Preliminary Environmental Information Report

Calderdale Energy Park

7 April 2026

Volume 2, Chapter 21 : Shadow Flicker
PINS Reference: EN0110023
Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 – Reg 5 (2) (a).

Calderdale energy park

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21 Shadow Flicker

21.1 Introduction

21.1.1 The Chapter has been prepared by TNEI Services Ltd on behalf of the Applicant and presents the preliminary likely significant effects of the Proposed Development from Shadow Flicker. It is based on the environmental information available to date (which is detailed in this Chapter), as well as the current description of the Proposed Development as set out in **Chapter 4: The Proposed Development**.

21.1.2 This Chapter of the Preliminary Environmental Information Report (PEIR) concludes there are no preliminary likely significant environmental effects of the Proposed Development from Shadow Flicker during the construction, operation and maintenance and decommissioning phases.

21.1.3 The concepts of 'Shadow Flicker' and 'shadow cast' must be properly understood at the outset of this Chapter, as they are two distinct phenomena, with strict definitions and interpretations. It is also useful to consider the impact of shadow density when considering the effects of shadows cast from turbines.

21.1.4 This Chapter is supported by:

- **Appendix 21-1: Predicted Shadow Flicker Events (Example)**; and
- **Appendix 21-2: Consideration of Public Rights of Way**.

21.1.5 Supporting Figures can be found at:

- **Figure 21-1: Calculation of Required Study Areas**;
- **Figure 21-2: Calculated Study Area and Assessment Area**;
- **Figures 21-3: Shadow Flicker Assessment Locations (SFALs)**; and
- **Figures 21-4**: Cumulative Assessment.

Shadow Flicker

21.1.6 The phenomenon that occurs inside a room when shadows from turbine blades pass across a window aperture. Shadow Flicker causes the light levels within the room to rapidly switch between two values. The phenomenon occurs only within buildings where shadows are cast across a window aperture and the intensity of the Shadow Flicker (i.e. the difference between the two light levels) will vary depending on:

- The size of the window;

- The proportion of window covered by the moving shadow;
- The density of the shadow (i.e. the proportion of the sun covered by the turbine blade); and
- The presence of other light sources (e.g. other windows or lights)

21.1.7 Shadow Flicker can be modelled using industry standard software, such as WindFarm or WindPro, such that every potential occurrence and duration of Shadow Flicker at any given Shadow Flicker Receptor throughout any time period can be calculated. The effects of Shadow Flicker are typically considered up to a distance of 10 times the rotor diameter from each wind turbine. Shadow Flicker can occur beyond this distance, however, the density of the shadow is reduced as the distance from the turbine increases. Accordingly, the intensity of the Shadow Flicker will also be reduced as the distance increases.

Shadow Cast

21.1.8 In contrast to Shadow Flicker, shadow cast occurs outdoors and refers to the shadow that is cast on the ground or on other objects. It is modelled using the same software used for modelling Shadow Flicker and is often modelled alongside Shadow Flicker to give a visual representation of how turbines cast shadows across the landscape. Shadow cast itself, however, is not something that is typically assessed in terms of its effects or impacts. It would be incorrect to assess shadow cast using Shadow Flicker assessment methodology.

Shadow Density

21.1.9 Although the extent, maximum daily occurrence, and total yearly hours that a shadow can be cast from a wind turbine can be modelled and plotted on a map, industry standard software does not consider shadow density. However, shadow density is an important consideration, referring to the intensity of the shadow as it reaches a Shadow Flicker Receptor. Both the density and the sharpness of a shadow decline with distance from the object casting the shadow, with an increasingly acute angle of the light source (the sun) to the Shadow Flicker Receptor also dissipating the shadow over a longer cast distance.

21.2 Legislation Policy and Guidance

21.2.1 There is no legislation in respect of Shadow Flicker in the UK. There are some national and local policies that provide some guidance, primarily in regard to defining study areas for assessment, but no limits or guideline thresholds are published within the UK. There is, however, some guidance available internationally, in respect of setting out guideline levels for exposure.

21.2.2 Key policy and guidance relating to Shadow Flicker that is of relevance to this preliminary assessment, is shown in **Table 21-1.**

Table 21-1: Legislation Policy and Guidance

Type	Name	Relevance to Assessment
National planning policy	NPS EN-1 (2025)[1]	NPS EN-1 is the overarching statement that sets out policy for energy NSIPs. It includes a list of direct impacts on health that may occur from energy infrastructure, such as noise or dust, however, it does not mention Shadow Flicker in this list and Shadow Flicker is not mentioned at all within the document.
	NPS EN-3 (2025)[2]	Policy Statement EN-3 is the primary decision-making policy document for the Secretary of State on nationally significant onshore renewable electricity generating stations in England and Wales. EN-3 provides the Secretary of State with guidance on what areas around wind turbines are susceptible to Shadow Flicker effects, as well as the distances (10 rotor diameters) beyond which there should not be significant Shadow Flicker impacts. In addition, EN-3 outlines how the Secretary of State should consider potential Shadow Flicker effects in decision making (paragraphs 2.12.166 – 2.12.168).
	NPPF (2024)[3]	While there is no specific reference to Shadow Flicker within the NPPF, Paragraph 135 refers to developments creating "*places that are safe, inclusive, accessible and which promote health and well-being, with a high standard of amenity for existing and future users…".*
	NPPF Plan-making and national	While there are no specific policies related to Shadow Flicker, Policy P3

[1] Department of Energy and Climate Change (DECC). (2025) Overarching National Policy Statement for Energy (EN-1). London: The Stationery Office
[2] Department for Energy Security and Net Zero (2025) National Policy Statement for Renewable Energy Infrastructure (EN-3). London: The Stationery Office.
[3] Ministry of Housing, Communities & Local Government (2024) National Planning Policy Framework. London: The Stationery Office.

Type	Name	Relevance to Assessment
	decision-making policies (consultation draft) (2025)[4]	Living Conditions and Pollution notes that developments should "*Be appropriate for their location taking into account the likely effects (including cumulative effects) of pollution on health, living conditions and the natural environment, as well as the potential sensitivity of the site or the wider area to impacts which could arise from the development*".
Local planning policy	Calderdale Local Plan 2018/19 – 2032/2033 (March 2023)[5]	Calderdale Council does not have specific guidance relating to Shadow Flicker in its adopted Local Development Plan (LDP).
	Local Plan for the Bradford District Core Strategy Development Plan Document (Adopted July 2017)[6]	The Bradford LDP outlines in Policy EN-6 that all renewable energy developments must include an assessment of the social impacts of the development, including an assessment of Shadow Flicker.
	Pendle Local Plan Fourth Edition 2021-2040 (the Local Plan) (Adopted December 2025)[7]	Pendle Council states in the LDP that a shadow flicker study may be required in support of a planning application for a proposed renewable and low carbon development, depending on its scale and location. However, Pendle Council does not have specific guidance outlining how Shadow Flicker should be assessed in its adopted LDP.
Guidance (International)	States Committee for Pollution Control - Nordrhein-Westfalen Notes	This document outlines the German limits for Shadow Flicker exposure under worst-case, and realistic-case conditions. Many countries that have limits for Shadow

[4] Ministry of Housing, Communities & Local Government (2025) National Planning Policy Framework. Plan-making and national decision-making policies. London: The Stationery Office.
[5] Calderdale Metropolitan Borough Council (2023) Calderdale Local Plan 2018/19–2032/2033.
[6] Bradford Council (2017) Core Strategy Development Plan Document. Bradford: Bradford Council.
[7] Pendle Borough Council (2025) Pendle Local Plan Fourth Edition (2021-2040) . Pendle: Pendle Borough Council.

