

8. Shadow Flicker

Introduction

- 8.1 This Chapter reports the outcome of the assessment of likely significant environmental effects in relation to shadow flicker.
- 8.2 Under certain combinations of geographical position, time of day and year the sun may pass behind a wind turbine rotor and cast a shadow over neighbouring buildings' windows. When the blades rotate and the shadow passes a window the shadow appears to flick on and off; this effect is known as shadow flicker.
- 8.3 The Chapter describes the scope of the assessment and assessment methodology and a summary of the baseline information that has informed the assessment.
- 8.4 In line with **Chapter 2: Approach to EIA**, the assessment reports on the likely significant environmental effects, the further mitigation measures required to prevent, reduce or offset any significant adverse effects, or further enhance beneficial effects. The conclusions are provided both in terms of the residual effects and whether these are considered to be significant. The assessment of effects takes into consideration both primary and tertiary mitigation (see **Chapter 2: Approach to EIA** for further details).
- 8.5 This Chapter, and its associated **Figure 8.1**, is intended to be read as part of the wider ES with particular reference to the introductory Chapters of this ES (**Chapters 1 – 5**).
- 8.6 In addition, this Chapter should be read in conjunction with **Chapter 16: Assessment of Cumulative Effects**.

Summary of Consultation

2025 ES

- 8.7 The Project Team undertook an EIA Scoping exercise (described further under the 'Scope of Assessment' section below) in support of the 2025 ES, which included consultation with Rochdale Metropolitan Borough Council (RMBC) and Rossendale Borough Council (RBC) and other stakeholders. The outcomes of this process are documented in **Chapter 2: Approach to EIA** and **Appendices 2.1** and **2.2**. No consultation has been undertaken over and above that completed during the EIA Scoping process. At the time of writing (May 2026), no Scoping Opinion has been received.

2026 FEI ES

- 8.8 No further consultation has been undertaken as part of this ES. However, statutory consultation responses received following submission of the 2025 ES that are directly relevant to the ES, and its supporting material have been considered, with the outcomes documented in **Appendix 2.4**. These consultation responses comprise feedback on the 2025 ES from Metrica Environmental Consulting (Metrica), who were commissioned by RBC to review the shadow flicker assessment included within the 2025 ES.

Scope of the Assessment

- 8.9 An EIA Scoping Report was submitted to RMBC and RBC on 16th December 2024, as presented as **Appendix 2.1**. At the time of writing (May 2026), no Scoping Opinion has been received. The Scope of Assessment is the same as that detailed in the EIA Scoping Report.

Effects Unlikely / Not Significant

- 8.10 The following effects were considered unlikely /not significant as part of the EIA Scoping Report (**Appendix 2.1**) and are not considered further in this Chapter and additional rationale has been provided:

Shadow flicker during construction and decommissioning.

- 8.11 This effect has been considered as not significant as part of the EIA because during construction and decommissioning the turbine blades will either not be installed or not be spinning, and so shadow flicker is not possible. During the hot commissioning period for the wind turbines, any potential for shadow flicker will be identical to the operational stage of the wind turbines and could be considered an extension of this stage and so shadow flicker arising from the hot commissioning phase is not required to be considered separately.

Shadow flicker effects on people with epilepsy

- 8.12 This effect is considered unlikely / not significant and the evidence to support this determination is outlined below.
- 8.13 Around one in one hundred people in the UK have epilepsy, although only 3% of those suffer from photosensitive epilepsy. The common frequency at which photosensitive epilepsy might be triggered varies from person to person, though generally it is between 3 and 30 flashes per second (hertz (Hz)); sensitivity under 3 hertz is not common (The National Society for Epilepsy¹).
- 8.14 These effects have been considered as not significant because commercial scale (>1 MW) wind turbines in the UK rotate much slower than the frequency generally considered to trigger photosensitive epilepsy, at between 0.2 and 1.0 Hz. This includes the wind turbines proposed as part of the Project for Assessment. The candidate turbine considered in this assessment (the Nordex N149) rotates at 6.2 - 12.2 revolutions per minuteⁱ, equating to a flash frequency of 0.31 Hz - 0.61 Hz. Therefore, no health effects arising from photosensitive epilepsy are predicted.
- 8.15 Therefore, shadow flicker effects on people with epilepsy are unlikely to be significant and have not been considered further within the EIA or reported in the ES.

Effects Likely / Significant

- 8.16 **Table 8.1** outlines the effects that are considered likely / significant and are reported within this Chapter.

ⁱ Nordex (the turbine manufacturer) confirmed these rotation speeds to the Applicant.

