# Technical Appendix 1.7: Shadow Flicker Appraisal

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## 1.1 Introduction

1.1.1 This Technical Appendix provides an appraisal of potential effects on residential amenity resulting from shadow flicker associated with the operation of the Proposed Development.

1.1.2 The term 'shadow flicker' refers to the flickering effect caused when rotating wind turbine blades periodically cast shadows over neighbouring properties as they turn, through constrained openings such as windows. The magnitude of the shadow flicker varies both spatially and temporally and depends on a number of environmental conditions coinciding at any particular point in time, including, the position and height of the sun, wind speed, direction, cloudiness, and position of the turbine to a sensitive receptor'[1].

1.1.3 The specific objectives of this Technical Appendix are to:

- Describe the shadow flicker baseline;
- Describe the potential effects, including direct, indirect and cumulative effects; and
- Describe the mitigation measures proposed to address potential effects

1.1.4 The assessment has been carried out by Ramboll UK Limited (Ramboll). The Lead author is Peter Bruce MSc BSc (Hons) MISEP CEnv, Director – Impact Assessment. Mr Bruce has over 19 years' of experience in environmental consultancy, specialising in Impact Assessment for renewable energy developments (refer to **Technical Appendix 1.2 (EIAR Volume 4)** for further details).

1.1.5 This Technical Appendix is supported by the following:

- Annex A: Figure 2.5.1: Shadow Flicker Study Area and Receptors
- Annex B: Shadow Flicker Modelling Results

## 1.2 Consultation

1.2.1 The Scoping Report (**Technical Appendix 1.4, EIAR Volume 4**) proposed to scope out an assessment of shadow flicker on the basis that, if shadow flicker effects could not be avoided through design, then a Shadow Flicker Mitigation Protocol would be implemented via a suitably worded planning condition included as part of any consent. In their scoping response, Leadhills Community Council requested that potential shadow flicker effects be scoped into the assessment in their scoping response. This technical appendix has been prepared to present details of the predicted shadow flicker effects at relevant properties and, where necessary, to provide appropriate mitigation.

## 1.3 Appraisal Methodology

### Legislation, Policy and Guidance

1.3.1 National Planning Framework 4 (NPF4)[2] requires onshore wind proposals to demonstrate that impacts on residential amenity, including shadow flicker, are addressed, with effective mitigation secured where necessary.

1.3.2 There is no statutory standard in the UK for the assessment of shadow flicker and no nationally prescribed thresholds for acceptable exposure. However, relevant planning guidance, contained within the Scottish Government's Online Renewables Planning Advice: Onshore Wind Turbines (2014)[3], states:

*"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."*

1.3.3 This is similar to advice from the UK Government's Shadow Flicker Evidence Base[1] which considers that shadow flicker effects are only considered to affect properties within 10 rotor diameters of a turbine and within 130 degrees either side of north relative to a turbine.

1.3.4 While there are currently no UK guidelines which quantify what exposure levels of shadow flicker are acceptable, Predac[4], an EU sponsored organisation that promotes best practice in energy use and supply, recommends that a maximum of 30 hours of shadow flicker in any calendar year or 30 minutes per day is acceptable for properties within 500 m of a turbine. These benchmarks are also set out in Northern Ireland's PPS18 Best Practice Guidance[5].

1.3.5 Supplementary Guidance[6] to South Lanarkshire Council Local Development Plan 2 reiterates the Scottish Government's Planning Advice on shadow flicker assessments, expecting any wind farm developers to follow any Scottish Government guidance.

### Scope of Appraisal

*Potential Impacts Scoped In*

1.3.6 Based on the above guidance, potential shadow flicker effects are considered for properties within 10 rotor diameters (RD) of the proposed turbine locations.

1.3.7 Using proprietary specialist modelling software 'Windfarm' (RESoft Windfarm V5.0.2.2), an annual analysis of shadow flicker for the Proposed Development was carried out, taking into account the behaviour of the sun, the local topography and the turbine layout and dimensions.