Type	Name	Relevance to Assessment
	on the Identification and Evaluation of the Optical Emissions of Wind Turbines (2002)[8]	Flicker are based on the German requirements.
Guidance (England)	Planning practice guidance (PPG) for renewable and low carbon energy (2024)[9]	This document provides advice on the planning issues associated with the development of renewable energy, including Shadow Flicker.
	Parsons Brinckerhoff (prepared for the former Department of Energy and Climate Change) (2011) Update of UK Shadow Flicker Evidence Base[10]	This report is a literature review and summary of international guidance relating to Shadow Flicker.
Guidance (Scotland)	Onshore wind turbines: planning advice (2014)[11]	The advice offered in this document is relevant only to Scotland but included as a useful reference as the country within the UK that has seen the most significant onshore wind development in recent years. The document provides advice on what the Scottish Government considers to be an appropriate distance for considering Shadow Flicker effects, which provides useful context and aligns with advice contained in NPS EN-3.
Guidance (Local)	Assessment of Areas of Suitability for Wind Development in	This document states that, when considering areas suitable for wind turbines, Shadow Flicker was not considered as a constraint as modern

[8] States Committee for Pollution Control – Nordrhein-Westfalen (2002) Notes on the Identification and Evaluation of the Optical Emissions of Wind Turbines. Düsseldorf: States Committee for Pollution Control – Nordrhein-Westfalen.
[9] (Former) Department for Communities and Local Government (2013) Planning Practice Guidance for Renewable and Low Carbon Energy. London: The Stationery Office.
[10] Parsons Brinckerhoff (2011) Update of UK Shadow Flicker Evidence Base. Prepared for the Department of Energy and Climate Change. London: Department of Energy and Climate Change.
[11] Scottish Government (2014) Onshore wind turbines: planning advice. Edinburgh: The Scottish Government.

Type	Name	Relevance to Assessment
	Calderdale (2017)[12]	turbines are now equipped with the technology to be able to turn off when Shadow Flicker is predicted to occur.
	Renewable and Low Carbon Energy Study (2010)[13]	The Renewable and Low Carbon Energy Study commissioned by Pendle Council in 2010 referred to the Planning Policy Statement (PPS) 2 Companion Guide document in its assessment, which states that "*Shadow Flicker effects have been proven to occur only within ten rotor diameters of a turbine.*"

21.3 Scoping and Stakeholder Engagement

2025 Scoping Response

21.3.1 In September 2025, a request for a Scoping Opinion was submitted alongside a Scoping Report to the Planning Inspectorate (PINS) under the EIA Regulations. The Scoping Opinion forms the primary statutory basis for defining the scope of the EIA. **Table 21-2** presents the details of the PINS Scoping Opinion relevant to Shadow Flicker and confirms how these have been addressed within the proposed scope of assessment. This has included addressing comments from Calderdale Council.

Table 21-2: Consideration of PINS Scoping Response

Consultee	PINS ID	Summary of Scoping Opinion Response	Consideration within Scope of Assessment
PINS	3.13.1	The Inspectorate is content to scope out Shadow Flicker during the construction phase. However, consideration of potential Shadow Flicker during the end of the construction phase is required.	The potential for Shadow Flicker to occur during the construction phase will be limited to the commissioning period only. If Shadow Flicker were to occur during commissioning then the effects would be the same as during the operation and

[12] LUC (2017) Assessment of Areas of Suitability for Wind Development in Calderdale. London: Land Use Consultants.
[13] Maslen Environmental (2010) Renewable and Low Carbon Energy Study. Pendle: Pendle Borough Council.

Consultee	PINS ID	Summary of Scoping Opinion Response	Consideration within Scope of Assessment
			maintenance phase. Accordingly, a separate assessment for the commissioning period is not required, as the operational and maintenance assessment can act as a proxy for the limited potential for Shadow Flicker during the construction period. As such, all possible Shadow Flicker effects at all stages of development are considered within the operational and maintenance assessment.
	3.13.2	The Inspectorate is content to scope out the potential for Shadow Flicker during decommissioning.	Noted. An assessment during the decommissioning phase has been scoped out.
	3.13.3	The Inspectorate is content to scope out Shadow Flicker effects on people with epilepsy.	Noted. An assessment considering effects on people with epilepsy has been scoped out.
	3.13.4	The Inspectorate suggests that the Applicant seeks to agree the final study area radius from the Proposed Development with the relevant consultation bodies, noting in particular the comments from Calderdale Council regarding the study area.	**Section 21.4** of this Chapter outlines the Shadow Flicker Study Area (and the Assessment Area) used for the assessment. The Shadow Flicker Study Area has been determined following recognised guidance, as well as taking into account the comments from Calderdale Council. Further consultation with Calderdale Council regarding the Shadow Flicker Study Area will be undertaken once the PEIR is submitted.

21.3.2 **Table 21-3** presents an overview of statutory consultee comments that informed the 2025 Scoping Response beyond PINS and provides a response where appropriate. Note that Burnley Council, Pendle Council and Bradford Council did not provide any response in respect of Shadow Flicker.

Table 21-3: Other Consultee Comments for 2025 Scoping Response

Consultee	Summary of Discussion	Discussion Response
Calderdale Council	The Council expects the ES to summarise relevant local amenity policies, national policies and international guidance and explain how SF findings will inform the policy tests.	An outline of the relevant national and local policy, and international guidance, used to determine the scope of this assessment is presented in **Table 21-1.** Additional consultation with Calderdale Council will be undertaken after submission of the PEIR to confirm which of the local policies should be considered within the Shadow Flicker assessment.
	Calderdale Council wants to see the use of worst-case turbine dimensions used in all modelling, in order to maximise potential Shadow Flicker.	Six candidate turbines are under consideration. This assessment uses the largest dimensions of those turbines under consideration, which is the worst-case.
	Calderdale Council does not accept limiting the Shadow Flicker Study Area to 10 × rotor diameter and would like to see a study area of 5 km. They have recommended property-level modelling (worst-case and cloud-corrected “realistic-case”) for all occupied buildings within at least 2 km of any turbine.	**Section 21.4** outlines the study area used for this preliminary assessment. The study area has been determined following recognised guidance, as well as taking into account the comments