Table 8.1: Effects likely / significant

Likely significant effect	Receptor(s)	Applicable stage(s)
Shadow flicker	Residential properties within 1,500 m (10 x the maximum rotor diameter) of the proposed turbines (as shown in Figure 8.1).	Operation

Assessment Methodology

Legislative Framework, Policy and Guidance

- 8.17 There is no standard for the assessment of shadow flicker in the UK and there are no guidelines which quantify what exposure levels would be acceptable.
- 8.18 The following policy has informed the assessment of effects within this Chapter:
- Overarching National Policy Statement for Energy (EN-1)²; and
 - National Policy Statement for Renewable Energy Infrastructure (EN-3)³.
- 8.19 National Policy Statements (NPSs) EN-1 and EN-3 set out national policy for nationally significant energy infrastructure, including wind turbines. In England, EN-1 and EN-3 may be a material consideration in decision making on applications that fall under the Town and Country Planning Act 1990 (as amended).
- 8.20 NPS EN-1 is the overarching statement that sets out policy for energy nationally significant infrastructure projects (NSIPs). NPS EN-1 discusses how onshore wind might be developed to meet the Clean Power 2030 goalsⁱⁱ and outlines how onshore wind developments have been reinstated into the NSIP regime for developments exceeding 100 MW. With regards to the impacts of wind turbines, NPS EN-1 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.
- 8.21 NPS 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. NPS 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, NPS EN-3 outlines how the Secretary of State should consider potential Shadow Flicker effects in decision making for NSIP applications.
- 8.22 The following guidance has informed the assessment of effects within this Chapter:

ⁱⁱ Clean Power 2030 Action Plan. Available at:
<https://www.gov.uk/government/publications/clean-power-2030-action-plan>

- **‘Planning Practice Guidance (PPG) for Renewable and low carbon energy’⁴:** This document provides guidance to help local councils in developing policies for renewable and low carbon energy and identifies the planning considerations relating to shadow flicker, as well as where it may occur.
- **‘An update of the UK shadow flicker evidence base’ produced by Parsons Brinckerhoff for the (former) Department for Energy and Climate Change (DECC)⁵:** This document outlines the commonly used approach to assessing shadow flicker in the UK. The report concludes that assessing receptors within 10 rotor diameters and within 130° either side of north is generally appropriate, while noting that methods and assumptions vary and real-world factors (e.g., cloud cover and wind direction) typically reduce effects compared with worst-case model outputs.
- **‘Notes on the Identification and Evaluation of the Optical Emissions of Wind Turbines’⁶:** This document guidance sets out how to assess shadow flicker from wind farms, and outlines commonly adopted screening/assessment assumptions and exposure limits (notably a worst-case limit of 30 minutes per day and 30 hours per year, with a more stringent 8 hours per year “real case” limit often referenced where mitigation is applied).
- **‘International Legislation and Regulations for Wind Turbine Shadow Flicker Impact’⁷:** This document provides legislation and regulations for assessing shadow flicker from wind farms worldwide. This document highlights that many jurisdictions broadly align with (or are influenced by) the German guideline approach, commonly referencing thresholds such as 30 minutes per day and 30 hours per year (often under worst-case assumptions).
- **‘Validation Checklist for Applications Submitted to the Local Planning Authority (September 2024)’ by Rossendale Borough Council (RBC)⁸** (the ‘Validation Checklist’): This document outlines the requirements set by RBC that planning applications must meet to be considered valid.

Note: RMBC has no specific guidance relating to shadow flicker from turbines at the time of writing.

Defining the Study Area

- 8.23 The study area for the assessment has been determined following the policy and guidance documents outlined above.
- 8.24 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.
- 8.25 Paragraph 2.12.106 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.”

8.26 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.”

8.27 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.

8.28 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 for Energy and Climate Change (DECC) issued the report ‘*An update of the UK shadow flicker evidence base*’ produced by Parsons Brinckerhoff. 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.”

8.29 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”.

8.30 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. Furthermore, the PB report also considered the extent to which shadow will be cast as distance increases from the turbines. The PB report quoted text included in the (now superseded) Planning for Renewable Energy – A Companion Guide to PPS22 Office of the Deputy Prime Minister (2004)⁹ which stated:

“At distance, the blades do not cover the sun but only partly mask it, substantially weakening the shadow. This effect occurs first with the shadow from the blade tip, the tips being thinner in section than the rest of the blade. The shadows from the tips extend the furthest and so only a very weak effect is observed at distance from the turbines.”

8.31 Accordingly, in line with the available guidance, this assessment has used a study area that extends to 10 rotor diameters from the 12 proposed wind turbine locations. With a rotor diameter of 150 m, this gives an initial study area of 1,500 m from the proposed wind turbines in all directions as shown in **Figure 8.1**. The study area was then further refined by considering only areas where shadow flicker is geometrically possible given the path the sun takes through the sky over the course of a year.