1.3.8 It should be noted that the modelling analysis was performed using the following standard (worst-case) assumptions:

- the sun will always be visible during daylight hours;
- the turbine blades are always turning at these times;
- the alignment of the turbine rotor blades with respect to the sun's position will always produce maximum shadow casting (conservative assumption: it is unlikely that the wind, and therefore the rotor blades, will track the sun in practice);

[1] UK Government's Shadow Flicker Evidence Base as reported for DECC by Parsons Brinckerhoff. Available at: https://www.gov.uk/government/publications/update-of-uk-shadow-flicker-evidence-base [accessed December 2025]
[2] Scottish Government, National Planning Framework 4 (2023 Available online from https://www.gov.scot/publications/national-planning-framework-4/
[3] Scottish Government, Online Renewables Planning Advice: Onshore Wind Turbines (2014) Available online from: https://www.gov.scot/publications/onshore-wind-turbines-planning-advice/ [accessed December 2025]
[4] Predac - European Actions for Renewable Energies (2004). Spatial Planning of Wind Turbines
[5] Northern Irish Government, Best Practice Guidance to PPS 18 'Renewable Energy' (2019) Available online from https://www.infrastructure-ni.gov.uk/sites/default/files/publications/infrastructure/Best%20Practice%20Guidance%20to%20PPS%2018%20-%20Renewable%20Energy_0.pdf [accessed June 2026)
[6] South Lanarkshire Council LDP2 Supplementary Guidance – Renewable Energy (2021) Available online from https://www.southlanarkshire.gov.uk/downloads/download/868/renewable_energy_supplementary_guidance [accessed June 2026]

- the analysis looks at shadow casting over the receptors from all directions rather than over vertical orientated elements of the buildings only;
- the intensity of the sun will be insufficient to cast strong shadows at elevations less than 2.0°; and
- while terrain shielding is modelled based on a digital terrain model, shielding due to features such as trees or other obstacles has not been taken into account.

1.3.9 On the basis of the UK Shadow Flicker Evidence Base report[1] referenced above, impacts are considered likely at receptors located within 10 RD of a turbine (1.7 km) where shadow flicker would exceed 30 hours per year or 30 minutes per day.

1.3.10 An assessment of cumulative effects from the Proposed Development in-combination with other operational, under-construction, and consented wind farm schemes is also considered. Developments nearing the end of their operational life are also considered to present a 'worst case scenario'. The cumulative assessment considers other wind farms within 10 RDs of any identified receptor as part of the shadow flicker assessment for the Proposed Development.

*Potential Impacts Scoped Out*

1.3.11 The assessment focusses on likely effects caused by the Proposed Development. A summary of the issues scoped out, together with reasoning for scoping them out is presented in **Table 1.7.1**.

**Table 1.7.1: Impacts Scoped Out of the Assessment**

| Impact | Reasoning |
|---|---|
| Shadow flicker effects as a result of the construction and decommissioning phases of the Proposed Development | As shadow flicker is a phenomenon caused by the moving shadow of the turbine rotor being cast over a narrow opening, such as a window or open door, no shadow flicker impacts as a result of the construction or decommissioning of the Proposed Development are likely. Consideration of potential shadow flicker effects resulting from the construction and decommissioning of the Proposed Development have therefore been scoped out. |
| Impacts to visual amenity due to reflected light stroboscopic effect | A related visual effect to shadow flicker is that of reflected sunlight. Theoretically, should light be reflected off a rotating turbine blade onto an observer then a stroboscopic effect could be experienced. In practice, a number of factors limit the severity of this phenomenon. Firstly, wind turbines have a semi-matt surface finish which means that they do not reflect light as strongly as materials such as glass or polished vehicle bodies. Secondly, due to the convex surfaces found on a turbine, the light would generally be reflected in a divergent manner. Thirdly, the variability in flow within a wind farm results in slightly differing orientation of rotor directions. Therefore, it is unlikely that an observer would experience simultaneous reflections from a number of turbines. Fourthly, as with shadow flicker, certain weather conditions and solar positions are required before an observer would experience the phenomenon. Therefore, it is concluded that the Proposed Development would not cause a material reduction to amenity owing to the reflected light. With this considered, impacts to visual amenity due to reflected light stroboscopic effect is scoped out and has not been considered further. |
| Impacts to human health | People with photosensitive epilepsy are usually sensitive to flickering light that is between 3 to 60 Herts (Hz). According to the Parsons Brinckerhoff paper[1] "the maximum frequency of the shadowing effect arising from commercial-scale wind turbines is less than 1 Hz". Therefore, any potential shadow flicker effects arising from the Proposed Development are purely an effect on amenity, rather than having the potential to affect the health or wellbeing of people. |