Consultee	Summary of Discussion	Discussion Response
	For properties between 2-5 km, Calderdale Council wants to see modelling of all properties where it is possible for Shadow Flicker to occur, and a map to show none have been omitted. If a smaller study area is selected, Calderdale Council want to see justification for this choice.	from Calderdale Council. The study area does not consider properties out to 5km and full justification for this is included in **Section 21.4** and supplemented with **Figures 21-1** and **21-2**.
	Calderdale Council would like to also see a cumulative Shadow Flicker assessment.	Cumulative effects are considered in **Section Error! Reference source not found.**, supported by **Figure 21-4**.
	Calderdale Council would like to see how magnitude and significance are defined in the absence of formal UK criteria, as well as management triggers for mitigation control, and how the mitigation system would be set up.	Magnitude of Impact and Significance of Effect are defined in **Section 21.4.** Significance is defined by combining magnitude with sensitivity and whether the effect is significant or not significant is determined by applying professional judgement. Mitigation control needs to be defined based on the specification of the final turbine, however, the ES will present the required controls that would be relevant for the candidate turbine.
	Calderdale Council's Public Rights of Way Officer has requested that the impact of shadows on horse riders on bridleways including the	A discussion of the potential shadow effects on the Public Rights of Way (PRoW)

Consultee	Summary of Discussion	Discussion Response
	Pennine Bridleway and Calder-Aire Link should be included in the assessment.	is included in **Appendix 21-2** with reference to The British Horse Society guidance.
	Calderdale Council has requested that a property-level Shadow Flicker Receptor schedule and plan be set for all Shadow Flicker Receptors within the study area. The schedule should include: unique ID, name/address (or anonymised ID where required), coordinates, use/classification (i.e. dwelling, school, workplace), relevant façades/orientation and glazing assumptions, storey/eye-level used, distance to nearest turbine, and screening/terrain notes.	Details of the properties selected for assessment are presented in **Table 21-6.** A complete list of all properties identified within the Study Area is included in **Appendix 21-1.** The method of assigning dimensions, number of storeys, orientation etc is detailed in **Section 21.4.** Façade details are not required as a “greenhouse” approach has been adopted assuming windows for the full width of assessed buildings. All assessed building facades are assumed to be face on to all turbines.
	Calderdale Council has requested that the ES should set out the Shadow Flicker Control System (SFCS) in detail and define clear trigger thresholds.	Details of how the SFCS should be set will vary depending on the final turbine specification, however, the ES will present the required controls that would be relevant for the candidate turbine.
	Calderdale Council has requested that the ES set out the proposed	It is not appropriate to include a SFMS within

Consultee	Summary of Discussion	Discussion Response
	Shadow Flicker Mitigation Strategy (SFMS) in detail. They have asked that the SFMS include "*a property-level mitigation protocol, data logging and annual reporting, a complaints/intake and response procedure with timescales, and review/adaptive management if thresholds are approached or exceeded*".	the ES as the final turbine specifications or exact turbine locations (due to micro-siting) will not be known. A requirement for an SFMS to be submitted and approved by the Council prior to first export could be incorporated as DCO requirement.
Natural England	Natural England state: "*We note the potential impacts of Shadow Flicker on health and would draw attention to the potential effects of blade shadow on horses using bridleways within/adjacent to the project area and recommend an assessment should be carried out to assess this risk.*"	Natural England do not provide any references to "*the potential impacts of Shadow Flicker on health*". EN-1 provides a list of potential direct impacts on health that may occur from energy infrastructure but does not mention Shadow Flicker. EN-3 states (paragraph 2.12.168) "*Shadow Flicker frequencies are not in the region known to induce seizures in sufferers of epilepsy (which is above 3 hertz), and as such, where the frequency of potential flashes will not exceed 3 hertz, the Secretary of State should give no weight to any claims of effects on people with epilepsy from onshore wind turbines*". It is noted that **Chapter 18: Human Health** considers Shadow Flicker as part of the

Consultee	Summary of Discussion	Discussion Response
		preliminary assessment. A discussion of the potential shadow effects on the PRoW is included in **Appendix 21-2** with reference to The British Horse Society guidance.

Further Stakeholder Engagement

21.3.3 No additional engagement has been undertaken to date. However, following submission of the PEIR and receipt of subsequent comments, it is proposed to undertake additional consultation with Calderdale Council to seek to agree the final scope of the assessment, including the definition of the study area and assessment area.

21.4 Assessment Methodology

Study Area

21.4.1 When the sun passes behind a wind turbine, shadows can, in theory, be cast anywhere that the turbine is visible. When the sun is at low angle, however (i.e. close to the horizon), shadows are elongated, dissipating the shadow over a longer cast distance and reducing the depth of the shadow, rendering it more diffuse. In addition, at lower sun elevations the sunlight is travelling for a greater distance through the earth's atmosphere, so it is subject to a greater degree of attenuation and diffusion. Furthermore, as the sun gets lower in the sky, shadows are much more likely to be blocked by topography or other intervening obstacles. For these reasons, assessments of Shadow Flicker are almost always limited to smaller study areas than the theoretical maximum.

21.4.2 For England, the most relevant guidance in respect to setting a study area is NPS EN-3, which provides the primary policy for decisions to be made by the Secretary of State on applications for energy infrastructure NSIPs.

21.4.3 Paragraph 2.12.105 of NPS EN-3 states that:

"As a general rule, there is unlikely to be a significant impact at distances greater than ten rotor diameters from a turbine. Where wind turbines have been proposed within ten rotor diameters of an existing occupied building, a Shadow Flicker assessment should be carried out by the applicant."

21.4.4 Paragraph 2.12.167 of NPS EN-3 states:

"Where wind turbines are proposed that are ten rotor diameters and beyond from properties, the Secretary of State should consider that the impacts are sufficiently diminished so as to have no significant impact on that property."

21.4.5 These two paragraphs clearly indicate that Shadow Flicker effects from wind turbines do not usually need to be considered for study areas greater than 10 times the rotor diameter are likely only significant when they occur within 10 rotor diameters of a turbine.

21.4.6 The guidance in NPS EN-3 is in line with previous material produced by, or on behalf of, the UK government. For example, in March 2011, the former Department of Energy and Climate Change (DECC) issued the report 'Update of UK Shadow Flicker Evidence Base', which was prepared by Parsons Brinckerhoff (PB)[14] (the 'PB report'). The PB report summarised the findings of research undertaken by PB with a view to enabling DECC to "*advance current understanding of the Shadow Flicker effect."*

21.4.7 The PB report; "*Presents an update of the evidence base which has been produced by carrying out a thorough review of international guidance on Shadow Flicker, an academic literature review and by investigating current assessment methodologies employed by developers and case study evidence".*

21.4.8 The PB report concluded that a study area of 10 rotor diameters, 130 degrees either side of north is appropriate for the UK, whilst noting that an adjustment may be required for sites with different latitudes.