8.32 **Figure 8.1** also sets out the area that is theoretically susceptible to shadow flicker, this illustrates the proportion of the study area where shadow flicker is possible taking account of the path of the sun across the sky and topographical blocking points (i.e. points where the landform will block the view of the wind turbines). This area is termed the “Assessment Area” on **Figure 8.1**.

- 8.33 Although a study area of 10 times the rotor diameter of the turbines was used for this assessment, the Rossendale Borough Council Validation Checklist notes that RBC will expect a report to be submitted which demonstrates that the impact on occupied properties within a radius of 10 times turbine height and if necessary, any mitigating measures.
- 8.34 To address the requirements of the Rossendale Borough Council Validation Checklist, and subsequent comments from Metrica on behalf of RBC, a response has been prepared and included in **Appendix 2.4**.

Background Studies to Inform the ES

- 8.35 **Table 8.2** summarises all studies / surveys / analysis / evaluations undertaken to inform the assessment presented within this Chapter.

Table 8.2: Studies / surveys / evaluations / analysis undertaken to inform the ES

Study / survey / analysis / evaluation	Overview	Date of completion
A desk-based review of inhabited properties within 10 times the rotor diameter of the proposed wind turbines	Ordnance Survey (OS) building data was used to identify structures and buildings within 10 times the turbine tip height radius of the wind turbines that comprise the Project for Assessment. Aerial imagery and Google Street View were then used to refine the building data to identify only residential buildings, as well as those that appeared inhabited.	April 2025
An assessment of window dimensions	A detailed assessment of window locations at properties within the study area was not undertaken. Instead, a worst-case approach where each façade of the buildings was assumed to be a window was used. This is termed 'the greenhouse approach' and is detailed further below in the Prediction Method / Parameters section.	April 2025

Assessment Process

Identification of Shadow Flicker Assessment Locations (SFALs)

- 8.36 The assessment considers potential receptors which may be sensitive to shadow flicker within the study area. Building location data was obtained through the use of aerial imagery to identify any buildings within the study area, as well as identifying building condition (habitable, derelict, etc.), and building dimensions. Any building that was clearly identified as uninhabitable (such as a farm outbuilding) or 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.

- 8.37 A representative sample of 28 residential properties within the study area were selected for assessment. These receptors were to the north, north-west, and south-east of the Project for Assessment, and are termed here as 'Shadow Flicker Assessment Locations' (SFAL). All SFALs are within the 10 rotor diameter study area (1500 m) of the wind turbines that form part of the Project for Assessment, in line with the guidance outlined above, and their positions are shown on **Figure 8.1**. To the north-west, the identified SFALs are isolated farmhouse properties. To the north, the SFALs are a mix of further isolated farmhouse properties and houses that from the outskirts of the village of Stacksteads. To the south-east, the SFALs are again a mix of isolated farmhouse properties and houses that from the outskirts of the village of Whitworth.
- 8.38 The RBC Local Development Plan 2019 – 2036¹⁰ contains Housing Site Allocation (HAS) areas, where new housing developments will be directed within the Local Authority boundary. There are 68 HSA areas within RBC (outlined in the Local Development Plan and the Policy Map¹¹ termed H1 – H68). The same nomenclature has been used to refer to the HSAs. Two HSA areas are within the study area (H22 and H62) as indicated on **Figure 8.1**. H22 is to the north of the Project for Assessment, between SFALs 5 and 7, and H62 is to the southeast of the Project for Assessment, south of SFAL20. If these housing areas were built out in full, the selection of the representative properties chosen for this assessment would still be a representative sample that would address these areas / additional receptors too. SFAL20 is within H62, and SFAL6 is in front of H22 (as they are either behind an SFAL or between them).
- 8.39 A further two HAS areas are within the 10 rotor tip height region (H24 and H59), which are indicated on **Figure 8.2**. H24 is north of the Project for Assessment, approximately 300m to the north of SFAL14, and H59 is located to the south-east of the Project for Assessment, approximately 200 m to the east of SFAL28. H24 and H59 are outside the study area, in areas where shadow flicker effects will be negligible, so no SFALs represent these areas.
- 8.40 No information regarding other additional receptors has been identified.

Factors that influence shadow flicker

- 8.41 The potential for shadow flicker to occur at a given location and the duration of such an effect depends upon the following factors:
- The location of the building relative to the wind turbine;
 - The distance from the wind turbine;
 - 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); and
 - The wind direction (which impacts on turbine orientation).

