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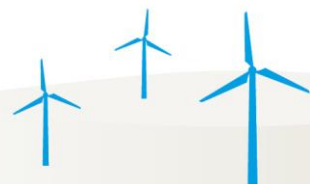
Balgray Wind Farm

Chapter 15: Other Issues

June 2025

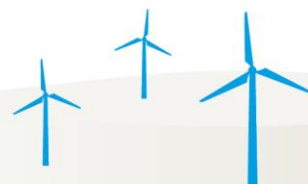
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List of Abbreviations

Abbreviation	Description
DTM	Digital Terrain Model
CTBT	Comprehensive Nuclear-Test-Ban Treaty
ECZ	Eskdalemuir Consultation Zone
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EKA	Eskdalemuir Seismic Array
m	metres
MoD	Ministry of Defence
RD	Rotor Diameter
rpm	revolutions per minute
RVAA	Residential Visual Amenity Assessment
SIL	Seismic Impact Limit



15. Other Issues

15.1. Introduction

- 15.1.1. This Chapter outlines the potential for effects relating to the Proposed Development on or from ice throw, shadow flicker and the Eskdalemuir Seismic Array (EKA). The findings of these studies are summarised here.
- 15.1.2. **Ice Throw:** In specific weather conditions, blade icing can occur on stationary turbines, which when turbines become operational again, can cause ice to be 'thrown' from the blades. Careful siting of turbines, coupled with sensors to control shutdown of turbines, ensures that the risk of ice throw is negligible.
- 15.1.3. **Shadow Flicker:** Shadow flicker guidance indicates that shadow flicker can occur at properties within 10 rotor diameters of wind turbines, located 130 degrees either side of north. A Shadow Flicker assessment confirms that shadow flicker events may occur at six properties in proximity to the site should conditions allow, but that these events are expected to have a negligible impact.
- 15.1.4. **Seismic Vibration affecting Eskdalemuir Seismic Array (EKA):** The proposed development lies within the Ministry of Defence's 50 km Consultation Zone, approximately 19.5 km from the Eskdalemuir Seismic Array. The site has been assessed by Xi Engineering Consultants to ensure it remains compliant with the MOD's cumulative 0.336 nm vibration threshold.

15.2. Ice Throw

- 15.2.1. This section will describe ice throw and consider its risk and mitigation in relation to the Proposed Development.
- 15.2.2. Blade icing is a rare occurrence that will only happen when the blades of the turbine are stationary and under near freezing temperatures and relatively high humidity, with either freezing rain or sleet. If these certain climatic conditions cause icing to occur, once operation recommences, the operational motion of the turbine blades and the forces of gravity can cause the ice to break off and fall vertically to the ground.
- 15.2.3. The risk of ice throw is dependent on the local climate and weather conditions in which the wind turbines are situated. Increases in temperature, wind speed and solar radiation can cause the ice to loosen and fall. This makes the area under the turbine the area of the greatest risk. Dependent on the conditions, there is the potential for the blades to propel the ice up to several hundred meters when they commence operation.
- 15.2.4. Siting the turbines away from occupied buildings, roads and public areas can mitigate the risk, and this has been done as far as is practical with the Proposed Development. There are specific sensors that identify the likeliness of the



climatic conditions that cause icing, so if ice accumulation is expected or occurs the turbines are shut down. This works when icing on the blades results in reduced performance, unusual loads, and/or vibrations. These are then detected by a control system and trigger an automatic shutdown of the turbine. Project operators use these detection systems to halt operation of certain turbines during icing events to prevent ice throws and equipment damage, and, in these cases, the turbine remains off-line until an operator visually inspects and manually restarts the turbine when the blades are clear of ice.

- 15.2.5. Modern turbines which are fitted with climatic detection systems like the ones being considered for the Proposed Development will help to mitigate against the potential occurrence of ice throw. As highlighted in Chapter 3: Description of Development, turbine procurement together with good practice site management procedures, including the use of visual warnings signs and restricted access to turbines where ice is present on blades, will mitigate and manage this potential hazard.
- 15.2.6. No significant residual effects are expected following the implementation of the proposed mitigation measures.

