19 Shadow Flicker

19.1 Introduction

19.1.1 Since the submission of the previous application for Beaw Field, an updated search was undertaken in May 2022 and no new sensitive receptors were identified in addition to those previously considered and therefore there are no changes to the baseline information previously presented. Given that the infrastructure of the Consented Development is not changing, there would be no shadow flicker effects. The findings of the previous shadow flicker assessment therefore remain valid, and the previous shadow flicker chapter is set out in full below, with a brief update included in relation to planning policy.

19.1.2 This chapter has been prepared by Wardell Armstrong LLP which has extensive experience of providing advice on the predicted effects of wind farm induced shadow flicker. The chapter presents a shadow flicker assessment for the Consented Development. The assessment is based on the description of the development presented in Chapter 3: Project Description.

19.1.3 The final choice of wind turbine has yet to be determined and so, for the purposes of the shadow flicker assessment, a candidate wind turbine with maximum dimensions coincident with the planning envelope was chosen in order to asses potential impacts. The candidate wind turbine has a hub height of 93m and a rotor diameter of up to 104m, giving an overall tip height of 145m. Other proposed infrastructure to be installed on the site includes the substation, access tracks and crane pads but these will not contribute to shadow flicker effects.

Risk and shadow flicker effects

19.1.4 Under certain daylight conditions, the relative position of the Earth and Sun can cause shadows to be cast from a wind turbine. These shadows move as the turbine blades rotate and the sun appears to track across the sky. At certain times of the day and of the year, this shadow movement may be cast across nearby dwellings. When observed from inside the building and viewed through a narrow aperture such as a window, the effect created may appear as a flickering of light and shadow. This phenomenon is known as shadow flicker. The potential significance of the effect of shadow flicker is dependent on a number of factors:

- The location of the relevant building relative to the position of the sun and the turbine;
- The distance of turbine from such buildings, the size of the window apertures and their location in the building relative to the turbine;
- The turbine height and rotor diameter;
- The presence of intervening topography, buildings or vegetation;
- The frequency of bright sun and cloudless skies;
- The time of the year; and
- The prevailing wind direction and rotor orientation.

19.1.5 Wind turbine objectors elsewhere have expressed concerns that shadow flicker from wind turbines may result in stroboscopic effects[a] that could induce epilepsy or similar symptoms. The effects of light flicker on humans in relation to shadow flicker from wind turbines have been reviewed by Verkuijlen and Westra[1] and again by Clarke[2]. Both references conclude that the frequencies capable of triggering epilepsy and general disturbance lie between 2.5Hz and 3Hz. Epilepsy is estimated to affect approximately 1% of the UK population[3], only 5% of which (0.05% of the population) have shown anomalous EEG[b] reactions to flickers as low as 2.5Hz.

19.1.6 Modern large-scale wind turbines of the type likely to be installed as part of the Consented Development operate at rotational speeds of up to about 22 revolutions per minute (rpm). Given the turbines will have three blades, the frequency at which a blade will pass a particular point will be up to about 66 times a minute which equates to 1.1 flashes per second (hertz). This is significantly less than the 2.5 to 3Hz frequency range generally thought to induce photosensitive epilepsy. As a result the issue of photosensitive epilepsy is not considered further in this assessment as there are no predicted adverse health effects.

19.2 Legislation, policy, and guidance

19.2.1 Shadow flicker is mentioned in Scottish Planning Policy (SPP, June 2014) at paragraph 169 as one of several considerations that must be taken account of in relation to energy infrastructure developments. Chapter 4 of the EIAR sets out the planning policy framework that is relevant to the Environmental Impact Assessment.

19.2.2 Draft National Planning Framework (NPF) 4 is under preparation and will include all aspects of national planning policy as per the provisions of the Planning (Scotland) Act 2019 and will replace NPF3 once adopted.Draft NPF4 requires that development proposals for renewable energy developments must take into account impacts on communities and individual dwellings, including shadow flicker.

19.2.3 In Scotland the current advice on shadow flicker is contained in the online guidance on Onshore wind turbines[4].

'Under certain combinations of geographical position, time of day and time of year, the sun may pass behind the rotor and cast a shadow over neighbouring properties. When the blades rotate, the shadow flicks on and off; the effect is known as "shadow flicker". It occurs only within buildings where the flicker appears through a narrow window opening.