Prediction method / parameters

- 8.42 Several specialist software packages are available which can take account of the variables listed above (except for frequency of cloudless skies and wind direction, which cannot be determined in advance) 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 software.
- 8.43 For this assessment, the levels of shadow flicker at each SFAL have been calculated based on a 'greenhouse' modelling approach, where the receptor is considered to be a single window that is always perpendicular to the modelled wind turbines. For the SFALs, each storey of the residential buildings is assumed to have a height of 2.4 m, so, as the buildings are modelled using the greenhouse method, a single story building has modelled windows with a height of 2.4 m, a two storey building has 4.8 m high windows, etc.
- 8.44 Shadow flicker was not calculated for periods when the sun is less than 2° above the horizon. This is because when the sun is close to the horizon, at dawn and dusk, the intensity of the sun's rays is reduced and are less likely to cast distinct shadows and there is an increased likelihood of screening in the form of topography and vegetation.
- 8.45 Wind direction (and the resulting orientation of the wind turbine) has not been considered at this stage, the modelling takes a worst-case approach and assumes that the wind turbine is always 'face on' to the receptor being considered.
- 8.46 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 assessment, climate data from the nearest long-term weather station to the Project for Assessment (Rochdale climate station (Lat (deg): 53.60, Lon (deg): -2.17) approximately 4.6km south of the Assessment Boundary) has been used to determine the average sunshine hours; this data is presented in **Table 8.3**. These values are used in this assessment to calculate what the likely amounts of shadow flicker at the assessed at the SFALs would be, given the historical record of cloudy and clear skies. These values are used to calculate a percentage of daytime hours with sun for each month. Calculated shadow flicker for each month under the worst-case scenario is reduced to these percentages. For example, if 30% of daylight hours have historically been sunny in March, then shadow flicker predicted in March under the worst-case scenario was reduced to 30% of the worst-case value.
- 8.47 It is worth noting that this correction does not account for additional reductions that would occur as a result of variations in wind speed, wind direction, or by determining whether there is line of sight between the turbine and receiver. The predicted levels of shadow flicker are, therefore, still considered to be a conservative estimate.

Table 8.3: Average daily sunshine hours per month at Rochdale Weather Station

Month	Mean Daily Sunshine Hours (hh:mm)	Percentage of Average Daylight Hours with Sunshine
January	1:02	13%
February	1:46	18%
March	3:11	27%
April	5:05	36%
May	5:39	35%
June	5:05	30%
July	5:30	34%
August	4:57	34%
September	3:52	31%
October	2:32	24%
November	1:23	16%
December	1:22	18%

Reporting of the Environmental Effect and Significance Criteria

- 8.48 The assessment of likely significant environmental effects as a result of the Project for Assessment has taken into account the operational stage. The following sections define the approach adopted within the assessment for the determination of sensitivity, magnitude of impact, the level of effect and significance.

Determining Sensitivity of Receptor

- 8.49 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 judgement.
- 8.50 Although no published standard exists that outline sensitivity to shadow flicker, some types of receptors are considered to be more sensitive to shadow flicker than others. For example, a residential property versus a barn. 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.
- 8.51 As this assessment only considers receptors that would have a high 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

- 8.52 The magnitude of impact in this assessment has been considered against prescribed thresholds and has been considered on a scale of **large, medium, small** or **negligible**.
- 8.53 No formal guidance is available regarding what levels of shadow flicker may be considered acceptable in the UK or how to consider the magnitude of impact. However, guidance and legislation relating to shadow flicker is available for other countries around the world.
- 8.54 The 'International Legislation and Regulations for Wind Turbine Shadow Flicker Impact'¹² 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'¹³.
- 8.55 The limit values within the German guidelines are 30 minutes per day and 30 days per year. These limits are, however, based on 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. If it is found that mitigation measures are required, then a further limit value of 8 hours per year is set based on the real case shadow flicker, i.e. what is actually occurring and not the theoretical maximum that may occur.
- 8.56 Many countries have adopted the German guideline limits, 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 a year or 30 minutes a day. The UK has no set limit but also typically adopts these guideline levels for assessment purposes.
- 8.57 For this assessment, the following definitions have been used:
- Any theoretical shadow flicker exceeding the 30 hours per year or 30 minutes per day constitutes a **large** magnitude of impact;
 - Any theoretical shadow flicker exceeding 20 hours per year or 20 minutes per day, but less than 30 hours per year or 30 minutes per day, constitutes a **medium** magnitude of impact;
 - Any theoretical shadow flicker equal to or less than 20 hours per year or 20 minutes per day, constitutes a **small** magnitude of impact; and
 - Although shadow flicker is possible at distances exceeding 10 rotor diameters from a turbine, any daily or annual duration of shadow flicker experienced at these distances is not considered to be problematic. Therefore, any amount of theoretical shadow flicker at receptors exceeding 10 times the rotor diameter of the turbines that comprise the Project for Assessment is considered to constitute a **negligible** magnitude of impact.
- 8.58 Theoretical shadow flicker in this context is identical to that from the German guidance and means the 'worst case' shadow flicker, in that this is the amount of shadow flicker

predicted assuming that the sun is always shining, the blades are always spinning and the turbines are always facing the receptors.

