Technical Appendix 2.3: Shadow Flicker Assessment

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Shadow Flicker Assessment

2.1 Introduction

2.1.1 This Technical Appendix considers the potential shadow flicker effects from the proposed Appin Wind Farm (hereafter referred to as 'the Proposed Development') on residential receptors. The assessment is based on the proposed turbine layout as detailed in **Chapter 4: Description of the Proposed Development** of the EIA Report.

2.1.2 Shadow flicker is an effect that can occur when the shadow of a moving wind turbine blade passes over a small opening (e.g. a window), briefly reducing the intensity of light within the room, and causing a flickering to be perceived. Shadow flicker occurs when a certain combination of conditions prevail at a certain location, time of day and year, and may have a negative effect on residents and occupants of affected properties.

2.1.3 This Appendix is supported by **Figure A2.3.1: Shadow Flicker**.

2.2 Scope of the Assessment

2.2.1 The assessment considers the potential operational effects of shadow flicker on habitable residential properties within the shadow flicker study area (see description of the study area below). Shadow flicker only occurs from operational turbines.

2.2.2 The assessment has not considered potential effects of shadow flicker relating to epilepsy. Approximately 1 in every 100 people has epilepsy[1]. Up to 3% of people with epilepsy are affected by flashing lights ('photosensitive epilepsy'). According to the Epilepsy Society[2] "*The turbine blades would need to rotate at speeds faster than 3 hertz (flashes per second)*"[3] to trigger epileptic seizures in people with photosensitive epilepsy. According to the National Policy Statement (NPS) for Renewable Energy Infrastructure (EN-3) (2011)[4] *"The maximum frequency of the shadowing effect from commercial scale wind turbines is less than 1 hertz…Therefore, shadow flicker frequencies are not in the region known to induce seizures in sufferers of epilepsy"* (page 72). Whilst the NPSs are not Scottish policy documents, the text quoted here is accepted to be generally applicable. Therefore, any potential shadow flicker effects arising from the Proposed Development are effects on residential amenity only, rather than having the potential to affect the health or well-being of residents.

2.3 Assessment Methodology

Legislation and Guidance

2.3.1 This assessment is carried out in accordance with the principles contained within the following documents:

- Department of Energy and Climate Change (DECC) (2011) Update of UK Shadow Flicker Evidence Base[5];
- Scottish Government (2014) Onshore Wind Turbines Planning Advice[6];
- UK Government (2013) Planning Practice Guidance for Renewable and Low Carbon Energy[7];

[1] Epilepsy Society (no date) Epilepsy Facts and Myths [online]. Available at: https://epilepsysociety.org.uk/about-epilepsy/what-epilepsy/epilepsy-facts-and-myths
[2] Formally called The National Society for Epilepsy.
[3] Epilepsy Society (no date) Photosensitive Epilepsy [online]. Available at: https://epilepsysociety.org.uk/sites/default/files/2025-04/PhotosensitiveepilepsyApril2025.pdf
[4] Department of Energy and Climate (2011) National Policy Statement for Renewable Energy Infrastructure (EN-3) [online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47856/1940-nps-renewable-energy-en3.pdf
[5] Department of Energy and Climate Change (DECC) (2011) Update of UK Shadow Flicker Evidence Base. Available [online] at: https://www.gov.uk/government/publications/update-of-uk-shadow-flicker-evidence-base
[6] Scottish Government (2014) Onshore Wind Turbines: Planning Advice [online]. Available at: https://www.gov.scot/publications/onshore-wind-turbines-planning-advice/
[7] UK Government (2013) Planning Practice Guidance for Renewable and Low Carbon Energy. Available at: https://www.gov.uk/guidance/renewable-and-low-carbon-energy

- Department of Northern Ireland (2009) Practice Guidance for Planning Policy Statement 18 (PPS18)[8] [9], (not Scottish guidance but applicable in relation to shadow flicker assessment for EIA purposes, as discussed further below); and
- Scottish Government (2023) National Planning Framework 4 (NPF4)[10].

Study Area

2.3.2 In the UK and at UK latitudes, shadow flicker is only likely to occur in a building located within a distance of 10 times the rotor diameter of a turbine[11]. The rotor diameter of the Proposed Development's turbines has been assumed for the purposes of this EIA Report to be 162 m; therefore, the potential area in which shadow flicker could occur will be 1.62 km from the turbines. **Section 2.8** details the approach to micrositing.