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

19.2.4 Research by Department of Energy and Climate Change[5] states:

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[a] Stroboscopic effect is an optical phenomenon that causes moving objects to appear stationary when viewed in discrete series of short or instantaneous samples as distinct from a continuous view.
[b] Electroencephalography (EEG) is an electrophysiological monitoring method to record electrical activity of the brain. It is typically non-invasive, with the electrodes placed along the scalp, although invasive electrodes are sometimes used in specific applications.

‘*On health effects and nuisance of the shadow flicker effect, it is considered that the frequency of the flickering caused by the wind turbine rotation is such that it should not cause a significant risk to health. Mitigation measures which have been employed to operational windfarms such as turbine shut down strategies, have proved very successful, to the extent that shadow flicker cannot be considered to be a major issue in the UK.*’

19.2.5 In addition to the above the Shetland Islands Council scoping response requests that consideration be given to the potential for shadow flicker to affect motorists travelling along the B9081.

19.3 Methodology

19.3.1 The seasonal duration of shadow flicker can be calculated from the geometry of the turbine and the latitude and topography of the Site.

19.3.2 The modelled shadow flicker is often an over-statement compared with actual shadow flicker occurrences once a wind farm is built. This is because modelling does not take into account a number of variables and site-specific factors which may serve to reduce the level of shadow flicker which occurs in practice:

- The proportion of day-light hours in which the turbines operate (wind turbines do not operate all the time, not rotating in calm and very high wind speeds and switching off during maintenance periods);
- The frequency of bright sunshine and cloudless skies (particularly at low elevations above the horizon);
- The prevailing wind direction; and
- The potential for screening from other buildings, walls and vegetation.

19.3.3 The model assumes that each of the receptors (typically a residential property) has a window facing each of the wind turbines which is rarely the case.

19.3.4 The model also assumes that the wind turbines are turned such that the swept area of the rotor occupies a plane perpendicular to the line of sight from the sun through the rotor and to the receptor, i.e. the software assumes that the turbine always aligns itself to face the sun and follow its trajectory, rather than following the wind’s direction. This maximises the areas shadowed by the rotors during flicker events and presents a worst case scenario.

19.3.5 Finally, the model assumes that turbines operate 100% of the time which is not the case as they are sometimes stopped due to either low or excessively high winds and for maintenance purposes.

19.3.6 The candidate wind turbine selected for the shadow flicker modelling has a 93m hub height and a rotor diameter of 104m. This turbine represents the most likely rotor diameter of the turbines currently being considered for the Consented Development and therefore the results of the modelling are representative of the highest possible levels of shadow flicker exposure. Shadow strength decreases with distance from the source and it is generally accepted that shadow flicker is not an issue at distances greater than 10 times the turbine rotor diameter (10D). On this turbine model this distance is 1,040m.

19.3.7 Notwithstanding this, to ensure that properties immediately outside this 10D boundary are included the actual assessed area was approximately 11D (1,144m). This area is subsequently referred to as the Study Area.

19.3.8 Figure 19.1 identifies the location of properties falling within the Study Area, which are all the properties located within 11 rotor diameters of the wind turbines. A further breakdown of these properties including their respective grid reference is provided in Table 19.1. Only properties within 130° either side of north, relative to the turbines can be affected at these latitudes in the UK, as turbines do not cast long shadows in their southern quadrant.

19.3.9 The further the observer is from the turbine the less pronounced the effect will be. There are several reasons for this:

- There are fewer times when the sun is low enough to cast a long shadow;
- When the sun is low it is more likely to be obscured by either cloud on the horizon or intervening buildings and vegetation;
- The centre of the rotor's shadow passes more quickly over the land reducing the duration of the effect; and
- 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.

19.3.10 Shadow flicker can be avoided by siting wind turbines at sufficient distance from residential properties likely to be affected.

19.3.11 Assessment of potential shadow flicker from the turbines has been undertaken using RESOFT WindFarm®, version 4.2.5.1, an industry standard software package widely used for design and assessment of wind farms. The software does not take into account prevailing climatic conditions and therefore presents a worst case scenario unlikely to be replicated in reality. In Britain, average daily sunshine hours range from between one and two in midwinter to between five and seven in midsummer. Winter sunshine is much reduced because of low cloud cover, fog and mist. This is a consequence of winds from the Atlantic and seas surrounding Britain, which bring high humidity[6].

19.3.12 Figure 1, Appendix 19.1 illustrates the variation in sunrise and sunset times over the course of the year (2016) for the Site[7]. This illustrates that a shadow flicker event occurring at 04:00 GMT in June is valid, whilst it is not possible to obtain such an effect at 08:00 GMT in January because there will be no sunlight.

