptor point. Account is taken for the effects of atmospheric refraction on the sun's apparent elevation.
- The azimuth and elevation of each turbine hub are then determined, along with the apparent extent of the rotor, again from the perspective of each receptor.
- By comparing the sun's positions with the locations and apparent extent of the turbines, it then determines the times at which the sun would be behind the rotor of each of the turbines, i.e., potential shadow flicker event times.
- Events are disregarded where the elevation of the sun above the horizon is less than two degrees as at such times shadow are generally weak.
- Events beyond a cut-off distance of 10 rotor diameters[2] (1,500m) from each turbine are also disregarded, as again shadows are likely to be weaker the greater the distance from the turbine.
- The DTM is sampled along the pathways from the receptor to turbine and receptor to sun position and if at any point between the receptor, turbine and sun, the ground profile interrupts either path, that particular event is disregarded. The effects of refraction and the curvature of the earth are also taken into account at this stage, as these can result in distant terrain appearing lower than in reality.
- Further processing determines the start and end time of each remaining, 'valid' shadow event to the nearest second.
- The tool then creates the following output tables:

[2] The 2018 EIAR also assessed shadow flicker effects within 10 rotor diameters and therefore the same approach has been adopted here. This represents industry standard practice and was supported by the Scottish Government's Online Planning Guidance for Onshore Wind prior to its withdrawal. The current Onshore Wind Policy Statement (2022) provides no specific guidance on shadow flicker. The use of a 10 rotor diameter calculation distance is supported by the 2011 Update of the UK Shadow Flicker Evidence Base prepared by Parsons Brinckerhoff for DECC

- A list of all valid shadow flicker event start and end times (to the nearest minute), with associated details including the turbine and receptor combination involved;
- Summaries of shadow flicker durations per turbine and receptor, per month and year;
- A shutdown calendar that can be used to programme a shadow flicker control system, in which the times of any events occurring for each turbine but at different receptors are merged into a single time interval; and
- Charts showing the times that shadow flicker could occur at each receptor as a result of each turbine as a function of date and time (**See Technical Appendix 14.1: Shadow Flicker Charts**).

14.4.3. The following assumptions are inherent within the model:

- The receptor is considered as a point at 2.0m above ground level;
- The turbine rotor is considered as a solid disc, angled perpendicular to the line between the receptor and turbine hub;
- The sun is a point and its rays are parallel;
- Sunlight is of sufficient brightness to cast shadows during all daylight hours;
- All turbines are turning during all daylight hours;
- Shadow flicker effects are not significant beyond 10 rotor diameters from the turbine or when the sun is lower than 2 degrees above the horizon;
- There are no structures or vegetation between the receptors and turbines that would prevent shadows being cast at the receptor;
- Each receptor has at least one window facing towards each turbine; and
- Each receptor is occupied at times that flicker could occur.

14.4.4. The results from the above therefore represent an unrealistic worst-case scenario as the actual occurrence and duration of shadow flicker will be reduced by factors including:

- Whether or not the sun is shining with sufficient strength to cast a visible shadow at the time of each event;
- The actual orientation of the turbine relative to the receptor;
- Whether the turbine is turning or not; if it is stopped due to low or high wind speed, or other factors, no flicker will occur;
- The size and orientation of windows; and
- The presence or vegetation or structures between the turbine and receptor.

14.4.5. In order to provide a realistic worst-case duration of effects for each receptor, long-term monthly average sunshine hours statistics for Machrihanish have been obtained from the Met Office[3]. That data was combined with daylight duration data[4] and then used to calculate long-term monthly average sunshine hours as a decimal fraction of daylight hours. These are used as scaling factors to reduce the theoretical duration, accounting only for the presence or absence of sunshine. The other factors listed above will also further reduce the occurrence and duration of flicker in practice but are not considered quantitively within this assessment.

14.4.6. The results using the in-house tool have been validated by comparison of results from a number of wind farms, using commercial shadow flicker modelling packages: ReSoft WindFarm, GH Windfarmer, OpenWind and WindPro. It was found that the tool provided results which were comparable with the commercial software. In the case of the Proposed Varied Development, all predicted start and stop times agreed with results from WindPro to within 5 minutes, with the majority (96%) agreeing to within 2 minutes. It should be noted that similar variation was also observed between results from different commercial software packages. These variations can be attributed to differences in available modelling assumptions and options. Notwithstanding, the resulting uncertainty in results is likely to be insignificant in comparison to the conservatism remaining in the process, even after accounting for sunshine duration.