15.3. Shadow Flicker

Introduction

- 15.3.1. This section of the Environmental Impact Assessment Report (EIAR) considers the potential for shadow flicker to occur at neighbouring properties due to the operation of the Proposed Development, as described in Chapter 3 of this EIAR: Description of Development. The layout of the Proposed Development has been designed to avoid the potential for shadow flicker occurrence as far as practicable in light of other constraints.
- 15.3.2. “Shadow flicker” refers to when rotating wind turbine blades periodically cast a temporary shadow over neighbouring properties (typically through constrained openings such as windows). The magnitude of the shadow flicker effect varies in relation to the relative location of the receptors and time of day/year, as well as also depending on several environmental conditions such as the position and height of the sun, wind speed and direction, and cloudiness. It is most likely to occur when the sun is low in the sky and shines on a building from behind a turbine rotor. As the shadow from the turbine is most pronounced in these periods, this can cause the shadow of the turbine blades to be cast onto the building, which appears to flick on and off as the turbine blades rotate. When this flicking shadow is viewed through a narrow opening it is known as shadow flicker. The magnitude of the shadow flicker effect therefore varies spatially and temporally.
- 15.3.3. It is important to note that not all properties within the potentially affected area will experience shadow flicker. In order for it to occur, the weather must be sunny, and the blades must also be rotating. The effect is also reduced if the



turbine rotors are perpendicular to the location experiencing flicker, since the turbines turn to face into the wind when operating. Vegetation such as trees or hedgerows or intervening buildings, and indeed topography, may also have a screening effect.

- 15.3.4. It is possible to calculate the number of hours per year that shadow flicker may occur at a building from the relative position of the turbine to the building, the geometry of the wind turbine, the latitude of the wind farm site and the width of the windows potentially affected. The specialist computer software 'Resoft Windfarm' has been used to quantify the levels of potential shadow flicker associated with the Proposed Development.
- 15.3.5. The turbines of the Proposed Development are expected to operate at around 6 to 14 revolutions per minute (rpm). Given each turbine will have three blades, the frequency at which a blade will pass a particular point will be in the order between 18 and 42 times per minute, which equates to between 0.3 and 0.7 flickers per second (hertz). This is significantly less than the 2.5 and 30 hertz frequency range generally thought to induce photosensitive epilepsy¹. The issue of photosensitivity epilepsy to potential users of the site upon which the Proposed Development is sited, or nearby residents, is not therefore considered further in this assessment, as there are unlikely to be any predicted adverse health effects.
- 15.3.6. There are no shadow flicker effects during the construction or decommissioning of a wind farm, as it only has potential to occur whilst the wind turbine blades are rotating.

Legislation, Policy and Guidance

- 15.3.7. There is no specific standard for the assessment of shadow flicker in the UK and no guidelines on acceptable levels of shadow flicker. However, the Office for the Deputy Prime Minister published 'Planning for Renewable Energy, A Companion Guide to PPS22' (most recently updated in 2014), which states:

"Under certain combinations of geographical position and time of day, the sun may pass behind the rotors of a wind turbine and cast a shadow over the neighbouring properties. When the blades rotate, the shadow flicks on and off; the effect is known as 'shadow flicker'. It only occurs inside 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 site."

¹ National Society for Epilepsy. (2002). Information on Epilepsy: Photosensitive Epilepsy.



“Shadow flicker can be mitigated by siting wind turbines at sufficient distance from residences likely to be affected. Flicker effects have been proven to occur only within ten rotor diameters of a turbine.”

“Only properties within 130 degrees either side of north, relative to the turbines can be affected at these latitudes in the UK – turbines do not cast long shadows on their southern side.”

- 15.3.8. The assessment set out herein has been based on a 10x rotor diameter distance as set out above.
- 15.3.9. While there are currently no UK guidelines which quantify what exposure levels of shadow flicker are acceptable, Predac, an EU sponsored organisation that promotes best practice in energy use and supply, suggests that a maximum of 30 hours of shadow flicker in any calendar year is acceptable for properties within 500 m of a turbine position².
- 15.3.10. Dumfries and Galloway Council Local Development Plan 2 Wind Energy Development: Development Management Considerations³ published in 2020 sets out supplementary guidance for the development management considerations in Policy IN2: Wind Energy.
- 15.3.11. Development Management Consideration E states that *‘the extent of any detrimental impact on communities, individual dwellings, residents and local amenity, including assessment of the impacts of noise, shadow flicker, visual dominance and the potential for associated mitigation’* must be evaluated, with specific evaluation of shadow flicker as follows:

E14 *‘Shadow flicker’ occurs when low sunlight falls behind the rotating blades of a turbine. The effect of alternate light and shade can cause distraction and annoyance and is more strongly experienced where narrow windows concentrate the effect and/or where the turbine is in close proximity to the viewer (‘receptor’). The potential for shadow flicker depends on the specific alignment of the sun, site and receptor (viewer) and needs to be assessed on a case-by-case basis. It does not occur at night or when the sun is obscured and is likely to be restricted to certain times of day and the year.*

E15 *Mitigation; Maintaining a separation distance of at least 10 times the turbine rotor blade diameter from sensitive uses/receptors can help reduce the effects but this may need to be extended depending on specific locational circumstances. Careful siting of turbines can reduce or eliminate most instances of shadow flicker and of instances where sunlight reflects of the blades (usually*

² Predac (2004). Spatial Planning of Wind Turbines.