19.3.13 The total number of daylight hours available each month, based on the site location is shown on Figure 2, Appendix 19.1. Also shown is the average number of hours of sunshine each month taken from Met Office data recorded at Lerwick weather station between 1930 and 2015[8]. At a distance of approximately 42km, this is the closest Met Office weather station to the site with historical sunshine records.

19.3.14 Additionally Figure 2, Appendix 19.1 shows the ratio of sunshine to daylight displayed as a percentage for each month. The data illustrates that even in the sunniest month (May), the actual incidence of shadow flicker events are expected to be around just 30.5% of that indicated by the model. During less sunny months, such as December, less than 8.5% of the predicted shadow flicker events may be expected to occur.

19.3.15 The relevant guidance gives no reference to significance criteria and therefore the basis for the significance criteria has been derived from professional understanding and extensive previous experience of shadow flicker intensity and duration from operational projects. For the purpose of this assessment, it has been assumed that any shadow flicker effects observable at residential properties within the Study Area will be significant in EIA terms and will therefore require mitigation.

Limitations

19.3.16 It is important to note that while the methodology presented here follows the best practice guidelines for undertaking a shadow flicker assessment there are some restrictions with the way the results should be used and interpreted. The digital terrain data used in the RESOFT WindFarm® model assumes a bare earth situation. This presents a worst case scenario as it ignores potential for screening from intervening hedges, trees, and buildings all of which could serve to reduce the amount of shadow flicker that will theoretically be observable at some properties.

19.3.17 Furthermore, the results are based on the sun path for 2016 and subsequent years will vary slightly although not significantly. Shadow flicker times are indicative and represent approximate times of events and duration. This study cannot be used post planning to implement shutdown times for wind turbines. If accurate off/on times are required, subject to investigation following complaint, a more detailed Digital Terrain Model (DTM), OS MasterMap base map and window/screening survey would need to be undertaken and the shadow flicker assessment repeated.

19.4 Baseline

19.4.1 Residential properties within the Study Area have been identified from OS Address base Plus data, aerial photography and from site survey. A list of the properties within the Study Area is presented in Table 19.1 and shown in Figure 19.1.

Table 19.1: Residential properties within the study area

House ID	*Easting*	*Northing*	*Building*	*Locality*	*Postcode*
1	452663	1183263	Middlesbrough	Gossabrough	ZE2 9AU
2	452625	1183152	Toonigarth	Gossabrough	ZE2 9AU
3	452755	1183028	Wirliegarth	Gossabrough	ZE2 9AU
4	452905	1182984	Gunnigarth	Gossabrough	ZE2 9AU
5	451773	1180560	Easterleigh	East Yell	ZE2 9AY
6	451823	1180356	Islesview	East Yell	ZE2 9AY
7	451911	1180310	Viewforth	East Yell	ZE2 9AY
8	452212	1180304	The Old Manse	East Yell	ZE2 9AY
9	452283	1180276	Olasound	Burravoe	ZE2 9AY
10	452347	1180261	Belvedere	Burravoe	ZE2 9AY
11	452390	1180265	Gentletown	Burravoe	ZE2 9AY

Table 19.1: Residential properties within the study area

House ID	Easting	Northing	Building	Locality	Postcode
12	451767	1180293	Westerleigh	East Yell	ZE2 9AY
13	451879	1180244	Shinshima	East Yell	ZE2 9AY
14	451928	1180202	Ullinish	East Yell	ZE2 9AY

19.4.2 There are two clusters of properties within the Study Area. Four dwellings are located to the northeast of Turbine 9 and a further cluster of 10 dwellings is located to the south of Turbines 16 and 17. There are no other dwellings within the defined Study Area.

19.4.3 There are no current shadow flicker effects on the houses identified in this Study Area as a result of existing wind farm development.

19.4.4 For the Consented Development, shadow flicker modelling was undertaken for the properties identified in Table 1, Appendix 19.1 (and shown in Figure 19.1), the distances and directions highlighted in yellow indicate which turbines would potentially result in shadow flicker at the properties. The turbine locations used for the analysis are given in Chapter 3: Project Description

19.4.5 It has been assumed that each house within the Study Area has a window of 1m × 1m, positioned at a height-to-centre of 2m above ground level directly facing each of the proposed wind turbines, as experience shows that this will give a good indication of the likely duration of shadow flicker at each of the properties. The properties have not been surveyed to determine the presence and size of facing windows for the purposes of this assessment.