21.4.9 Therefore, with due regard to the above documents, Shadow Flicker assessments in England typically adopt a study area that extends to 10 times the rotor diameter from the turbines. This is also true for the rest of the UK. For the Proposed Development, which has a maximum rotor diameter of 175m for the 200m to tip candidate turbines, and 136m for the 150m to tip candidate turbines, this would equate to a study area of 1750m and 1360m respectively around each turbine, when considering the candidate turbines with the largest rotor diameter[15].

21.4.10 Calderdale Council have requested a much larger study area[16], stating

[14] Parsons Brinckerhoff (2011) Update of UK Shadow Flicker Evidence Base. Prepared for the Department of Energy and Climate Change. London: Department of Energy and Climate Change.
[15] Six candidate turbines are currently being considered. This is detailed below.
[16] It is worth noting that Calderdale Council requested this study area prior to the release of NPS EN-3, when there was no published policy regarding Shadow Flicker in England.

"Use a primary study radius of 5km around the turbine array for receptor identification and screening, applying the maximum rotor diameter and other Rochdale maxima (hub/tip, layout) in all inputs.

Undertake property-level modelling (worst-case and cloud-corrected "real-case" for all occupied buildings within at least 2 km of any turbine. For 2–5km, apply an orientation/topography screening and run targeted models where geometry indicates potential exposure.

Provide a justification for departing from a 5km radius if the applicant proposes a smaller core and include a 5km screening map to evidence that no at-risk receptors have been omitted."

21.4.11 With due regard to the options for using a 10 times rotor diameter, a 2km study area, or 5km study area, the following paragraphs consider the real-world shadow conditions that might occur within the area around any UK wind turbine development. A Shadow Flicker Study Area and an Assessment Area that is appropriate for the Proposed Development is then proposed.

21.4.12 The report, '*International Legislation and Regulations for Wind Turbine Shadow Flicker Impact*'[17] presents an overview of the assessment methodologies most commonly used in countries that have their own specific legislation or guidance with regards to Shadow Flicker effects. The paper states that nearly all countries base their guidance on the German guidelines '*Guideline for Identification and Evaluation of the Optical Emissions of Wind Turbines*'[18] (hereafter referred to as the *Guidelines*).

21.4.13 According to the Guidelines, the limit of a wind turbine blade shadow that needs to be considered within a Shadow Flicker assessment is set by two factors:

- The angle of the Sun over the horizon must be at least 3 degrees; and
- The blade of the wind turbine must cover at least 20% of the Suns disc (from the observer position).

21.4.14 So, under the Guidelines, the maximum distance that Shadow Flicker is considered to be a distinct or notable phenomenon is based on the blade width, as this affects how much of the sun's disc will be covered by the blades at a given distance. Beyond this maximum distance, a turbine will not contribute to Shadow Flicker. Given this, it is necessary to consider the blade width of the candidate turbines to

[17] WTN. (2017) International Legislation and Regulations for Wind Turbine Shadow Flicker Impact.
[18] States Committee for Pollution Control – Nordrhein-Westfalen (2002) Notes on the Identification and Evaluation of the Optical Emissions of Wind Turbines. Düsseldorf: States Committee for Pollution Control – Nordrhein-Westfalen.

establish whether Shadow Flicker could occur beyond the standard 10 times rotor diameter study area, and within 2km and 5km of the Proposed Development.

21.4.15 At this stage of the layout design, the height of 32 of the 34 proposed turbines will be 200m to tip, and the remining two will be 150m to tip.

21.4.16 There are four turbine models currently being considered for the 200m to tip turbines, and two for the 150m to tip turbines, representing the realistic worst case. The model names and blade dimensions are detailed in **Table 21-4**. Should the Development Consent Order (DCO) be granted, the final choice of turbine would be subject to a competitive tendering process.

Table 21-4: Candidate Turbines

Model Name	Tip Height (m)	Rotor Diameter (m)	Blade Width (m)	
			Maximum	At 90% Radius
Vestas 162-7.2	200	162	4.32	1.69
Vestas 172-7.2	200	172	4.35	1.26
Nordex 163	200	163	4.15	1.11
Enercon E175	200	175	4.01	1.11
Vestas 136	150	136	4.10	1.20
Nordex 133	150	133	3.94	1.13

21.4.17 The industry standard WindPro software can be set to calculate the distance at which 20% of the Suns disc would be covered by the blades, beyond which a single turbine will not contribute to Shadow Flicker. For this calculation, which is undertaken in accordance with the Guidelines, both the maximum blade width and the blade width at 90% of the rotor radius (from the root of the blade) are used. **Table 21-5** provides details of the calculated study areas for the candidate turbine models.

Table 21-5: Calculated Study Areas for Individual Turbines

Turbine Model	Calculated required study area (m)	
	10 x rotor diameter	20% sun coverage
Vestas 162-7.2	1620	2044
Vestas 172-7.2	1720	1908
Nordex 163	1630	1788

Turbine Model	Calculated required study area (m)	
	10 x rotor diameter	20% sun coverage
Enercon E175	1750	1741
Vestas 136	1360	1804
Nordex 133	1330	1725

21.4.18 To maximise the study area, the Vestas 162-7.2 for the 200m to tip turbines, and the Vestas 136 for the 150m to tip turbines, have been used.

21.4.19 Based on the calculated areas detailed in **Table 21-5,** the two possible study areas can be defined. These are shown on **Figure 21-1** alongside the Calderdale Council proposed 2km and 5km study area criteria. The following should be noted:

- The 10x rotor diameter calculated study area is smaller than the 20% sun coverage calculated study area. This indicates that Shadow Flicker could occur beyond 10 rotor diameters;
- The 20% sun coverage calculated study area is very similar to the Calderdale Council 2km criteria, varying around the development by small amounts. Accordingly, a hybrid study area is proposed that uses the largest extents of both the 20% sun coverage calculated study area and the 2km criteria;
- There can be no Shadow Flicker effects beyond this study area. Accordingly, it is not necessary to consider any Shadow Flicker Receptors beyond the study area out to 5km; and
- **Figure 21-2** presents the "Calculated Study Area" used for the assessment, with the 20% sun coverage calculated study area and the 2km criteria buffers merged together to create a single boundary.

Assessment Area

21.4.20 The Calculated Study Area is further refined by considering only areas where Shadow Flicker is geometrically possible, which considers topographical blocking points (where the landform will block the view of the wind turbines) and the path of the sun across the sky in the UK (where no shadows can be cast 130 degrees either side of north). This is shown on **Figure 21-2** as the Area Theoretically Susceptible to Shadow Flicker, and this effectively informs the Assessment Area. The Area Theoretically Susceptible to Shadow Flicker is referred to from this point onwards as the 'Assessment Area'.

21.4.21 All sensitive Shadow Flicker Receptors located within the Assessment Area are considered within the preliminary Shadow Flicker assessment presented below.

Data Sources

21.4.22 Candidate turbine models being considered for the Proposed Development have been provided by the Applicant. Turbine dimensions used in the assessment are included within the WindPRO software.

21.4.23 *AddressBase* data that includes postal addresses and unique property references out to 2km from the Turbine Area was provided by the Applicant. This includes both commercial and residential properties, as well as other features of interest, such as bridges.