³ Dumfries and Galloway Council (2020). Local Development Plan 2 Wind Energy Development: Development Management Considerations. Available here: https://www.dumfriesandgalloway.gov.uk/sites/default/files/2025-05/Wind-Energy-SG-Final-PDF-2025-Version_0.pdf. Accessed 21/02/2025.



only seen when the blades are wet and the sun is at a particular angle in relation to the viewer). Developers should demonstrate that these aspects have been properly considered and addressed as far as is practicable (this could include proposals to limit turbine use at identified particularly sensitive times of the day/year).

Methodology

- 15.3.12. As the effects of shadow flicker can be calculated in a quantitative manner, it is not necessary to define sensitivity or magnitude of change as set out in the EIA methodology in Chapter 4: Approach to Environmental Impact Assessment Report. Therefore, this methodology has not been followed in this chapter.
- 15.3.13. Specialist software 'Resoft Windfarm' has been used to quantify the extent of shadow flicker that could occur within a study area of 10 times rotor diameter plus a 50m micro-siting allowance. This model accounts for the latitude and longitude of the Proposed Development and uses a model of the sun's position in the sky throughout the year to calculate shadow lengths, positions and times. A 5 metre (m) Digital Terrain Model (DTM) was also used in the assessment to take account of the topography between receptors and turbines. This assessment does not take into consideration the effect of any woodland screening therefore is considered worst case.
- 15.3.14. The assessment study area was defined as the area over which shadow flicker effects could impact residential properties (i.e. within 10 rotor diameters of each turbine). Given the parameters of the Proposed Development described in Chapter 3 of this EIAR: Description of Development, a buffer radius of 1670m was applied to each turbine location to determine the overall study area, which is shown in Figure 15.1. This is based on a maximum 162m rotor diameter x10, plus an additional 50 m proposed micro-siting allowance.
- 15.3.15. Following the results of the calculations, and due to the lack of specific standards or guidelines for shadow flicker as referenced in 15.3.7, professional judgment is then applied in light of predictions as to the extent of any shadow flicker which is expected to arise.

Baseline Environment - Residential

- 15.3.16. Based on the guidance set out above, a shadow flicker impact assessment has been carried out on the nearest sensitive receptors to the Proposed Development. These are shown relative to the proposed turbine location in Figure 15.1. It should be noted that the distances provided refer to the closest part of the dwelling excluding garden areas. As set out above shadow flicker is only expected to occur within buildings so the amenity areas have been excluded.



Table 15.1: Residential properties considered in the assessment

Property	Name of location	Easting	Northing	Distance from nearest turbine (m)
R1	Hutton Lodge	316482	589746	1103
R2	Hallhills Farm	314975	587984	1386
R3	Little Millriggs	316971	590087	1480
R4	Stobohill	3187690	587781	1405
R5	Gall Farm	317177	590076	1533
R6	Corsehill	317814	589644	1553
R7	Heithat Park	318108	589404	1540
R8	Gall House	317347	590094	1619
R9	Nether Hutton	316222	589792	1207
R10	River House	315949	589933	1445

15.3.17. Ten properties are shown to have their curtilage within 1620m of the proposed turbines (Table 15.1). An assessment has been undertaken to understand if shadow flicker may occur at any location within these properties.

Embedded Mitigation

15.3.18. The evolution of the design of the Proposed Development has resulted in a significant reduction in the number of turbines proposed from those originally considered (see Chapter 2: Site Selection and Design Evolution). Through this reduction in the number of turbines and the layout of the final design, potentially significant effects on receptors have largely been avoided. This has resulted in a reduction in the number of properties potentially affected by shadow flicker.

Assessment of Effects

15.3.19. The effect of shadow flicker can be assessed using specialist software. This software models the shadow flicker from the following geometric considerations:

- The position of the sun at a given date and time;
- The size and orientation of the windows that may be affected; and,
- The size of the proposed turbines that would cast the shadow.

15.3.20. A shadow flicker assessment was undertaken using Resoft's Windfarm software to demonstrate the extent of shadow flicker in the area assuming worst-case assumptions. The output map is shown in Figure 15.2 for the Proposed Development. The contours mark the number of hours of potential impact to an individual window at 2m above ground level. Each contour represents 20 hours of worst-case shadow flicker events per annum.