19.4.6 As identified in Paragraph 19.2.5, The Shetland Islands Council scoping response requests that consideration be given to the potential for shadow flicker to affect motorists travelling along the B9081. The B9081 passes through the site running north to south with turbines T7, T10, T14 and T16 to the west and turbines T9, T13, and T15 to the east.

19.5 Assessment of impacts

19.5.1 The results of the shadow flicker assessment are summarised in Table 19.2 and Table 19.3. The results in Table 19.3 have been corrected to account for the expected climatic conditions i.e., the expected amount of sunshine relative to daylight hours during those months when shadow flicker is theoretically possible. Figure 19.2 shows a map with contours indicating the total duration of potential shadow flicker events per annum.

Table 19.2: Summary of shadow flicker times on each house from each turbine

House & turbine shadow interactions	Distance between house and turbine (m)	Degrees from house to turbine(°)	Number of days when flicker may occur per turbine	Total number of days when flicker may occur	Maximum hours of flicker in a day per turbine	Maximum hours of flicker in a day	Average number of hours of flicker per day per turbine	Average number of hours of flicker per day	Total number of hours per year per turbine	Total number of hours per year
H1 T9	1,022	221	42	84	0.44	0.6	0.33	0.38	14.1	31.9
H1 T12	1,090	206	55		0.42		0.32		17.8	
H2 T7	1,113	207	31	119	0.40	0.62	0.31	0.39	9.7	46.5
H2 T9	914	244	42		0.48		0.39		16.2	
H2 T12	973	223	57		0.47		0.36		20.5	
H3 T9	930	217	38	78	0.47	0.48	0.37	0.40	14.0	31.0
H3 T12	937	234	46		0.48		0.37		17.0	
H4 T9	1,034	246	33	69	0.42	0.44	0.33	0.35	10.8	24.0
H4 T12	1,003	241	38		0.44		0.35		13.2	
H5 T15	1,023	19	0	0	0	0	0	0	0	0
H5 T16	888	349	0	0	0	0	0	0	0	0
H5 T17	907	40	0	0	0	0	0	0	0	0
H6 T16	1,098	349	0	0	0	0	0	0	0	0
H6 T17	1,045	31	0	0	0	0	0	0	0	0
H7 T17	1,044	25	0	0	0	0	0	0	0	0
H8 T17	961	9	0	0	0	0	0	0	0	0
H9 T17	981	4	0	0	0	0	0	0	0	0
H10 T17	993	1	0	0	0	0	0	0	0	0
H11 T17	990	358	0	0	0	0	0	0	0	0
H12 T10	1,128	32	0	0	0	0	0	0	0	0
H13 T10	1,118	25	0	0	0	0	0	0	0	0
H14 T10	1,136	22	0	0	0	0	0	0	0	0

19.5.2 In order to consider the shadow flicker effects on vehicles passing through the Consented Development on the B9081 it is necessary to consider what shadow flicker is. It has potential to cause 'nuisance' but is not considered to be a health and safety issue. To experience shadow flicker from a turbine you would need to be in a particular location being shadowed by the rotor for a period of time. As cars will generally be moving along a road they would pass out of any shadow zone from a particular turbine very quickly. There would be some potential for successive turbines on the same side of the road to cast shadows over the road but turbines on the opposite side of the road would not as the shadows would be cast away to the other side. To receive shadow flicker for an extended period of time whilst travelling along a road the driver would need to be facing towards the sun with the rotors interrupting the light from the sun to the vehicle. In this situation, given the relatively low rotational speed of the candidate turbine, the momentary respite from the sun's intensity may actually be beneficial for the driver who would otherwise be subjected to its continuous glare.

Predicted effects

19.5.3 Figure 19.2 shows the modelled shadow flicker effects. The theoretical duration of shadow flicker modelled at properties H1 to H4 is shown in Table 19.2 above. Houses H5 to H18 are not expected to experience shadow flicker from the operational turbines.