21.4.24 Google Earth image data has been used to scan for properties beyond 2km to the edge of the Calculated Study Area.

21.4.25 Although Calderdale Council requested properties be considered out to 5km, this data has not been sourced, as Shadow Flicker effects cannot occur beyond the defined Assessment Area.

21.4.26 Building dimension data has been estimated through a combination of Google Earth and Google Street View. Google Earth was used to measure building widths, and Google Street View was used to estimate building heights.

Methodology – Modelling Parameters

Identification of Shadow Flicker Assessment Locations (SFALs)

21.4.27 A total of 95 Address Base entries have been identified within the Calculated Study Area. An additional 10 properties were added to the dataset after the desktop review using Google aerial and Streetview imagery. All of these properties are detailed in **Appendix 21.1: Precited Shadow Flicker Events (Example)**.

21.4.28 The preliminary assessment presented in this Chapter has considered all Shadow Flicker Receptors that may be sensitive to Shadow Flicker within the Assessment Area. Buildings considered as potentially sensitive in this assessment are dwellings, offices and similar workplaces, health care facilities, and schools. Farm buildings, industrial units and similar are considered to have limited sensitivity to Shadow Flicker, and so not assessed.

21.4.29 A manual filter of the dataset using Google Earth aerial and Streetview imagery was undertaken in order to remove entries listed in the data that were not necessary to be included in the assessment (noting that the AddressBase data included empty fields and bridges). In addition, any building that was clearly identified as having limited sensitivity to Shadow Flicker or uninhabitable (i.e. derelict) was removed. However, where this was not possible to confirm, the building was considered as part of the assessment as a worst-case approach.

21.4.30 The remaining buildings were further filtered based on whether they are in the Assessment Area or not. Buildings outside of the Assessment Area were excluded from further assessment, as Shadow Flicker is not possible at these buildings given the current design of the Proposed Development.

21.4.31 This filtering left 37 Shadow Flicker Receptors within the Assessment Area, which have been classified as SFALs and included in the assessment. SFALs 34, 35, 36 and 37 are located in an area where there is no potential for significant Shadow Flicker impacts, as per the advice in NPS EN-3 (paragraph 2.12.167). **Figure 21-3** details the SFALs, as well as the properties not included in the assessment.

Modelling Parameters

21.4.32 The potential for Shadow Flicker to occur at a given location, and the duration of the effect, depends predominantly upon the following factors:

- The location of the building relative to the wind turbine;
- The distance from the wind turbine(s);
- The blade width[19];
- The turbine hub-height and rotor diameter;
- The time of year (which impacts the trajectory of the sun's path across the sky);
- The frequency of cloudless skies (particularly at low elevations above the horizon);
- Whether the wind is blowing; and,
- The wind direction (which impacts on turbine orientation).

21.4.33 Several specialist software packages are available that can take account of the variables listed above to determine the maximum theoretical amount of time that Shadow Flicker could occur at each window location. The modelling presented in this Chapter has been undertaken using the WindPro[20] software.

21.4.34 For this assessment, the levels of Shadow Flicker at each SFAL have been calculated based on a "worst-case" scenario, and a "cloud-corrected" scenario.

21.4.35 The worst-case scenario assumes that the sun is always shining, the turbines are always spinning, and all turbines are face on to each SFAL. These results present

[19] Blade width is considered as a factor that influences shadow flicker in German shadow flicker assessments.
[20] EMD International A/S. (2015) WindPRO. Aalborg: EMD International A/S.

the maximum amount of time that it is geometrically possible for Shadow Flicker to occur at the SFALs.

21.4.36 The modelling approach for the realistic-case scenario is identical to the worst-case scenario, except that the average amount of sunshine hours per month is taken into consideration. This reduces the levels of predicted Shadow Flicker to more 'realistic' levels, as Shadow Flicker cannot occur without direct sunshine. However, it will still over-predict the actual hours that Shadow Flicker may occur and therefore provides a conservative approach.

21.4.37 The SFALs have been modelled using a 'greenhouse' approach, where the Shadow Flicker Receptor is considered to be a single window across the full width of the façade and it is always perpendicular to the modelled wind turbines. Each storey of the assessed buildings is assumed to have a height of 2.4m, (e.g. a single-story building is modelled with windows with a height of 2.4m, a two storey building with 4.8m high windows, and etc.). Where it has not been possible to determine the number of storeys for a building, the SFAL was assumed to be two storeys tall and this has been assumed for 13 of the SFALs (noted by an asterisk in the table below). **Table 21-6** details the SFAL coordinates and assumed width and height.

Table 21-6: Details of SFALs

SFAL ID	Easting	Northing	Width (m)	Height (m)
1	393529	433008	14.07	4.8
2	393534	433021	7.45	2.4
3	394536	432426	14.49	4.8
4	394896	432047	12.89	4.8
5	395154	431659	36.14	4.8
6	395509	432142	14.05	4.8*
7	395546	431557	13.43	4.8
8	395581	431533	25.54	4.8
9	396557	431154	13.64	4.8
10	396592	431150	12.44	2.4
11	396595	431666	21.09	4.8
12	397592	431536	18.96	4.8*
13	399047	432920	14.97	4.8*
14	399366	431525	18.81	4.8*

SFAL ID	Easting	Northing	Width (m)	Height (m)
15	399401	431831	20.79	4.8
16	399475	431773	10.00	4.8
17	399478	431782	10.00	4.8
18	399480	431788	10.00	4.8
19	399483	431796	10.00	4.8
20	399487	432227	16.98	2.4
21	399560	431595	10.44	2.4
22	399667	435338	10.75	4.8*
23	399673	435349	10.75	4.8*
24	399675	435364	13.23	4.8*
25	399711	432924	32.97	4.8
26	400003	432707	14.31	4.8
27	400025	431989	22.34	4.8*
28	401136	434838	17.90	4.8
29	401322	434638	36.46	4.8*
30	401426	434552	11.0	4.8
31	401441	434708	25.00	4.8
32	401483	434588	26.23	2.4
33	401500	434568	30.40	4.8*
34	401519	433373	18.14	4.8
35	401752	434671	25.50	4.8*
36	401770	434695	26.86	4.8*
37	401267	435442	32.20	4.8*
* two stories assumed				

21.4.38 The turbine locations and dimensions used in the model are provided in **Table 21-7.**

Table 21-7: Details of Modelled Turbines

Turbine ID	Easting	Northing	Tip Height (m)	Rotor Diameter (m)	Hub Height (m)
T01	394796	435048	200	175	112
T02	394027	433609	200	175	112
T03	394480	434487	200	175	112
T04	395011	434247	200	175	112
T05	395694	434379	200	175	112
T06	394003	434941	200	175	112
T07	394365	435255	200	175	112
T08	394902	435636	200	175	112
T09	395277	435216	200	175	112
T10	395691	435352	200	175	112
T11	396095	435357	200	175	112
T12	396326	434925	200	175	112
T13	396234	434512	200	175	112
T14	395224	434684	200	175	112
T15	395184	433926	200	175	112
T16	394765	433542	200	175	112
T17	395528	433664	200	175	112
T18	395090	433238	200	175	112
T19	397053	434973	200	175	112
T20	397413	434873	150	136	82
T21	397514	434519	150	136	82
T22	397385	433900	200	175	112
T23	395982	434034	200	175	112
T24	398225	432450	200	175	112