2.3.3 Properties which are beyond 130 degrees either side of north, relative to the turbine were excluded, following the UK Government's Planning Practice Guidance for Renewable and Low Carbon Energy (2013)[12]. This is because turbines do not cast long shadows on their southern side.

Desk Based Research and Data Sources

2.3.4 The following data sources have informed the assessment:

- OS AddressBase data;
- Google Maps aerial imagery;
- Met Office Data: Sunshine at Glenlee Climate Station[13]; and
- National Oceanic and Atmospheric Administration (NOAA) Data: Global Monitoring Laboratory Sunrise and Sunset at the Proposed Development[14].

2.3.5 The identification of relevant properties through desk based assessment and verification of inhabited properties through the various surveys has been used to inform the shadow flicker assessment.

Assessing Shadow Flicker Effects

The Scottish Government Onshore Wind Turbines Planning Advice (2014) states that:

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

Where this could be a problem, developers should provide calculations to quantify the effect. In most cases however, where separation is provided between wind turbines and nearby dwellings (as a general rule, 10 rotor diameters), 'shadow flicker' should not be a problem. However, there is scope to vary layout/reduce the height of turbines in extreme cases." (page 6)

[8] No formal guidance is available (at the time of writing) as to what levels of shadow flicker are considered to be acceptable in Scotland. Therefore, in the absence of any specific guidance for Scotland, the PPS18 is considered to be a valid reference for determining the significance of shadow flicker effects.
[9] Department of Northern Ireland (2009) Practice Guidance for Planning Policy Statement 18 (PPS18) [online]. Available at: https://www.infrastructure-ni.gov.uk/sites/default/files/publications/infrastructure/Best%20Practice%20Guidance%20to%20PPS%2018%20-%20Renewable%20Energy_0.pdf
[10] Scottish Government (2023) National Planning Framework 4. Available [online] at: https://www.gov.scot/publications/national-planning-framework-4/
[11] 10 times the rotor diameter is used as a general rule as shadow flicker should have no effect on properties located further than this distance (Scottish Government (2014) Onshore Wind Turbines: Planning Advice).
[12] It is noted that these standards were published for use in England, however in the absence of Scottish planning advice on this topic, they are considered to be a reasonable basis for informing this assessment.
[13] Met Office UK Climate Averages. Available [online] at: https://www.metoffice.gov.uk/research/climate/maps-and-data/location-specific-long-term-averages/gcv12y6nc
[14] NOAA (no date) Global Monitoring Laboratory, Sunrise Table for 2023, Location: Latitude 55.312741 Longitude -3.555932. Available [online] at: https://gml.noaa.gov/grad/solcalc/table.php?lat=55.25&lon=-4.02&year=2025

2.3.6 Although the effect has been quantified as part of the shadow flicker assessment for the Proposed Development, there is no formal guidance available (at the time of writing) regarding the limit on the amount of shadow flicker that is considered acceptable or not acceptable within Scotland. In absence of this, the Department of Environment Northern Ireland (2009) Best Practice Guidance for Planning Policy Statement 18 (PPS18): Renewable Energy provides an indication of what may be an acceptable duration of shadow flicker, stating that:

> "*It is recommended that shadow flicker at neighbouring offices and dwellings…should not exceed 30 hours per year or 30 minutes per day.*" (page 29)

2.3.7 This limit has also been utilised in the Republic of Ireland, Germany and Belgium, and is generally used across Scotland for shadow flicker assessments.

2.3.8 As this limit is widely accepted as a suitable metric in shadow flicker analysis for wind farms, it is considered to be an appropriate threshold against which to make a professional judgement on the significance of the Proposed Development's effects with respect to shadow flicker. In this way, predicted effects are judged as being **Significant** and require mitigation whereby shadow flicker occurrence is estimated to exceed the aforementioned thresholds. Any values below these thresholds represent effects that are Not Significant. Where a significant effect is identified, this is considered to be significant in the context of the EIA Regulations. It should be noted, however, that as there is no formal guidance available on this topic within the UK or Scotland, the conclusions drawn are relative to these thresholds and are based on professional judgement and common practice.