Determining the Level of Effect

8.59 The level of effect has been informed by the magnitude of impact due to the Project for Assessment, the evaluation of the sensitivity of the affected receptor. The level of effect has been determined using professional judgement and **Table 8.4** has been a tool which has assisted with this process.

8.60 Whilst **Table 8.4** provides ranges, the level of effect is confirmed as a single level and not a range, informed by professional judgement, where possible.

Table 8.4: Matrix to support determining the level of effect

Magnitude of change (or impact)	Sensitivity				
		High	Medium	Low	Negligible
	Large	Major	Moderate to Major	Minor to Moderate	Negligible
	Medium	Moderate to Major	Moderate	Minor	Negligible
	Small	Minor to Moderate	Minor	Negligible to Minor	Negligible
	Negligible	Negligible	Negligible	Negligible	Negligible

8.61 The following terms have been used to define the level of the effects identified and these can be 'beneficial' or 'adverse':

- **Major effect:** Where the Project for Assessment is likely to cause a considerable change from the baseline conditions and the receptor has limited adaptability, tolerance or recoverability or is of the highest sensitivity;
- **Moderate effect:** Where the Project for Assessment is likely to cause either a considerable change from the baseline conditions at a receptor which has a degree of adaptability, tolerance or recoverability or a less than considerable change at a receptor that has limited adaptability, tolerance or recoverability;
- **Minor effect:** Where the Project for Assessment is likely to cause a small, but noticeable change from the baseline conditions on a receptor which has limited adaptability, tolerance or recoverability or is of the highest sensitivity; or where the Project for Assessment is likely to cause a considerable change from the baseline conditions at a receptor which can adapt, is tolerant of the change and / or can recover from the change; and
- **Negligible:** Where the Project for Assessment is unlikely to cause a noticeable change at a receptor, despite its level of sensitivity or there is a considerable change at a receptor which is not considered sensitive to a change.

- 8.62 The duration of the effect has been assessed as either 'short-term', 'medium-term' or 'long-term'. Short-term is considered to be up to 1 year, medium-term is considered to be between 1 and 10 years and long-term is considered to be greater than 10 years.

Determining Significance

- 8.63 For each effect, a statement has been made as to whether the level of effect is '**Significant**' or '**Not Significant**'. This determination has been based on professional judgement and / or relevant guidance / legislation, where applicable.
- 8.64 Significance has only been concluded for residual effects (i.e. following the identification of secondary mitigation).
- 8.65 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 shadow flicker exceeding 30 hours per year **or** 30 minutes per day is the threshold for significant. Exceedance of either of these limits (i.e. a Major effect) 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.
- 8.66 Although the German guidance for shadow flicker has been adopted, which references the theoretical worst-case levels of shadow flicker, it is important to note that these values should be seen in the context of several mitigating factors that will reduce the levels or perceived effect of shadow flicker.
- The sun will not always be shining. During cloudy times of the day, shadow flicker will not be possible;
 - Screening of the turbines from other buildings, trees, and other obstacles will reduce or eliminate shadow flicker in some cases;
 - Shadow flicker is less perceptible or imperceptible when the turbines are side on to the receptor. As turbines cannot face all directions at once, some shadow flicker will be eliminated for certain receptors, depending which way the wind is blowing and which direction the turbines are facing at the time;
 - Shadow flicker occurring in the summer may occur very early in the day or very late in the evening when people are asleep or will usually have the curtains drawn, so will not perceive shadow flicker;
 - The windows included in the model have been estimated using the greenhouse approach. In practice the windows will be smaller and may not face the Project for Assessment; and.
 - Shadow flicker in some rooms will likely not be perceived as negatively as in others, such as a garage or bathroom, versus a living room or bedroom.

Baseline Conditions

- 8.67 There is considered to be currently no shadow flicker at the identified SFALs.
- 8.68 There are 28 SFALs that have been considered in this assessment, which are deemed to be a representative sample of the residential properties within the study area. **Table 8.5** provides details of the chosen SFALs.