**Method of Baseline Characterisation**

*Extent of the Study Area*

1.3.12 The Shadow Flicker Study Area is a 10 RD radius around each proposed turbine (1.7 km), and within this radius the Study Area is limited to 130 degrees either side of north of any turbine location.

1.3.13 The Study Area in relation to shadow flicker is shown in **Figure 1.7.1 (Annex A)**.

*Desk Study*

1.3.14 A desktop assessment was undertaken in January 2026 using Royal Mail address base data and publicly available aerial and satellite images in order to identify all residential and commercial properties located within the Study Area.

*Modelling Methodology*

1.3.15 The computer software 'WindFarm' (RESoft Windfarm V5.0.2.2) was used to identify potential areas susceptible to shadow flicker, and the extent of shadow flicker effects. This software identified the Study Area for the assessment based on candidate turbine dimensions and orientations, as well as model periods of predicted shadow flicker. The following model parameters were used:

- A candidate wind turbine with a hub height of 135 m, a rotor diameter of 170 m and a blade tip height of 220 m;
- The maximum distance of shadow flicker influence considered is 10 times the RD (170 m x 10 = 1,700 m = 1.7 km);
- The centre of the window (viewing height) is 3 m above ground level;
- Each property has two windows facing the Proposed Development;
- Each window is 1 m by 1 m[7];
- The calculation year is 2026;
- The maximum sun height is 2° above the horizon; and
- Topography has been considered using 20 m grid spaced digital terrain model (DTM) data and the Earth's curvature has been accounted for.

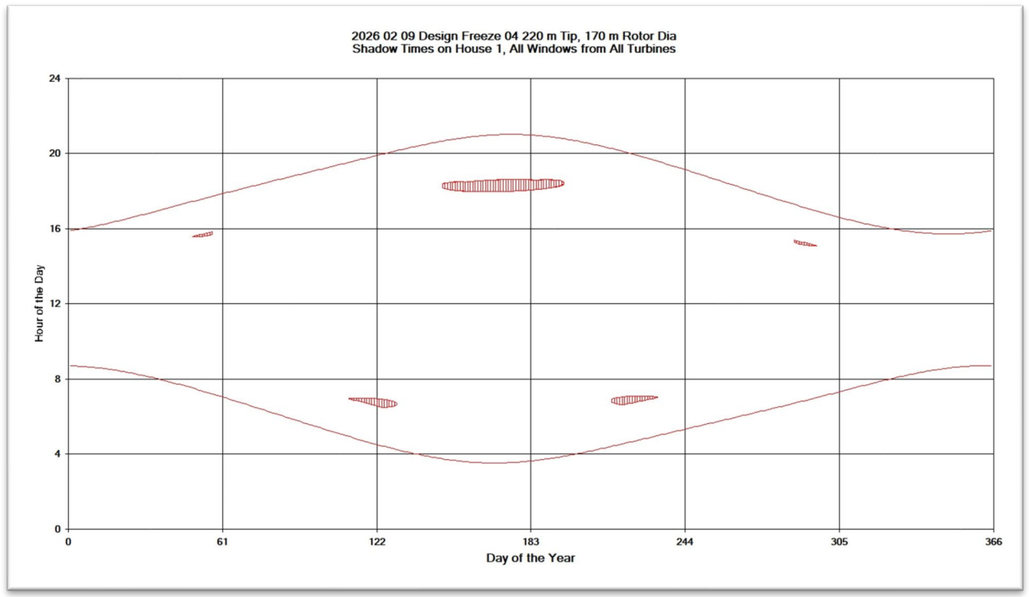
*Model Output*

1.3.16 For each property within the Study Area, the model predicted the number of days per year, maximum and mean minutes per day, and total hours per year (including an adjustment for sunlight) that the property would experience shadow flicker. A summary of model output is presented in **Table 12.5**, with the full output set out within **Annex B**.