14.4.7. Any shadow flicker occurring at receptors within 10 rotor diameters of a turbine is considered to be a significant effect in terms of the EIA Regulations.

14.5. Consented Development EIAR Baseline

14.5.1. **Chapter 17: Shadow Flicker** of the 2018 EIAR identified the receptors that are located within the previous study area of 1,300m of the Consented Development. **Technical Appendix 17.1** of the 2018 EIAR provided full details of how the shadow flicker was predicted at each of these receptor locations.

14.6. Summary of Effects Predicted & Mitigation Measures proposed for the Consented Development

14.6.1. The 2018 EIAR identified 12 receptors within 1,300m of the Consented Development. The shadow flicker assessment identified Killarow Farm as the receptor predicted to experience the maximum occurrence of shadow flicker

[3] Machrihanish Location-specific long-term averages

[4] Machrihanish, Scotland Sunrise and Sunset Times

(48.2 theoretical hours per year) between April and August. However, it is important to note that, like the tool described in section 14.4, the theoretical maximum number of shadow flicker hours was based upon a number of worst case assumptions. Therefore, in reality the likely occurrence of shadow flicker at Killarow Farm was predicted to be 15.4 hours per year.

14.6.2. The 2018 EIAR suggested that a planning condition requiring a shadow flicker control system would be required to ensure that the turbines do not operate where shadow flicker is predicted. Therefore, no significant shadow flicker effects would then occur.

14.7. Revised Assessment of Effects for the Proposed Varied Development

14.7.1. A desk-based assessment identified 24 receptors within 1,500m of the Proposed Varied Development, as shown in **Figure 14.1**. Details of the identified receptors are provided in **Table 14.1**.

Table 14.1: Shadow Flicker Receptors

Receptor Name	Receptor ID	Easting (m)	Northing (m)
Breakachy House	SFR01	167058	626814
High Balevain Cottage	SFR02	166571	626827
4 Breakachy	SFR03	167031	626866
6 Breakachy	SFR04	167055	626869
5 Breakachy	SFR05	167045	626870
Drumalea Farm	SFR06	166144	627128
The Wild Chameleon	SFR07	167602	627285
Dalnaspidal	SFR08	167600	627295
Algacidal Tangy	SFR09	167593	627318
Tangylea Tangy	SFR10	167444	627616
Tangy Mill Croft	SFR11	166126	627650

Receptor Name	Receptor ID	Easting (m)	Northing (m)
Tangy	SFR12	167446	627733
Tangy Mill	SFR13	166278	627734
Tangy Smithy	SFR14	166066	627738
Drumalea Farm Cottage	SFR15	166065	627751
Tangy Glen Cottage	SFR16	166067	627760
Killarow Cottage	SFR17	166068	627768
22/01793/PP	SFR18	166088	627850
Maleen	SFR19	165941	627915
Killarow Farm	SFR20	166268	628026
Tigh na Mara	SFR21	166080	628172
Tangy Moil	SFR22	166205	628550
Tighnamoile	SFR23	166237	628594
Lagalgarve	SFR24	165924	629341

14.7.2. **Table 14.2** details the shadow flicker modelling results for receptors where flicker is predicted to occur. For receptors not listed within **Table 14.2**, no shadow flicker has been predicted. In addition, Plates 1 to 12 (in **Technical Appendix 14.1**) illustrate the times of year and times of day when shadow flicker could theoretically occur.

Table 14.2: Summary of Shadow Flicker Modelling Results

Receptor ID	Days Per Year	Theoretical Hours Per Year	Maximum Hours Per Day	Mean Hours Per Day	Realistic Hours Per Year
SFR11	58	24.4	0.50	0.42	7.6
SFR13	57	26.3	0.56	0.46	8.1
SFR14	83	35.3	0.50	0.43	11.0

Receptor ID	Days Per Year	Theoretical Hours Per Year	Maximum Hours Per Day	Mean Hours Per Day	Realistic Hours Per Year
SFR15	86	35.3	0.50	0.41	11.0
SFR16	88	35.3	0.50	0.40	11.0
SFR17	89	34.8	0.50	0.39	10.9
SFR18	86	33.8	0.54	0.39	10.6
SFR19	44	15.5	0.45	0.35	5.0
SFR20	119	52.7	0.61	0.44	16.5
SFR21	95	34.5	0.50	0.36	11.0
SFR22	170	62.4	0.52	0.37	18.4
SFR23	157	59.7	0.52	0.38	17.4

14.7.3. The modelling results identified Tangy Moil (SFR22) as the receptor predicted to experience the maximum occurrence of shadow flicker (62.4 theoretical hours per year) between March and October. As with the 2018 EIAR, the theoretical maximum number of shadow flicker hours are based on a number of conservative assumptions and so in reality, the likely occurrence of shadow flicker at Tangy Moil is predicted to be 18.4 hours.