Table 8.5: Details of SFALs

SFAL Name	Easting	Northing	Window Width (m)	Window Height (m)
SFAL1	383674	420425	14.5	4.8
SFAL2	383941	420083	22.5	4.8
SFAL3	384059	420538	10	4.8
SFAL4	384106	420748	10	4.8
SFAL5	384387	420935	12.3	4.8
SFAL6	384825	420785	24	4.8
SFAL7	385260	421331	14.6	4.8
SFAL8	385516	421093	20	4.8
SFAL9	385627	421216	15	4.8
SFAL10	385686	421434	8	4.8
SFAL11	385735	421392	8	4.8
SFAL12	385761	421482	11	4.8
SFAL13	385851	421330	7	4.8
SFAL14	385862	421491	8.5	4.8
SFAL15	386033	421309	5	4.8
SFAL16	386184	421362	10	4.8
SFAL17	386539	421405	16	4.8
SFAL18	387583	418439	7.5	4.8
SFAL19	387679	417451	12	4.8
SFAL20	387778	417158	9	4.8
SFAL21	387828	417801	7	4.8
SFAL22	387858	417254	7	4.8
SFAL23	387939	417006	7	4.8
SFAL24	387950	417464	7	4.8
SFAL25	387977	417818	18.5	4.8
SFAL26	387983	417623	6.5	4.8

SFAL Name	Easting	Northing	Window Width (m)	Window Height (m)
SFAL27	387998	417281	6	4.8
SFAL28	388060	417453	8	4.8

Future Baseline

- 8.69 Shadow flicker can only occur with the presence of a wind turbine or a similar rotating object. If the Project for Assessment were not constructed, since no such other developments are planned or proposed in the study area, shadow flicker is not expected at any current or future receptors. The future baseline is therefore zero shadow flicker.

Primary and Tertiary Mitigation

Operational Stage

- 8.70 The primary and tertiary mitigation which has been evaluated as part of the operational stage assessment is outlined below.
- Operational shadow flicker has been a key consideration throughout the design process for the Project for Assessment. The design presented in this assessment is the result of an iterative process, to ensure that the final wind turbine layout and their locations strike a balance between maximising the potential for renewable energy generation while providing appropriate protection of residential amenity.

Assessment of Effects, Secondary Mitigation and Residual Effects

Operational Stage

Shadow Flicker

- 8.71 The predicted theoretical levels of shadow flicker at the SFALs accounting for primary mitigation only are outlined below in **Table 8.6**. Results in columns 2 and 4 of **Table 8.6** are colour coded to indicate where the 30 minute or 30 hour thresholds outlined in 'Determining Magnitude of Impact' apply. Where the name of the SFAL is shown in **bold**, this indicates that the 30 minute or 30 hour threshold has been exceeded.
- 8.72 For additional context the 'cloud corrected' predicted levels have also been included in column 5. These values have been adjusted to consider the likely sunshine hours detailed above in **Table 8.3**.

Table 8.6: Predicted theoretical levels of shadow flicker

SFAL name	Number of days per year on which shadow flicker can occur	Maximum Theoretical Shadow Hours per year (hh:mm)	Maximum Theoretical Hours of Shadow Flicker per day (hh:mm)	Cloud Corrected Hours of Shadow Flicker per year (hh:mm)
SFAL1	88	26:01	00:36	04:45
SFAL2	120	46:02	00:44	11:44
SFAL3	64	24:04	00:35	05:23
SFAL4	37	12:06	00:27	02:29
SFAL5	61	22:30	00:29	03:21
SFAL6	79	74:53	01:12	11:52
SFAL7	37	12:31	00:24	02:08
SFAL8	36	12:33	00:33	01:49
SFAL9	63	54:06	01:01	08:48
SFAL10	42	14:12	00:25	02:24
SFAL11	43	14:02	00:24	02:22
SFAL12	30	07:56	00:20	01:23
SFAL13	0	00:00	00:00	00:00
SFAL14	19	03:32	00:14	00:38
SFAL15	23	05:33	00:18	00:59
SFAL16	9	01:04	00:10	00:11
SFAL17	23	05:13	00:17	00:56
SFAL18	69	18:29	00:24	04:54
SFAL19	46	19:31	00:33	06:44
SFAL20	58	22:08	00:30	07:38
SFAL21	34	10:32	00:28	03:00
SFAL22	45	15:27	00:28	05:21
SFAL23	62	19:54	00:26	06:47
SFAL24	34	11:38	00:26	03:58
SFAL25	26	05:35	00:20	01:36
SFAL26	32	10:15	00:25	03:14
SFAL27	38	12:02	00:25	04:11
SFAL28	34	10:08	00:24	03:27
SFALs with less than 20 minutes of predicted theoretical worst-case shadow flicker per day or 20 hours of predicted theoretical worst-case shadow flicker per year				
Key	[Blank]			
Key		SFALs with between 20 and 30 minutes of predicted worst-case shadow flicker per day, or between 20 and 30 hours of predicted theoretical worst-case shadow flicker per year		
		SFALs with 30 or more minutes of predicted worst-case shadow flicker per day, or 30 hours of predicted theoretical worst-case shadow flicker per year.		