1.3.17 In addition, the model has produced a graph illustrating the time of day and time of year shadow flicker effects could potentially arise for each property within the Study Area. An example graph for Property 1 (P1) is illustrated below in Graph 1.7.1.

[7] These are generic assumption and have not been verified in the field, but are considered to be a reasonable basis upon which to base an assessment to identify potential shadow flicker effects because the model assumes that the façade facing the turbines has an unobstructed line of sight to the turbines and that there are windows to habitable rooms on the façade of a size that could experience a flicker effect.

**Graph 1.7.1: Potential Shadow Flicker Effects at Property 1**




1.3.18 The area between the two red lines in **Graph 2.5.1** represents daylight hours over the course of a calendar year (calculation year 2026). The red circular areas represent times when the shadow flicker effects as a result of the Proposed Development could potentially occur at this property. A similar graph for each receptor that is predicted to experience shadow flicker effects is provided in **Annex B**.

*Limitations and Assumptions*

1.3.19 A number of worst-case assumptions were made to generate the modelling output for the appraisal. It should also be noted that even if shadow flicker effects occur at a specific location, this does not imply that it would be witnessed. Potential receptors may be occupying a room on the other side of the house, or indeed absent from the location altogether (e.g., at work) during the times of the shadow flicker effects.

1.3.20 The use of these assumptions is considered to provide a precautionary basis for the purpose of this appraisal.

1.3.21 The instances of shadow flicker would always be less than that predicted by the model. The occurrence of shadow flicker is only possible during the operation of the wind turbine (i.e., when the rotor blades are turning, excluding times when wind speeds are below the cut-in threshold, or during maintenance and shutdown periods) and when the sky is clear enough for the sun to cast strong shadows.

1.3.22 It is important to consider the following facts when making an assessment:

- Climatic conditions dictate that the sun is not always shining. Met Office data gives average annual sunshine hours for the west of Scotland to be 29% of total daylight hours[8], based on climate data from 1981 to 2010. Cloud cover during other times may obscure the sun and prevent shadow flicker occurrence. While some shadow may still be cast under slightly overcast conditions, no shadow at all would be cast when heavy cloud cover prevails.
- Objects such as trees or walls may surround windows and obscure the view of the turbine and hence prevent or limit shadow flicker.
- During operation, the turbine rotors would automatically orientate themselves to face the prevailing wind direction. This means the turbine rotors would not always be facing the affected receptor and in fact would sometimes be 'side-on' to the receptor. Very little of the blade movement would be visible during such occurrences and therefore the potential for shadow flicker is reduced.

### Cumulative Assessment

1.3.23 Based upon a review of cumulative schemes, specifically Clyde Wind Farm, no properties identified as sensitive to shadow flicker from the Proposed Development are located within 11 RDs of any cumulative schemes. Therefore, no cumulative assessment was deemed necessary for the shadow flicker assessment.

## 1.4 Baseline Conditions

### Current Baseline

1.4.1 The desk study identified five properties within the Study Area, the locations of which are shown on **Figure 2.5.1 (Annex A)**:

- Property (P) 1 – Waterhead Toll (E 288843, N 618151) located approximately 0.5 km southeast of Turbine 2;
- P2 – New Glendorch (E 288800, N 617739) located approximately 0.8 km southeast of Turbine 2;
- P3 – North Shortcleugh Farm (E 292810, N 616351) located approximately 0.9 km southeast of Turbine 16;
- P4 – South Shortcleugh Farm (E 292832, N 616731) located approximately 1.3 km southeast of Turbine 16; and
- P5 – Kirkton Farm (E 293277, N 621076) located approximately 1.6 km northeast of T10

1.4.2 P3 is financially involved in the Proposed Development. Notwithstanding this, the property is still considered as part of the shadow flicker appraisal.