Assessment Limitations

Theoretical 'Maximum-Case' Scenario

2.3.9 The shadow flicker assessment has been undertaken using ReSoft Windfarm Shadow Flicker module ('ReSoft model' or 'ReSoft modelling'). In the ReSoft modelling, the following worst-case assumptions have been made and have been used to determine a maximum theoretical level of shadow flicker occurrence:

- All properties within the study area are assumed to have a specified window size (in this case 1.5 m x 2 m) facing directly on to each turbine that has the potential to cause an effect.
- The turbine blades are assumed to be rotating 24 hours a day for 365 days per year, and therefore no reductions due to low or unproductive windspeeds, or turbine maintenance are considered.
- The turbine blades are assumed to always be positioned so that their full face will be between the sun and each property, therefore no reductions due to wind direction or blade pitching are considered.
- It is assumed that the sun always shines in a clear sky on every day of the year, i.e. there are no periods of cloud cover or low visibility due to fog, mist and haze etc.
- A human receptor is deemed to be present in all affected rooms at all times.
- No account is taken of the potential shielding effects of trees or vegetation.
- Curtains or blinds are assumed not to be fitted to windows.

2.3.10 The ReSoft modelling is therefore based on a theoretical 'maximum-case', or 'worst-case' scenario based on conservative (i.e. high) estimates, and this is what is shown in **Figure A2.3.1**. However, the occurrence of shadow flicker is only possible during the operation of the wind turbines (i.e. when the rotor blades are turning), when the sun is shining and when the sky is clear enough to cast shadows, therefore, the real-life instances of shadow flicker will always be less than that predicted by the ReSoft model.

'Realistic' Scenario

2.3.11 To quantify a more appropriate (realistic) occurrence of shadow flicker, which could be experienced by residential receptors within the study area and upon which to base the significance of effects, the initial theoretical maximum-case results are adjusted to take account of the average percentage of time the sun shines during the daytime in the area local to the Site.

2.3.12 The initial estimates have been translated into realistic estimates by considering typical daylight hours across each month of the year and when the sunshine will most likely be shining brightly enough to cast a shadow (accounting for

average cloud cover). Daylight hours and sunshine hours data was taken from NOAA at the Site and from the most recent meteorological records collected at the nearest climate station to the Site (Glenlee Climate Station), and inputted into the ReSoft modelling. The modelling was then re-run to set out the realistic occurrence; the findings of which are shown in **Figure A2.3.1**.

2.3.13 **Table 2.1** shows the average percentages of time for when the sun is shining throughout a typical year at the Site.

Table 2.1 Monthly percentage of Sunny Daylight Hours

Month	Average Daylight Hours per month	Total daylight hrs / month	Typical sunshine hours per month	Monthly % of Sunny Hours
January	7.87	243.98	31.36	12.85
February	9.70	271.67	59.57	21.93
March	11.90	368.92	97.93	26.55
April	14.19	425.62	140.77	33.07
May	16.23	503	180.76	35.94
June	17.33	519.88	149.55	28.77
July	16.75	519.27	158.16	30.46
August	14.91	462.18	142.11	30.75
September	12.70	393.55	110.52	28.08
October	10.43	323.43	73.95	22.86
November	8.37	251.1	44.45	17.70
December	7.23	224.07	25.96	11.59
Annual	**12.30**	**4489.55**	**1215.09**	**27.06**

2.3.14 It should be noted that the more ‘realistic’ scenario, like the theoretical maximum scenario, does not reflect the fact that the turbines will not be continually rotating 365 days a year, for example, due to changes in wind speed and maintenance/shutdown periods.

2.3.15 It should also be noted that even if shadow flicker impact does occur at a specific location, this does not imply that it will be witnessed. Potential witnesses may be sleeping or occupied in a room on another side of the property which is not impacted, or indeed absent from the location altogether (e.g. at work, on holiday, etc) during the time of shadow flicker events. Furthermore, trees, outbuildings and other obstacles may screen an observer from shadow flicker effects.

2.3.16 The effects of shadow flicker which occur under the ‘realistic’ estimation will, therefore, be reduced further, however, it is not practicable or proportionate to model every scenario and therefore the realistic estimation, albeit still unlikely and overly conservative, is considered to be a reasonable approach.