Turbine ID	Easting	Northing	Tip Height (m)	Rotor Diameter (m)	Hub Height (m)
T25	397300	433173	200	175	112
T26	397225	432509	200	175	112
T27	397506	432924	200	175	112
T28	398449	434067	200	175	112
T29	399461	434318	200	175	112
T30	399886	434116	200	175	112
T31	396325	432476	200	175	112
T32	396121	432852	200	175	112
T33	396693	433225	200	175	112
T34	398318	432096	200	175	112

21.4.39 Shadow Flicker was calculated for all periods of the sun greater than 2° above the horizon.

21.4.40 Historic weather data compiled by the Met Office can be used to give an indication of the likelihood of cloudy skies and the associated reductions in the levels of predicted Shadow Flicker. For this cloud-corrected scenario, climate data from the nearest long-term weather station was used[21], which is approximately 15.3 km east of the Proposed Development.

21.4.41 The Average Daily Sunshine Hours, which are calculated by dividing the total number of monthly sunshine hours by the number of days in the month, enable the calculation of Realistic-Case Shadow Flicker. This data is presented in **Table 21-8.**

Table 21-8: Average Daily Sunshine Hours per Month at Bradford Climate Station

Month	hh:mm
January	1:05
February	1:56
March	2:56
April	4:23

[21] Bradford Climate Station, (Lat (deg): 53.81, Lon (deg): -1.77.

Month	hh:mm
May	5:23
June	5:52
July	5:17
August	4:49
September	3:52
October	2:38
November	1:34
December	0:50

Methodology – Assessment Parameters

Determining the Sensitivity of Shadow Flicker Receptors

21.4.42 The sensitivity of different types of Shadow Flicker Receptors to Shadow Flicker effects is not defined in the currently available guidance. Therefore, as no published standards exist, the sensitivity of Shadow Flicker Receptors to shadow flicker has been made based on professional judgements.

21.4.43 As outlined in 21.4.28, some types of receptor are considered to be more sensitive to shadow flicker than others. On the basis that there is no published guidance to define shadow flicker sensitivity, a granular approach to sensitivity is not appropriate. Therefore, for this assessment, only two categories of sensitivity to shadow flicker are defined; high, and low. Receptors with a greater sensitivity to shadow flicker are defined as high sensitivity receptors, and receptors with a lower sensitivity to shadow flicker are defined as low sensitivity receptors.

21.4.44 As this assessment only considers receptors that would have a higher sensitivity to shadow flicker, for this assessment, the sensitivity of the SFALs is assumed to be high in all cases.

Determining the Magnitude of Impact

21.4.45 No formal guidance is available regarding what levels of Shadow Flicker may be considered acceptable in the UK or how to define a magnitude of impact, therefore, reference is made to the aforementioned Guidelines (see Paragraph 21.4.12 above). The magnitude of impact in this assessment has been considered against prescribed thresholds outlined below.

21.4.46 The limit values within the Guidelines are 30 minutes per day and 30 hours per year. These thresholds are based on the predicted worst-case conditions (i.e. the

total theoretical number of hours per year that Shadow Flicker may occur, assuming that the sun is always shining during daylight hours, rather than the actual amount of Shadow Flicker that will occur). Accordingly, if the worst-case predicted levels exceed the thresholds then mitigation measures are required to be installed.

21.4.47 Many countries have adopted these same thresholds, either directly or with some small adjustments. Australia, Belgium (Walloon region), Brazil, Canada, India, Sweden, and USA all have a worst-case limit of 30 hours per year or 30 minutes a day. The UK has no set limit but also typically adopts the Guidelines levels for assessment purposes.

21.4.48 With due regard to the limits presented in the Guidelines, the magnitude of impact used for this assessment is presented in **Table 21-9.** Worst-case predictions assume the sun is always shining, the blades are always spinning, and the turbines are always facing the Shadow Flicker Receptors.

Table 21-9: Magnitude of Impact

Number of hours per year	Number of minutes per day	Magnitude of Impact
More than 30, cloud corrected predictions	n/a	Large
More than 30, worst case predictions	More than 30, worst case predictions	Medium
30 or Less, worst case predictions	30 or Less, worst case predictions	Small
0 hours predicted	0 minutes predicted	No Impact

Level of Effect

No formal guidance is available regarding what levels of Shadow Flicker may be considered acceptable in the UK, and beyond which amenity effects are significant. Therefore, the German Shadow Flicker guidance has been considered to determine the significance of any impacts.

For the purposes of this assessment, theoretical worst-case Shadow Flicker exceeding 30 hours per year or 30 minutes per day is the threshold for Significant. Exceedance of either of these limits is considered to result in an effect that is significant on the amenity of the occupants of an SFAL and may require mitigation.

For levels of Shadow Flicker below this limit, the effect is considered not significant.

Determining Significance

21.4.49 The significance of effect is informed by the sensitivity and magnitude of impact.

21.4.50 All SFALs are assumed to have a high level of sensitivity.

21.4.51 Where the magnitude of impact is determined to be Large or Medium (and sensitivity is high) the significance of effect is determined to be significant.

21.4.52 Where the magnitude of impact is determined to be Small or No Impact (and sensitivity is high) the significance of effect is determined to be not significant.

Limitations and Assumptions

21.4.53 The following limitations and assumptions apply:

- The dimensions of each property, as input into the modelling software, have been informed by aerial imagery rather than measured on-site. As such, accurate window dimensions are not available for the SFALs. Therefore, modelling was undertaken using the greenhouse approach. In practice, the windows will be smaller and may not face the Proposed Development.
- Screening of the turbines from other buildings, trees, and other obstacles will reduce or eliminate Shadow Flicker in some cases. This level of detail is not included in the model; and,
- Shadow Flicker is less perceptible or imperceptible when the turbines are side on to the Shadow Flicker Receptor. As turbines cannot face all directions at once, some Shadow Flicker will be eliminated for certain Shadow Flicker Receptors, depending on the direction the wind is blowing and the direction that turbines are facing.

21.4.54 All of the above information gaps and assumptions mean that the assessment has considered a worst-case scenario. In reality levels of Shadow Flicker will be less than calculated. However, the approach adopted allows the preliminary assessment of the likely significant effects to be identified and reported.

21.4.55 The final turbine specification is yet to be determined, therefore candidate turbines have been used for the preliminary assessment. Prior to first operation, Shadow Flicker calculations will need to be re-run based on the dimensions of the turbine installed.

21.5 Baseline Conditions

Existing Baseline

21.5.1 There are 37 SFALs within the Assessment Area. None of these Shadow Flicker Receptors currently receive any Shadow Flicker, as there are no other wind turbine developments are within 10 rotor diameters of these SFALs.