### Future Baseline

1.4.3 If a new property were to be constructed within the Study Area during the operational phase of the Proposed Development, this would create a potential new shadow flicker receptor. No consented or proposed residential developments have been identified within the Study Area on the South Lanarkshire Council Planning Portal at the time of writing (February 2026).

1.4.4 In addition, if any of the existing properties within the Study Area were modified, for example, a new window or door was installed, or the property is extended, this could alter the individual property's sensitivity to shadow flicker. No consented or proposed planning applications to modify existing properties within the Study Area have been identified on the South Lanarkshire Council Planning Portal.

1.4.5 No further changes to the shadow flicker baseline are anticipated.

### Summary of Sensitive Receptors

1.4.6 A summary of the receptors considered likely to be affected by shadow flicker from the Proposed Development and therefore scoped into the EIAR are set out in **Table 1.7.2.**

[8] Calculated based on figures available at https://www.metoffice.gov.uk/public/weather/climate/ [accessed October 2025]

| Table 1.7.2: Summary of Sensitive Receptors | | |
|---|---|---|
| **Receptor** | | **Justification** |
| P1 – Waterhead Toll | Residential property | Located within 1.7 km and within 130 degrees either side of north of a turbine |
| P2 – New Glendorch | Residential property | |
| P3 – North Shortcleugh Farm | Residential property | |
| P4 – South Shortcleugh Farm | Residential property | |
| P5 – Kirkton Farm | Residential Property | |

## 1.5 Potential Effects

1.5.1 A summary of the outputs from the shadow flicker model for the Proposed Development are detailed in **Table 1.7.3**.

| Table 1.7.3: Summary of Model Output | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Receptor** | **Easting** | **Northing** | **Shadow Flicker Predictions** | | | | |
| | | | **Days per Year** | **Max Minutes per Day** | **Mean Minutes Per Day** | **Total Hours per Year** | **Total Hours per Year (incl. adjustment for sunlight)*** |
| P1 | 288843 | 618151 | 107 | **37.8** | 21.0 | **37.3** | 10.8 |
| P2 | 288800 | 617739 | 117 | **33.0** | 25.8 | **49.9** | 14.5 |
| P3 | 292810 | 616351 | 80 | 24.0 | 13.2 | 17.5 | 5.1 |
| P4 | 292832 | 616731 | 56 | 27.6 | 21.0 | 19.7 | 5.7 |
| P5 | 293277 | 621076 | 56 | 27.6 | 19.2 | 17.9 | 5.2 |
| **The Met Office data shows that the west of Scotland receives an average of 29% sunshine of the total daylight hours annually. This percentage is applied to total annual hours column to estimate the expected total sunshine hours for the year.* *Grey highlighted cells represent where the assessment indicates that the potential number of shadow flicker hours experienced at the receptor exceeds 30 hours per year (based on adjustment for sunlight) and/or 30 minutes per day.* | | | | | | | |

1.5.2 The modelling indicates that all five properties located within the Study Area could be subject to shadow flicker from the proposed turbines.

1.5.3 P3, P4 and P5 would experience acceptable levels of shadow flicker in accordance with the criteria described above, whereby shadow flicker levels at these properties would be less than 30 minutes per day and 30 hours year (inclusive of adjustment for sunlight).

1.5.4 The impact of shadow flicker on P1 and P2 would be greater than 30 minutes per day but less than 30 hours per year (inclusive of adjustment for sunlight). As such, the impact of shadow flicker on P1 and P2 may be significant in terms of daily exposure but would be below the threshold of what is considered acceptable in terms of yearly total.

1.5.5 It should be emphasised that this analysis provides a reasonable worse case estimate of the extent to which properties would experience effects in relation to shadow flicker. In addition to the frequent cloud cover (which is factored into **Table 1.7.3)**, the actual amount of shadow flicker affecting properties would be further reduced by low irradiance intensity, by the turbines not turning at all times and by the turbine rotors not being aligned with the sun in a way to cast maximum shadow onto the relevant property.