19.5.4 The instances of shadow flicker would always be less than that predicted by the model as it is based on a worst case scenario. The occurrence of shadow flicker is only possible during the operation of the wind turbines (i.e., when the rotor blades are turning) and when the sky is clear enough to cast shadows. It is therefore relevant to consider the following factors in order to evaluate predicted effects:

- The modelling assumes that each house has a window facing towards the turbine which is within the Study Area. In reality some of the properties may not have any windows facing the turbine.
- Climatic conditions dictate that the sun is not always shining. Cloud cover, fog and mist obscure the sun and prevent shadow flicker occurrences. It is considered that weather conditions could reduce actual occurrence of shadow flicker by at least half, compared to calculated levels. Regional Met Office data recorded at Lerwick weather station between 1930 and 2015 gives the average annual sunshine hours to be 1072 hours. The total amount of daylight hours for the Site is 4531. Therefore, it is predicted that on average the sun will be shining for approximately 23.7% of total daylight hours per year at the Site. This is likely to reduce shadow flicker by a similar percentage.
- Objects such as vegetation, farm buildings or walls may surround windows and obscure the view of the turbine and hence prevent shadow flicker.
- During operation, the turbine rotors automatically orientate themselves to face the prevailing wind direction. This means the turbine rotors would not always be facing the affected window. Very little of the blade movement would be visible during such occurrences and therefore the potential for shadow flicker is reduced.
- The turbine would not operate for 100% of daylight hours. During periods of very low wind speed or very high wind speed or maintenance shut-downs, the rotors do not turn. During such periods shadow flicker is not possible.

19.5.5 The annual modelled shadow flicker event times are shown graphically for each house in Figures 3-6 in Appendix 19.1, but no account has been taken for any of the variables described above which would serve to reduce the annual duration of the shadow flicker. Therefore, these graphics can be considered 'worst case'.

Assessment of significance

19.5.6 The overall predicted extent of shadow flicker on individual properties has been summarised in Table 19.3 together with the significance of the effect. It should be noted that while the expected number of days and hours when shadow flicker is likely to occur on average (based on an averaged climatic condition correction) the significance of effects is based upon the modelled shadow flicker durations as this reflects a true worst case scenario.

19.5.7 The potential effects on drivers using the B9081 are considered to be transient and not expected to cause undue distraction or disturbance. As such these momentary impacts will not be significant and therefore no mitigation is required.

Table 19.3: Summary of overall shadow flicker effects and likely significance

House no.	*Days of flicker / year*	*Hours of flicker/ year*	*Max mins per day*	*Earliest – Latest times when events expected to occur (hh:mm)*	*Months when affected*	*Avg. sunshine in those months %*	*Re-calculated expected days of flicker (climatic correction)*	*Re-calculated expected hours per year (climatic correction)*	*Significance of Effects*
1	84	31.9	36	13:29-15:22	Jan, Feb, Oct, Nov	17.01	14.3	5.4	**Significant**
2	119	46.5	37.2	13:30-16:48	Jan, Feb, Mar, Oct, Nov, Dec	16.83	20.0	7.8	**Significant**
3	78	31.0	28.8	14:10-16:14	Jan, Feb, Mar, Oct, Nov	18.50	14.4	6.1	**Significant**
4	69	24.0	26.4	14:44-16:36	Feb, Mar, Oct, Nov	20.16	13.9	4.8	**Significant**
5	0	0	0	n/a	n/a	n/a	0	0	Not Significant
6	0	0	0	n/a	n/a	n/a	0	0	Not Significant
7	0	0	0	n/a	n/a	n/a	0	0	Not Significant
8	0	0	0	n/a	n/a	n/a	0	0	Not Significant
9	0	0	0	n/a	n/a	n/a	0	0	Not Significant
10	0	0	0	n/a	n/a	n/a	0	0	Not Significant
11	0	0	0	n/a	n/a	n/a	0	0	Not Significant
12	0	0	0	n/a	n/a	n/a	0	0	Not Significant
13	0	0	0	n/a	n/a	n/a	0	0	Not Significant

Table 19.3: Summary of overall shadow flicker effects and likely significance

House no.	Days of flicker / year	Hours of flicker/ year	Max mins per day	Earliest – Latest times when events expected to occur (hh:mm)	Months when affected	Avg. sunshine in those months %	Re-calculated expected days of flicker (climatic correction)	Re-calculated expected hours per year (climatic correction)	Significance of Effects
14	0	0	0	n/a	n/a	n/a	0	0	Not Significant

19.5.8 It is assumed that any shadow flicker observable from residential dwellings within 10 rotor diameters of the turbines will be considered to be significant in EIA terms. Thus the threshold for a significant effect to arise is any instance where shadow flicker will be >0 hours per year.

19.5.9 Assuming that there are windows facing directly towards all turbines within range, the assessment predicts that the four houses to the northeast of Turbine 9 (Houses H1 - H4) have potential to experience shadow flicker effects.