15.3.21. The calculated flicker events are detailed in Table 15.2 below.

Table 15.2: Details of theoretical shadow flicker events

Property	No of shadow flicker events (days)	Maximum length of event (hours/day)	Average length of event (hours/day)	Total per year (hours)
R1	19	0.39	0.25	4.8
R2	40	0.5048	0.40	15.9
R3	0	0.00	0.00	0
R4	30	0.49	0.39	11.6
R5	0	0.00	0.00	0.0
R6	69	0.46	0.31	21.1
R7	78	0.47	0.34	26.1
R8	0	0.00	0.00	0.0
R9	33	0.41	0.33	10.9
R10	0	0.00	0.00	0.0

15.3.22. Figure 15.3 illustrates the shadow flicker events throughout the year at the impacted properties which shows that the potential shadow flicker events occur at 6am, 10am and between 2pm-6pm for a period between January and early April, and then again at 6am, between 10am-midday and between 0am-6pm for a period between August and December.

15.3.23. These results are worst case, and the actual instances of shadow flicker should be less than those predicted by the model. Shadow flicker only occurs under specific conditions during the operation of a wind farm (i.e. when the rotor blades are turning, and when the sky is clear enough to cast shadows). It is important to take account of the following worst-case assumptions used when considering this assessment:

- There are no obscuring features around the property which would minimise views of the development and hence reduce or eliminate the potential for shadow flicker;
- Daylight hours consist of 100% sunshine; and,
- The wind direction is always parallel with the line between the sun, the turbine and the window in question (which means the turbine will always be facing the house). When the wind is from another direction the turbine blades move to face the wind. This will reduce the extent of shadows falling in the direction of the window.



15.3.24. Consideration of the above assumptions mean the results of the shadow flicker model represent a theoretical assessment of shadow flicker. Actual shadow flicker effects at the properties will be greatly reduced because:

- A house can be partially screened by vegetation;
- Daylight hours would typically experience 30 – 35 % sunshine rather than 100%;
- The hours when the wind is blowing in a line between the turbines and the house will be considerably less than 100% and will not necessarily coincide with daylight hours; and,
- Shadow flicker will only be an issue when the blades of turbines are roughly perpendicular to the line between the house and the sun – this will occur when the wind is parallel to the line between the house and the sun. The shadow flicker model assumes that the wind direction is such that the extent of shadow flicker is maximised at all times.

15.3.25. Based on these factors, it is considered that the maximum number of hours of theoretical shadow flicker at the impacted houses (accounting for the 30-35% sunshine during daylight hours) would be as shown in Table 15.3.

Table 15.3: Predicted shadow flicker impact (adjusted for reduced sunshine)

Property	Total per year (hours)
R1	1.4 - 1.7
R2	4.8 - 5.6
R4	3.5 - 4.1
R6	6.3 - 7.4
R7	7.8 - 9.1
R9	3.3 - 3.8

15.3.26. There are currently no UK guidelines which quantify what exposure levels of shadow flicker are acceptable however, Predac, an EU sponsored organisation that promotes best practice in energy use and supply, suggests that a maximum of 30 hours of shadow flicker in any calendar year is acceptable for properties within 500 m of a turbine position⁴. The effect of shadow flicker on the six properties modelled to be affected (Hutton Lodge, Hallhill Farm, Stobohill, Corsehill, Heithat Park and Nether Hutton) is therefore considered not significant in terms of the EIA Regulations.

⁴ Predac (2004). Spatial Planning of Wind Turbines.



Mitigation and Monitoring

- 15.3.27. No routine mitigation is proposed; this will however be kept under review during the operation of the Proposed Development in case particular combinations of circumstances arise that increase the potential for disturbance (particularly where rooms affected are in regular occupancy and the effect proves to be a frequent occurrence).
- 15.3.28. Where issues arise, mitigation measures such as standard shadow flicker controllers can be installed on turbines to shut them down when all parameters needed to cause shadow flicker are present, thereby eliminating the problem.

Residual Effects

- 15.3.29. There are no predicted residual effects. Shadow flicker occurrence will be kept under review during the operational stage of the Proposed Development and mitigation measures will be applied to remove the effects of any shadow flicker occurrence if necessary.

Cumulative Effects

- 15.3.30. There are no proposed wind farms that have a combined shadow flicker study area with the Proposed Development; therefore, there will be no cumulative effects from shadow flicker.