## 1.6 Mitigation

1.6.1 Two receptors would potentially be affected by shadow flicker as a result of the Proposed Development.

1.6.2 The Applicant proposes that prior to the erection of the first turbine, a Wind Farm Shadow Flicker Protocol would be submitted to and approved in writing by the Local Planning Authority. This would set out the protocol to be followed should a shadow flicker complaint be received from a receptor within the Study Area and the potential mitigation measures. These mitigation measures may include the provision of internal or external screening at the property of the complainant, or programming of the turbines to reduce effects. Operation of the Proposed Development would be undertaken in accordance with the Wind Farm Shadow Flicker Protocol. The requirement for the Wind Farm Shadow Flicker Protocol would be secured through a Condition attached to the consent.

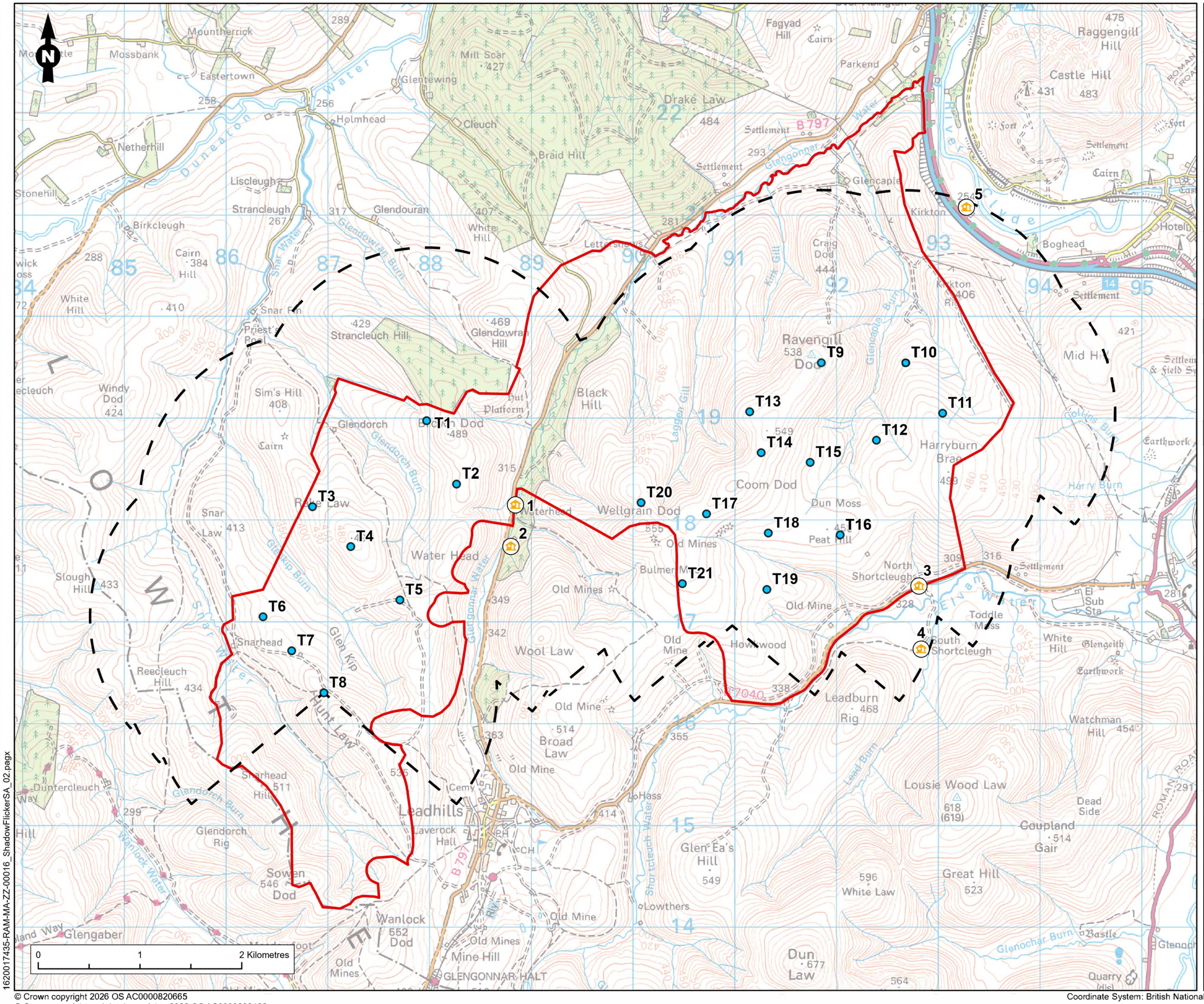
## 1.7 Summary

1.7.1 Two receptors would potentially be affected by shadow flicker as a result of the Proposed Development; Waterhead Toll Cottage and New Glendorch. However, mitigation is proposed in the form of a Wind Farm Shadow Flicker Mitigation protocol and it is considered that potential impacts could be reduced to an acceptable level.

| Table 1.7.4: Summary of Potential Effects and Mitigation | | | |
|---|---|---|---|