- 8.73 Shadow flicker has the potential to occur at 27 of the 28 SFALs assessed, with SFAL13 predicted to experience no shadow flicker across the year. When considering all SFALs, shadow flicker has the potential to occur in every month of the year, on 336 out of 365 days. Across all SFALs, shadow flicker can occur at the earliest at 06:56. The last time with shadow flicker at any of the assessed SFALs is 20:14.
- 8.74 An assessment of shadow flicker at the SFALs with regard to the 30 hours per year and 30 minutes per day thresholds is presented below. As each SFAL is a residential receptor, the sensitivity of all SFALs is considered to be high.

30 Hours per Year Threshold

- 8.75 Under the worst-case scenario, where the sun is always shining and the turbines are always spinning, three SFALs exceed the 30 hour a year threshold, SFAL2, SFAL6 and SFAL9 (highlighted in blue in **Table 8.6**). The highest levels of shadow flicker predicted to occur at SFAL6, which would receive a maximum of 74 hours and 53 minutes of shadow flicker. The lowest amount of shadow flicker predicted at these three receptors is at SFAL2, at 46 hours and two minutes a year. For these three SFALs the magnitude of impact is considered to be large. Therefore, there is likely to be a direct, temporary, long-term, adverse effect which is considered to be major.
- 8.76 There are four SFALS (SFAL1, SFAL3, SFAL5, and SFAL20) where the amount of predicted shadow flicker is more than 20 hours per year, but less than 30 hours per year, and as such the magnitude of impact is considered to be medium. Therefore, there is likely to be a direct, temporary, long-term, adverse effect, which is considered to be moderate.
- 8.77 There are 20 SFALs where the amount of predicted shadow flicker per year is less than 20 hours (excluding SFAL13 where no shadow flicker was predicted), and so the magnitude of impact is considered to be small. Therefore, there is likely to be a direct, temporary, long-term, adverse effect which is considered to be minor.
- 8.78 It is worth noting however that, under the cloud corrected scenario, which takes into account the average levels of sunshine outlined in **Table 8.6**, the predicted number of hours decreases substantially. SFAL6 would receive the greatest amount of predicted shadow flicker, at 11 hours and 52 minutes. Aside from SFAL13, the lowest levels of shadow flicker under this scenario are still predicted at SFAL16, at 11 minutes.

30 Minutes per Day Threshold

- 8.79 When considering the 30 minutes of shadow flicker a day threshold, seven of the SFALS (SFAL1, SFAL2, SFAL3, SFAL6, SFAL8, SFAL9, and SFAL19) assessed exceed the limit to be considered significant. These are highlighted blue in **Table 8.6**. SFAL6 is predicted to experience the greatest levels of shadow flicker in a single day, at up to one hour and 12 minutes.
- 8.80 For the seven SFALs that are predicted maximum daily levels of shadow flicker exceeding the 30 minute a day threshold, the magnitude of impact is considered to be large. Therefore, there is likely to be a direct, temporary, long-term, adverse effect which is considered to be major.

- 8.81 For the 15 SFALs that are predicted maximum daily levels of shadow flicker between 20 and 30 minutes per day (highlighted in pink in **Table 8.6**, the magnitude of impact is considered to be medium. Therefore, there is likely to be a direct, temporary, long-term, adverse effect which is considered to be moderate.
- 8.82 Five SFALs (SFAL14, SFAL15, SFAL16, SFAL17, and SFAL25) are predicted to experience maximum daily levels of shadow flicker between zero and 20 minutes per day, and the magnitude of impact is considered to be small. Therefore, there is likely to be a direct, temporary, long-term, adverse effect which is considered to be minor.
- 8.83 SFAL13 is predicted to experience zero hours of shadow flicker, and as such the magnitude of impact is considered to be negligible. Therefore, there is likely to be a direct, temporary, long-term, adverse effect which is considered to be negligible.
- 8.84 Application of micrositing allowance has the potential to reduce or increase the predicted levels of shadow flicker, although the impact on the predicted number of hours is expected to be small.