2.4 Existing Conditions

2.4.1 There are two properties located within the study area and within 130 degrees either side of north, relative to the proposed turbines, which could experience shadow flicker effects, as shown on **Figure A2.3.1**[15]. These are:

- 5: Blairoch; and
- 6: Benbuie.

2.4.2 A property at Cairnhead to the north-west of the two properties identified above has not been included within the shadow flicker assessment as it is classed as a bothy and is not in residential use. The location of this bothy can be seen on **Figure A2.3.1**.

2.4.3 Annual average sunlight hours were calculated using Met Office Data from the Glenlee Climate Station (for typical sunshine hours) and NOAA Data at the Proposed Development Site (for typical daylight hours). Glenlee Climate Station is the closest climate station to the Proposed Development, located approximately 20 km south-west of the nearest proposed turbine (T9). Sunny daylight hours are only expected to occur approximately 27.06% of the time on average over the course of a year, as detailed within **Table 2.1**.

2.5 Implications of Climate Change

2.5.1 In summary, the projections highlight that the summer and winter temperatures are likely to be greater than the current baseline, with winter rainfall increasing and summer rainfall decreasing. As shadow flicker effects are intrinsically linked to weather, there is the potential that the current baseline sunny daylight hours could be affected in the future due to climate change. The baseline percentage of sunny daylight hours per year is, however, not expected to change over the 50-year operational life of the Proposed Development to such a degree that the assessment of effects will be materially affected.

2.6 Future Baseline in the Absence of the Proposed Development

2.6.1 In the absence of the Proposed Development, it is likely that the Site will continue under the same land use, with no shadow flicker effects being generated in consequence. However, the effects of shadow flicker may occur as a result of alternative wind energy development as wind farm development is a clear force for change and is likely to continue within the area. This is also supported by the Onshore Wind Policy Statement (December 2022)[16]. There are an increasing number of operational, consented and proposed domestic wind turbines of varying heights and rotor diameters, located within the surrounding landscape. As farmers diversify income and seek opportunities to generate energy for domestic and commercial use, interest in this type of development may continue.

2.7 Design Considerations

2.7.1 **Chapter 3** describes the design process. As part of the design of the Proposed Development, proximity of turbines to properties was considered in relation to reducing effects on residential visual amenity and operational noise and a minimum buffer of 1 km was adopted. This in turn has helped to reduce the potential for shadow flicker occurrence at certain properties

2.8 Micrositing

2.8.1 A general micrositing allowance of 100 m is being sought for the Proposed Development to allow a degree of flexibility in the layout of site components during construction should unfavourable ground conditions be encountered. Depending on the direction of any micro-siting, shadow flicker occurrence may theoretically increase or decrease depending on the distance and orientation to individual properties. Should the turbines move closer to the properties assessed, shadow flicker may need to be reassessed. However, it is not anticipated that any changes to the turbine locations would materially alter the findings of this assessment.

[15] Figure A2.3.1 also shows the location of Cairnhead bothy which is not a residential property and so has not been included in the assessment; notwithstanding this it can reasonably be concluded that any shadow flicker experienced at the bothy will not be such that significant adverse effects will occur.
[16] Scottish Government (2022) Onshore Wind: Policy Statement 2022. Available [online] at: https://www.gov.scot/publications/onshore-wind-policy-statement-2022/

2.9 Assessment of Effects

2.9.1 The assessment of operational effects is based on the turbine layout provided in **Chapter 4**. Potential effects identified are considered to be adverse unless otherwise stated.

Operational Effects

2.9.2 Applying the assumptions above, the maximum theoretical shadow flicker occurrence (i.e. the 'Theoretical Maximum Hours per Year' and 'Theoretical Maximum Hours per Day') for each property within the study area has been calculated. The results of the modelling for the study area are shown in **Table 2.1** along with their significance. Results are also shown on **Figure A2.3.1**.

2.9.3 As per the methodology, **Table 2.2** also presents the 'realistic' estimate which is the initial theoretical maximum hours per year and minutes per day factored down by the percentage of time the sun is expected to realistically be shining (27.06%, see **Table 2.1**) for the purposes of judging likely significant effects.