| **Description of Potential Effect** | **Description of Mitigation** | **Timing of Mitigation** | **Consultation or Approval Required** |
| Potential operational shadow flicker effects on residential receptors | Wind Farm Shadow Flicker Protocol to be submitted and approved by the LPA ahead of the erection of the first turbine.<br>This would set out the protocol that would be followed should a shadow flicker complaint be received from a receptor within the Study Area.<br>Mitigation measures may include the provision of internal/ external screening at the property of the complainant, or programming of the turbines. | Pre-construction Operation | Yes |

# Annex A – Figures

Figure 1.7.1: Shadow Flicker Survey Area




## Legend

- Site Boundary
- Study Area (10X Rotor Diameter)
- Turbine Layout
- Residential Receptor

| | |
|---|---|
| Figure Title | Shadow Flicker Study Area and Receptors |
| Project Name | Ravengill Energy Park |
| Project No./Filery ID | 1620017435 / REH2024N04129 |
| Date | February 2026 |
| Figure No. | TA 1.7.1 |
| Revision | 1.0 |
| Prepared By | RD |
| Scale | 1:35,000 @A3 |
| Client | **Ravengill Energy Park Limited** |

RAMBOLL

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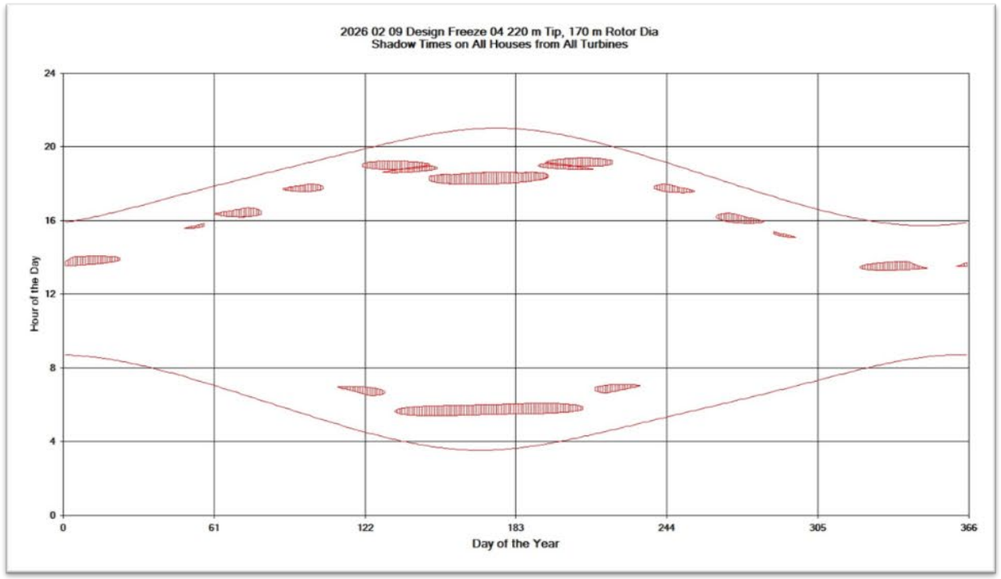
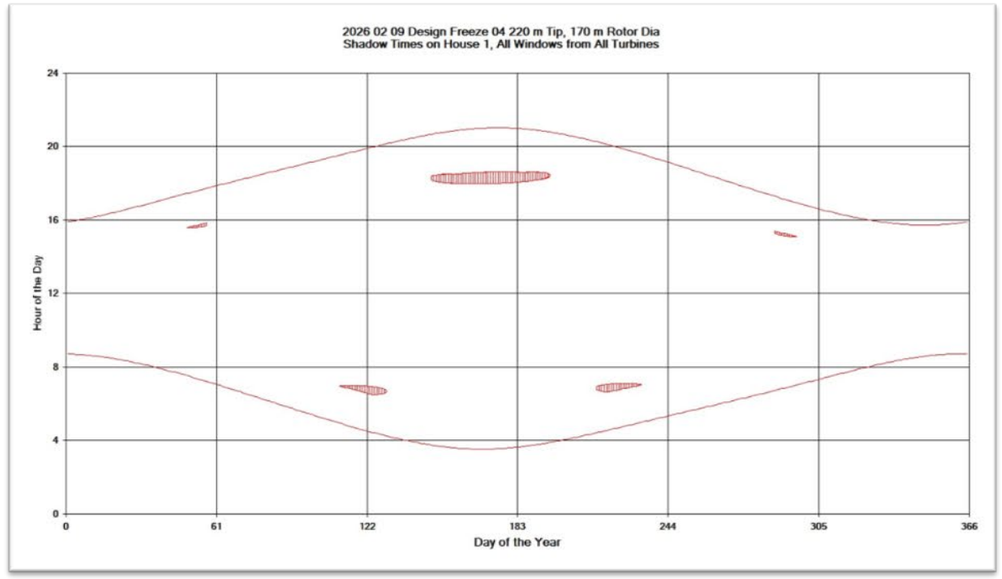
Coordinate System: British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936.