Secondary Mitigation or Enhancement

- 8.85 As stated above, there are no guidelines in the UK which quantify what exposure levels of shadow flicker are acceptable. However, in order to comply with the limits outlined in the German shadow flicker guidance used here, a shadow flicker turbine control system will be installed during the construction of the wind farm that can be used to mitigate the effects of shadow flicker.
- 8.86 The system will halt turbines when the system detects that it is geometrically possible for shadow flicker to occur and the environmental conditions necessary for shadow flicker to occur (the sun shining and the wind blowing) are present. The operation of these systems can be proactive, reactive, or both:
- With the proactive approach, modelled shadow flicker events are mitigated before any complaints could be received. Some or all predicted events of shadow flicker are mitigated when the conditions for shadow flicker occur, regardless of whether they cause a disturbance;
 - With the reactive approach, no mitigation is implemented immediately. If complaints relating to shadow flicker are received, the shadow flicker control system is used to stop the turbines during periods to which the complaints are related, assuming that the conditions for shadow flicker to occur are met; or
 - With a combined approach, some shadow flicker events are mitigated proactively, and others are dealt with reactively.
- 8.87 It is proposed that a combined approach is adopted, where predicted shadow flicker impacts on SFALs located within 10 rotor diameters of a proposed wind turbine will be proactively mitigated using a shadow flicker control system. Shadow flicker control systems will be included on the wind turbines, which can be used to deactivate the wind turbines should shadow flicker effects be geometrically possible and the conditions for shadow flicker (such as the sun shining and the blades spinning) are also met. The system would be designed based on a detailed survey undertaken post-

consent and would mitigateⁱⁱⁱ shadow flicker at all of the identified SFALs located within 10 rotor diameters of a turbine. This will be provided as part of an operational shadow flicker management strategy.

- 8.88 Reactive mitigation will be used for all properties located beyond 10 rotor diameters of a turbine.
- 8.89 This combined approach 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.”*
- 8.90 Furthermore, paragraph 2.12.166 of NPS EN-3 states that *“In circumstances where a wind turbine has the potential to affect a property but can be controlled to minimise shadow flicker, the Secretary of State should give no weight to the shadow flicker impacts on that property.”* While this text relates specifically to NSIPs, it provides support on the use and effectiveness of modern shadow flicker control systems.
- 8.91 The installation, set up, and operation of the shadow flicker control system can be secured by requirements to the development consent, in the form of a suitably worded planning condition.
- 8.92 Following the implementation of this secondary mitigation, minimal shadow flicker would occur as a result of the Project for Assessment. As such, shadow flicker at all properties within 10 rotor diameters of a turbine will be negligible, as will shadow flicker at all occupied properties within the 10 x tip height study area.

Residual Effect

- 8.93 The sensitivity of all SFALs is considered to be high. The magnitude of change, following secondary mitigation, is considered to be negligible. Therefore, there is likely to be a direct, temporary, long-term, adverse residual effect which is considered to be **negligible**.
- 8.94 Application of micrositing allowance does not change the residual level of effect reported above as the final location of the wind turbines would be considered in the design of the shadow flicker control system.

Significance

- 8.95 This effect is considered to be **Not Significant**.

ⁱⁱⁱ It should be noted that the mitigation provided by the shadow flicker control system will be subject to a response time (e.g. if the sun appears on an otherwise cloudy day the turbine will react to the changing conditions and perform a controlled shut down). Short periods of shadow flicker may therefore occur, but the system will reduce levels as far as is reasonably practical.

Limitations and Assumptions

- 8.96 To ensure transparency within the EIA process, the following limitations and assumptions have been identified.
- A representative sample of 28 receptors within the study area were assessed as opposed to all occupied properties within the study area;
 - The dimensions of each property, as input into the modelling software, were informed by aerial imagery rather than measured on-site. As such, accurate window dimensions were not available for the SFALs, and therefore modelling was undertaken using the greenhouse approach; and
 - The final turbine selection for the Project for Assessment is unknown at this stage therefore a candidate turbine has been used.
- 8.97 Although these information gaps have been identified, the assessment has considered a worst-case scenario using the available data and the use of more precise information would reduce the values presented in this report. Therefore, sufficient information has been able to identify and assess the likely significant effects.

Summary

- 8.98 **Table 8.7** provides a summary of the effects, receptors, residual effects and conclusions of significance considered within the Chapter.
- 8.99 The table only provides a summary of the residual effects identified within the assessment and details of all primary and secondary mitigation measures that have been taken into account are set out in detail within the Chapter and summarised in the Environmental Management Plan included in **Volume 3: Environmental Management Plan**.

Table 8.7: Summary of residual effects

Effect	Receptor	Residual effect	Is the residual effect Significant?
Operational stage			
Shadow flicker	Residential properties within 1500 m of the proposed turbines (as shown in Figure 8.1).	Negligible adverse	No

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