Further Data Collection

21.5.2 No further surveys are required in order to inform the baseline.

Future Shadow Flicker Conditions

Collection of Predicted Data

21.5.3 A search of the planning application history and application status at the location of the Proposed Development and surrounding area indicates that no other wind farm developments are proposed or awaiting decision within 5 km. There are also no other wind farms at the screening or scoping stage within the surrounding 5 km area.

Future Baseline

21.5.4 Given that there are no proposed wind farms in the vicinity of the Proposed Development, the future baseline is that zero Shadow Flicker is expected at the SFALs in the future in the absence of the Proposed Development.

21.6 Environmental Measures

Construction

21.6.1 There are no specific environmental measures relevant to Shadow Flicker for the construction phase.

Operation and Maintenance

21.6.2 There are no specific environmental measures relevant to Shadow Flicker for the operational and maintenance phase.

Decommissioning

21.6.3 There are no specific environmental measures relevant to Shadow Flicker for the decommissioning phase.

21.7 Potential Effects Scoped Out

21.7.1 This section lists the effects which are scoped out of the Shadow Flicker assessment as they are not likely / not significant. No effects beyond those already identified at the Scoping stage have been scoped out (see **Table 21-2**), however, **Table 21-10** is provided in respect of Shadow Flicker Receptors that have not been considered in the assessment.

Table 21-10: Potential Effects Scoped Out

Effects Scoped Out	Justification	Phase
Shadow Flicker During Construction	Shadow Flicker has no potential to occur during the Construction phase outside of limited testing during commissioning, which is addressed in the Operational and maintenance phase assessment.	Construction
Shadow Flicker effects on people with epilepsy	NPS EN-3 states: *"Shadow Flicker frequencies are not in the region known to induce seizures in sufferers of epilepsy (which is above 3 hertz), and as such, where the frequency of potential flashes will not exceed 3 hertz, the Secretary of State should give no weight to any claims of effects on people with epilepsy from onshore wind turbines."*	Operation and maintenance
Shadow Flicker During Decommissioning	Shadow Flicker has no potential to occur during the Decommissioning phase.	Decommissioning
Shadow Flicker Effects beyond the Calculated Study Area[22]	The study area is defined by the greatest extents of the Calderdale Council 2 km study area criteria combined with the maximum area where Shadow Flicker may be present, based on consideration of the blade width of the largest candidate turbines.	Operation and maintenance

21.8 Preliminary Environmental Assessment

21.8.1 The Preliminary Environmental Assessment will detail the effects that are considered to be likely significant including providing details of how and why such a conclusion has been reached.

21.8.2 This is a preliminary assessment of Likely Significant Effects with the environmental measures in place without additional mitigation.

[22] Note that this has been added since the Scoping Report to clarify the extent of the operational assessment.

Construction Phase

21.8.3 Scoped out.

Operational and Maintenance Phase

Predicted Levels of Shadow Flicker

21.8.4 The predicted levels of worst- case Shadow Flicker that might occur if the sun was to shine all day, every day and assuming that all turbines are always spinning and are always face on to the Shadow Flicker Receptor are provided below in Columns 2, 3 and 4 of **Table 21-11.**

21.8.5 Column 5 of **Table 21-11** presents the realistic-case Shadow Flicker calculations, which consider the amount of Shadow Flicker that might occur if the average frequency of clear skies is taken into account, though it still assumes that all turbines are always spinning and are always face on to the Shadow Flicker Receptor.

Table 21-11: Predicted Worst-Case and 'Realistic' Shadow Flicker at SFALs

SFAL ID	Worst- case Shadow Flicker		Realistic Case	
	Max Shadow days per Year	Max Shadow hours per Year (hh:mm)	Max Shadow Hours Per Day (hh:mm)	Shadow Hours Per Year (hh:mm)
1	124	19:46	00:22	06:26
2	69	10:51	00:18	03:30
3	67	19:03	00:25	05:59
4	96	26:51	00:28	08:56
5	38	11:28	00:24	03:54
6	114	61:55	00:48	20:37
7	60	19:59	00:23	06:42
8	54	17:57	00:24	06:03
9	68	20:58	00:21	07:00
10	64	20:31	00:22	06:52
11	116	35:46	00:25	11:47
12	30	7:21	00:19	02:30

SFAL ID	Worst- case Shadow Flicker		Realistic Case	
	Max Shadow days per Year	Max Shadow hours per Year (hh:mm)	Max Shadow Hours Per Day (hh:mm)	Shadow Hours Per Year (hh:mm)
13	175	69:06	00:43	16:08
14	46	18:29	00:30	06:15
15	118	61:21	00:38	20:22
16	116	53:51	00:34	17:54
17	118	54:43	00:34	18:10
18	119	54:57	00:34	18:15
19	121	55:24	00:34	18:23
20	91	38:16	00:34	11:48
21	93	44:41	00:35	14:54
22	85	43:05	00:56	05:34
23	85	41:08	00:54	05:19
24	84	39:03	00:51	05:05
25	74	25:57	00:28	05:59
26	56	16:38	00:23	04:18
27	65	19:44	00:25	06:09
28	55	14:42	00:27	03:38
29	56	18:59	00:29	04:59
30	48	14:41	00:25	03:58
31	52	16:33	00:26	04:18
32	48	15:13	00:25	04:05
33	32	10:10	00:26	02:43
34	44	13:00	00:24	04:17
35	28	07:26	00:21	01:56
36	27	07:16	00:22	01:52

SFAL ID	Worst- case Shadow Flicker		Realistic Case	
	Max Shadow days per Year	Max Shadow hours per Year (hh:mm)	Max Shadow Hours Per Day (hh:mm)	Shadow Hours Per Year (hh:mm)
37	38	11:34	00:24	02:02
Key		Exceeds 30 Hour Per Year Threshold	Exceeds 30 Minutes Per Day Threshold	

21.8.6 In total:

- 13 SFALs exceed the "30 Hour Per Year" threshold; and
- 12 SFALs exceed the "30 Minutes Per Day" threshold.

21.8.7 The greatest number of days on which worst-case Shadow Flicker is predicted to occur at a Shadow Flicker Receptor is 175 days at SFAL13. SFAL13 is located less than 1km to the northeast of T24 and T34, and less than 2 km from T25, T26, and T27.

21.8.8 The greatest total amount of worst-case Shadow Flicker that is predicted to occur at any SFAL over the course of a year is 69 hours and 6 minutes, also at SFAL13.

21.8.9 The maximum duration of Shadow Flicker that is predicted to occur on a single day is 56 minutes at SFAL22, which is approximately 1km north of T29 and 1.2km northwest of T30.

21.8.10 Accounting for the likelihood of clear skies and sunshine over the course of the year, the highest levels of predicted Shadow Flicker are at SFAL6, located approximately 880m southwest of T31, and 930m southwest of T32.