## Annex B – Shadow Flicker Modelling Results







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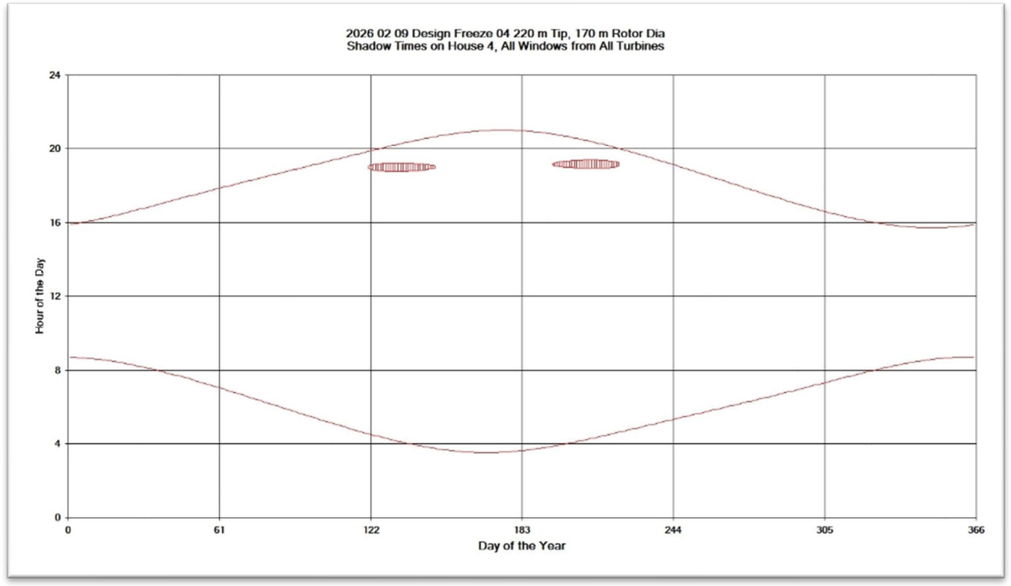
2026 02 09 Design Freeze 04 220 m Tip, 170 m Rotor Dia
Shadow Times on House 4, All Windows from All Turbines
Hour of the Day
0
4
8
12
16
20
24
0
61
122
183
244
305
366
Day of the Year