Summary of Assessment

- 15.3.31. A shadow flicker analysis has been undertaken for 10 properties present within the study area (Table 15.1). Of the 10 properties under consideration, four are not expected to experience shadow flicker events following the modelling exercise undertaken. It has been shown that for worst case conditions, the maximum occurrence of shadow flicker is predicted to be between 6.9 - 26.1 hours per year. Taking the expected number of sunshine hours into account, it is predicted that in a more realistic scenario shadow flicker would only occur at these properties for a maximum 2.4 – 9.1 hours per year.
- 15.3.32. However, it should be noted that the actual amounts of shadow flicker is expected to be significantly less than the model has predicted, due to local screening effects, the fact that the blades may not be orientated in a direction that causes shadow flicker or may not be moving during the hours when there is potential for shadow flicker to occur (see section 15.3.21).
- 15.3.33. It has been demonstrated that the frequency at which shadow flicker might occur at the affected properties (up to 1 hertz) is significantly less than the frequency at which photosensitive epilepsy is usually triggered (between 2.5 and 30 hertz). While some people are sensitive at higher frequencies, it is uncommon to have photosensitivity below 2.5 hertz. It is therefore considered that shadow flicker from the Proposed Development will have no adverse health effects.



15.4. Eskdalemuir Seismic Array (EKA)

Introduction to Eskdalemuir

- 15.4.1. The Balgray Wind Farm lies approximately 19.5 km from the Eskdalemuir Seismic Array and sits within the Ministry of Defence's 50 km Consultation Zone. The Eskdalemuir Array is a critical national defence asset forming part of the UK's obligations under the Comprehensive Nuclear-Test-Ban Treaty (CTBT). It is protected from seismic interference by a cumulative vibration threshold of **0.336 nanometres (nm)**, applied to all developments within the zone.
- 15.4.2. Historically, this threshold has been safeguarded using a conservative 2014 predictive model co-authored by Xi Engineering Consultants. This model was based on limited data and was intentionally cautious but is now acknowledged to **over-estimate turbine vibration** — a fact confirmed by the MOD's own 2025 consultation.
- 15.4.3. Since 2020, the **Scottish Government, the MOD, and industry stakeholders** have worked to develop a more accurate and equitable safeguarding strategy based on **empirical, real-world measurements**. This approach, which reflects modern turbine performance, has been endorsed by the UK Government's Onshore Wind Taskforce and RenewableUK.
- 15.4.4. To ensure fair allocation of the seismic budget, the Scottish Government and industry have also introduced the **Seismic Impact Limit (SIL)**, a per-turbine emission limit scaled by turbine capacity and distance from the array. This approach is supported across national policy groups and is now recognised as the basis for future consenting decisions in the region.
- 15.4.5. The UK Government's Onshore Wind Strategy, published on 4 July 2025, confirms a commitment to implementing an enduring solution for the EKA. Specifically, Action 30 mandates collaboration between DESNZ, the Scottish Government and the MoD to develop a technical solution that enables onshore wind development within the EKA while maintaining protection of the Array. This work will include consultation on the SIL which underpins the mathematical analysis forming the basis for site viability. The solution assumes adoption of the revised SIL. Government guidance, expected to be finalised by the end of 2025, will bridge the timing gap ahead of dedicated legislation, making the approach robust enough for the MoD to lift its objection without having to wait for the full legislative process to conclude.

Balgray Assessment and Results

- 15.4.6. A full technical analysis of the Balgray Wind Farm was carried out by **Xi Engineering Consultants**, the UK's leading experts on wind turbine seismic impact and original co-authors of the 2014 algorithm (Technical Appendix 15.1). Their analysis used:



- Empirical turbine emission data;
- A queue-based SIL budgeting approach;
- A standardised before-and-after seismic monitoring protocol;
- And all proposed SIL thresholds from 1.0 GW to 2.5 GW.

15.4.7. The modelling confirmed that **Balgray remains within the MOD's 0.336 nm cumulative limit under all SIL queue scenarios**, provided that standard monitoring and turbine selection strategies are adopted.

15.4.8. Several turbine models have been identified that **can be deployed without mitigation**, particularly where background noise is accounted for through before-and-after measurement. Should mitigation ever be required, Balgray has retained the flexibility to implement industry-standard techniques such as foundation isolation or time-based curtailment.

Conclusion

15.4.9. The Eskdalemuir safeguarding strategy proposed for Balgray is:

- Aligned with the latest MOD, Scottish Government, and UK Government policy developments;
- Backed by Xi Engineering's empirical analysis and national working group recommendations;
- Structured around **real-world data and proven safeguards**;
- And designed to ensure that the development can proceed **without adversely affecting the Eskdalemuir Seismic Array**.

15.4.10. Balgray stands as a model for how responsible wind energy development can be achieved in sensitive areas and should be considered consentable on both technical and policy grounds.





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