21.8.11 Across all of the SFALs assessed here, some Shadow Flicker occurs on every day of the year. The earliest time that Shadow Flicker occurs is at 05:17. The latest time that Shadow Flicker occurs at any SFAL is 21:08.

21.8.12 With due regard to the assessment criteria set out in **Table 21-9** and the calculated Shadow Flicker reported in **Table 21-11**, the Magnitude of Impact for all SFALs is presented in **Table 21-12.**

Table 21-12: Magnitude of Impact at SFALs

Magnitude of Impact	No Impact	Small	Medium	Large
Number of SFALs	0	24	13	0

21.8.13 The Applicant's preliminary assessment identified that there are no SFALs where the predicted levels of realistic-case Shadow Flicker exceed 30 hours. Therefore, there are no SFALs where the Magnitude of Impact is considered Large.

21.8.14 There are 13 SFALs where the worst-case predicted levels of Shadow Flicker exceed 30 hours a year or 30 minutes a day, and for these Shadow Flicker Receptors the Magnitude of Impact is medium. Combined with the high sensitivity of the Shadow Flicker Receptors, the significance of effect is determined to be Significant. Accordingly, additional mitigation measures will be required to lessen the effects at these Shadow Flicker Receptors.

21.8.15 For the remaining 24 SFALs, the Magnitude of Impact is small and, combined with the high sensitivity of the Shadow Flicker Receptors, the significance of effect is determined to be not significant.

Additional Mitigation

21.8.16 The Applicant proposes to install a Shadow Flicker turbine control system during the construction of the wind farm that can be used to mitigate the effects of Shadow Flicker.

21.8.17 A Shadow Flicker control system will halt the relevant turbine(s) when it detects:

1) That it is geometrically possible for Shadow Flicker to occur; and

2) The environmental conditions necessary for Shadow Flicker to occur (i.e. the sun is shining and the wind is blowing) are present.

21.8.18 The implementation of these systems can be proactive or reactive:

- With a proactive approach, predicted Shadow Flicker events are mitigated when the meteorological conditions are present for Shadow Flicker to occur. The amount of predicted Shadow Flicker events that are mitigated will vary depending on the exposure levels that the operator has committed to, for example, a maximum of 30 minutes a day or 30 days a year; and

- With a reactive approach, no mitigation is implemented immediately. However, if complaints relating to Shadow Flicker are received, the Shadow Flicker control system can be implemented to stop the turbines during predicted Shadow

Flicker events (when the meteorological conditions for Shadow Flicker to occur are met) for a specific Shadow Flicker Receptor or group of Shadow Flicker Receptors.

21.8.19 It is proposed that Shadow Flicker arising from the Proposed Development be mitigated via a combined approach. Proactive mitigation will be used for all properties located within 10 rotor diameters of a turbine. Reactive mitigation will be used for all properties located beyond 10 rotor diameters of a turbine. This is in line with NPS EN-3, which states; "*Where wind turbines are proposed that are ten rotor diameters and beyond from properties, the Secretary of State should consider that the impacts are sufficiently diminished so as to have no significant impact on that property.*"

21.8.20 There are no guidelines in the UK that quantify what exposure levels of Shadow Flicker are acceptable. Notwithstanding, the control system will be programmed to achieve near-zero occurrences of Shadow Flicker for all Shadow Flicker Receptors within 10 rotor diameters.

21.8.21 Note that is not possible to have zero instances of Shadow Flicker, as there will be a slight delay for the system to recognise the correct conditions. For example, the turbine will not shut off instantly when the sun comes out from behind a cloud as the system needs to determine whether the change in light level is intermittent or not. Similarly, once a control message is sent to turn off a turbine there will be a short period where the blades need to slow down to a stop.

21.8.22 The Shadow Flicker control system will be installed to deactivate the wind turbines when Shadow Flicker effects are geometrically possible and the meteorological conditions for Shadow Flicker are also met. The system would be designed based on the final turbine specifications and the mitigation will be employed for all sensitive Shadow Flicker Receptors within 10 rotor diameters identified through a post-consent survey.

21.8.23 Note that the 10 rotor diameter mitigation area may differ from the 10 rotor diameter study area presented in this assessment, as it is dependent on the final turbine specifications.

21.8.24 Details of both the proactive and reactive Shadow Flicker mitigation will be provided to Calderdale Council as part of an operational SFMS. The SFMS would include the period nearing the end of construction when the turbines are being commissioned.

21.8.25 Following the implementation of the SFMS, minimal Shadow Flicker would occur as a result of the Proposed Development (aside from any short periods before the control system can react and slow down the blades). As such, Shadow Flicker at all properties in the vicinity of the Proposed Development will be negligible.

21.8.26 **Appendix 21.1: Predicted Shadow Flicker Events (Example)** contains an example of a Shadow Flicker shutdown schedule for SFAL01 for the year 2025[23] based on the study area used in this assessment. The example is included to give an indication of what such a shutdown log may look like and contains only the times for a single Shadow Flicker Receptor for brevity. The entire log is of considerable length but can be provided upon request.

Residual Effects

21.8.27 Once additional mitigation is applied, then there will be no residual significant Shadow Flicker effects, aside from the brief period where the Shadow Flicker system is reacting and slowing the blades down to a halt.

21.8.28 With due regard to the assessment criteria set out in **Table 21-9** and the calculated Shadow Flicker reported in **Table 21-11**, the magnitude of impact for all SFALs is between no impact and small and, combined with the high sensitivity of Shadow Flicker Receptors, the significance of effect is determined to be Not Significant.

Decommissioning Phase

21.8.29 Scoped Out.

Next Steps

21.8.30 Consultation with Calderdale Council is required to ensure that they are satisfied with the study area used for the assessment and proposed mitigation measures. Otherwise, no further steps are required.

21.8.31 Post-consent, a survey would need to be undertaken to identify all sensitive Shadow Flicker Receptors with 10 rotor diameters based on the final turbine specifications and revised Shadow Flicker calculation made considering the years of operation and turbine dimensions.

21.9 Conclusions

21.9.1 **Table 21-13** summarises the Preliminary Assessment for each Shadow Flicker Receptor scoped in for assessment. This follows the approach described in **Section 21.4** and includes consideration of the environmental measures described in **Section 21.6** as additional mitigation measures are being developed/defined.

[23] Note that calculated Shadow Flicker start times may vary slightly year on year, but overall worst-case predicted Shadow Flicker levels would remain the same.

Table 21-13: Summary of Preliminary Assessment of Effects

Element	Preliminary assessment of likely impacts	Additional mitigation	Residual effects	Next steps
Shadow Flicker: Construction Phase	No significant effects	None required	No Likely Significant Effects	None required
Shadow Flicker: Operational and Maintenance Phase	Significant effects at 13 Shadow Flicker Receptors. No significant effects at 24 Shadow Flicker Receptors	Shadow Flicker control system to be fitted to turbines	No Significant Effects at all Shadow Flicker Receptors	Consultation with Calderdale Council to agree study area for ES.
Shadow Flicker: Decommissioning Phase	No significant effects	None required	No significant effects	None required

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