Table 2.2 Theoretical 'Maximum-Case' Occurrence of Shadow Flicker experienced by Properties located within the Study Area

Property ID (Receptor)	Theoretical Days per Year	Theoretical Maximum Hours per Day	Theoretical Mean Hours per Day	Theoretical Total Hours per Year	Realistic Shadow Flicker – Minutes per Year	Realistic Shadow Flicker – Minutes per Day	Realistic Shadow Flicker – Hours per Year
5. Blairoch	44	0.13	0.09	4.04	65.59	2.1	1.1
6. Benbuie	0	0	0	0	0	0	0

2.9.4 The assessment of shadow flicker effects on the potential receptors identified in **Table 2.2** indicates that the maximum theoretical occurrence of shadow flicker amounts to 4.04 hours per year at the most affected property, Blairoch (ID 5). Neither property in this assessment surpasses the Maximum Theoretical Minutes per Day threshold of 30 minutes. Therefore, it is considered that these properties will not experience significant effects due to shadow flicker under the theoretical maximum scenario.

2.9.5 Trees, vegetation and local topography in the vicinity of the residential receptors may have a screening effect which could either reduce the effects of shadow flicker or eliminate shadow flicker completely. There is substantial forestry cover within the area between Blairoch and the Proposed Development which has the potential to provide screening from the effects of shadow flicker.

2.9.6 Based on the results above (maximum and realistic scenario), the property at Benbuie (ID 6) will not experience any shadow flicker effects from the Proposed Development. The property at Blairoch (ID 5) is predicted to experience shadow flicker effects which are considered to be below the thresholds in accordance with guidance, and therefore, **not significant**.

Mitigation

2.9.7 It is not considered that additional mitigation for shadow flicker effects is required based on the above assessment. The Applicant is nonetheless committed to promptly investigating any complaints of shadow flicker and taking appropriate action as required. As stated in the Standard Conditions and detailed in **Chapter 2**, a Wind Farm Shadow Flicker Protocol would be submitted and approved by Dumfries and Galloway prior to the operation of the first turbine. This would set out the protocol to be followed should a shadow flicker complaint be received from a receptor within the study area, and potential mitigation measures.

2.10 Interrelationship Between Effects

2.10.1 Shadow flicker potentially affects the experience of residential amenity, and in this sense is one of a wider group of effects including noise and other residential visual amenity effects. However, bearing in mind the amenability of shadow flicker effects to mitigation, and the fact that shadow flicker effects are different in kind from noise and other

visual effects, there are no significant effects predicted due to the interrelation between shadow flicker and any other effects relating to residential amenity.

2.11 Summary of Effects

2.11.1 The predicted effects of the Proposed Development with respect to shadow flicker are **Not Significant** in the context of the EIA Regulations and the potential effects of shadow flicker are scoped out of further consideration in the EIA Report.

Statkraft

N

Site Boundary

Turbine

10 x Rotor Diameter Study Area (1620 m)

Estimated Theoretical Hours of Shadow Flicker Per Year

0 - 30

30 - 100

> 100

Non Residential Property – Cairnhead Bothy

Residential Property

1: Shinnelhead

2: High Appin

3: Appin Lodge

4: High Auchenbrack

5: Blairoch

6: Benbuie

7: Glenjaan

8: Corriedow

Notes:

'Estimated Theoretical Hours of Shadow Flicker per Year' show 27.06% of the maximum hours possible of shadow flicker at each coloured location on the map. The 27.06% is derived from Met office data for average daily hours of sunlight (1991-2020) as a proportion of daylight during the sunniest month of the year (June) from Glenlee climate station.

Less than 30 hours of shadow flicker per year is considered to have a minimal effect on properties.

Theoretical occurrence does not take into account screening by vegetation and topography.

Study area = 1620 m (10 x rotor diameter)
Sun angle = 2° above horizon
Viewer height = 1.5 m

0 0.5 1 Km

Source: LUC, Pell Frischmann, OS

Produced By: HD
Checked By: NE
Version: 00

Date: 06/05/2025
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Figure A2.3.1
Shadow flicker

Appin Wind Farm
EIA Report

Map scale 1:22,000 @ A3