14.7.4. As shadow flicker has been predicted to occur at receptors within 10 rotor diameters of turbines, such effects are potentially significant in terms of the EIA Regulations. Mitigation measures are discussed in the following section.

14.8. Revised Mitigation Measures for the Proposed Varied Development

14.8.1. Wind turbine control systems are available which can mitigate shadow flicker by shutting down operation of certain wind turbines during specific times and conditions to prevent the occurrence of shadow flicker effects at sensitive receptors. There are two categories of mitigation system which may be implemented:

- A Calendar Based System – Turbine shut-downs are implemented based on a set of pre-calculated dates and times when shadow flicker may occur. The calculations are typically undertaken using a software model,

and the shut-down times are then uploaded to the turbine control system. Once programmed, the control system will shut down operation of the turbines during these pre-set periods, providing the correct conditions are present (see below).

- A Location/Geometry Based System – Similar to the Calendar Based System, however the shut-down times are calculated in real time by the turbine control software, based on location data for the turbines and sensitive receptors. This type of system offers more flexibility for adjustment, if required, and can more easily account for any annual variation in shadow times.
- Both types of system typically incorporate light-level sensors, to ensure that mitigation is implemented only where ambient light levels (typically measured at the turbines) exceed a threshold considered sufficient for strong shadows to be cast.

14.8.2. Depending on the system offered by the manufacturer of the turbine model selected for installation, one of the above types of mitigation system will be included in the wind farm's control system.

14.8.3. The Consented Development included a pre-commencement planning condition (Condition 14) which required a shadow flicker control scheme to be submitted for the approval of the Local Planning Authority prior to commencement of development. This condition was submitted to A&BC in February 2024, however no response has yet been received. The Applicant anticipates that a similar pre-commencement condition would be attached if consent for the Proposed Varied Development is granted. The Applicant would then apply to discharge the update condition through submission of an updated shadow flicker control scheme.

14.8.4. Following the implementation of the above mitigation, shadow flicker is unlikely to occur at receptors within a distance of ten rotor diameters of any turbine. Mitigated effects are therefore considered to be **not significant** in terms of the EIA Regulations.

14.8.5. It is possible that minor shadow flicker effects may occur at separation distances greater than 10 rotor diameters. In the event that reports of such effects are received, they will be investigated and, if verified, adjustments will be made to the control system to prevent recurrence.

14.9. Conclusion

14.9.1. An updated shadow flicker assessment has been undertaken for all receptors located within 1,500m of the proposed wind turbine locations. The shadow

flicker study area has been increased from 1,300m due to an increase in nominal rotor diameter (i.e. 130m to 150m).

14.9.2. Previously, the 2018 EIAR predicted the maximum occurrence of shadow flicker to be experienced at Killarow Farm (48.2 theoretical hours or 15.4 realistic hours). In this updated assessment, the maximum occurrence of shadow flicker is predicted to be experienced at Tangy Moil (62.4 theoretical hours or 18.4 realistic hours). Any shadow flicker occurring at receptors within 10 rotor diameters of a turbine is considered to be a significant effect in terms of the EIA Regulations.

14.9.3. Planning condition 14 of the Consented Development requires a shadow flicker control scheme to be submitted to and approved by the Local Planning Authority prior to commencement of development. A similar condition is anticipated as part of this Proposed Varied Development, where an updated control scheme will be submitted to A&BC for approval before commencement of development.

14.9.4. Following the implementation of the above mitigation, shadow flicker is unlikely to occur at receptors within a distance of ten rotor diameters of any turbine. Mitigated effects are therefore considered to be **not significant** in terms of the EIA Regulations.

14.10. References

Tangy IV Wind Farm, Environmental Impact Assessment Report, Chapter 17: Shadow Flicker, August 2018

Tangy IV Wind Farm, Environmental Impact Assessment Report: Technical Appendices, Appendix 17.1: Shadow Flicker August 2018

Update of UK Shadow Flicker Evidence Base, Prepared by Parson Brinckerhoff for Department for Energy and Climate Change, 2011