19.5.10 H1 (Middlesbrough) appears to be a bungalow with windows orientated such that most windows face west southwest and east northeast. The windows facing west south west will have views towards the norther part of the windfarm. As some shadow flicker effects are anticipated at this property effects prior to mitigation are considered to be ‘Significant’.

19.5.11 H2 (Toonigarth) is another dwelling of bungalow design. It is similarly orientated to H1 and will share similar views towards the northern section of the windfarm. As some shadow flicker effects are anticipated at this property effects, prior to mitigation are considered to be ‘Significant’.

19.5.12 H3 (Wirliegarth) is a property orientated with its primary views facing towards the NE. The rear of this property, which faces towards the central portion of the windfarm, appears to be recessed slightly into the ground and does not carry any major windows at risk of experiencing shadow flicker. There are two velux windows in the pitched roof which could conceivably receive flicker and the skylights on the rear lean-to may also receive some shadow flicker effects. As some shadow flicker effects are anticipated at this property effects, prior to mitigation are considered to be ‘Significant’.

19.5.13 H4 (Gunnigarth) is also northeast facing with the rear southwest facing side of the building looking towards the southern extent of the windfarm. There are limited windows in this property which again has lean-tos attached to the rear wall. However some of the windows do have some potential to receive shadow flicker, as do some of the velux windows on the property. As some shadow flicker effects are anticipated at this property, effects prior to mitigation are considered to be ‘Significant’.

19.5.14 Shadow flicker effects at Houses 5-14 are not expected to manifest at all. This is because these houses are located due south of the proposed turbine positions. This prevents the alignment of the sun behind the rotor blades of the turbine being observable from windows within those properties and hence shadow flicker effects cannot occur. Consequently, there are no significant effects expected at any of these properties.

19.6 Cumulative impacts

19.6.1 There are no other large turbines present within the Study Area or within sufficient proximity to cause shadow flicker effects to be observable from the same receptors as identified above. There are a number of smaller turbines located to the south of the Consented Development as shown in Figure 16.2. These include Evance R9000 [5kW] turbines, Elotech Scirocco [6kW] turbines and Proven [6kW] turbines. However, due to their small size and relative positions (as discussed above, there we be no shadow flicker from the Consented Development observable by properties to the south) there will be no cumulative effects experienced.

19.7 Mitigation measures

19.7.1 Mitigation would be delivered by programming the three turbines (Turbines 7,9 and 12) which have *potential* to cause shadowing effects to switch off during times when shadow flicker could occur. This is achieved by installing a light meter at the wind turbine and then switching off the turbine at times when shadow flicker has been predicted and natural light levels on that day are sufficiently strong to cause the potential for shadow flicker. Shutting down the turbine in this way is expected to reduce the output of the entire wind farm by less than 0.00013% per annum. Following mitigation no shadow flicker would be experienced at any of the properties considered in this assessment.

19.8 Residual effects

19.8.1 Following mitigation there are not expected to be any residual effects.

19.9 Monitoring

19.9.1 No additional monitoring will be required. If consented, a detailed survey of windows on the properties at risk of experiencing shadow flicker would be carried out, prior to commissioning of the development. This would enable the operational shutdown plan to be designed and the relevant wind turbines would be programmed to shut down at those times when shadow flicker had been modelled as possible and when climatic conditions were appropriate to enable the effects to manifest.

19.9.2 Should any complaints of shadow flicker be received by the Shetland Islands Council and corroborated by evidence that this effect was actually occurring; the operator would modify the shutdown programme accordingly to ensure that effects did not persist. This requirement can be conditioned into a planning consent. However at this stage it is expected that the modelled potential for shadow flicker is comprehensive and would ensure that no further complaints would be forthcoming.

19.10 Summary and conclusions

19.10.1 Shadow flicker modelling of the 14 dwellings within 11 rotor diameters of the turbine locations has been undertaken and the assessment has shown that four of these properties have potential to experience shadow flicker effects. These four properties (Houses H1 - H4) are located to the northeast of Turbine 9. Houses H5 - H14 lie to the south of the turbine locations and are outside of the zone of potential shadow flicker effects. They will therefore not experience any shadow flicker effects at all.

19.10.2 Mitigation will be employed to shut down the turbine at the correct time and if the meteorological conditions exist for shadow flicker to occur.

19.10.3 Following mitigation no properties will experience shadow flicker and therefore there will be no residual significant effects.

[1] Verkuijlen, E. and Westra, C.A Shadow Hindrance by Wind Turbines, European Wind Energy Conference, 22-26 October 1984, Hamburg

[2] Clarke, A. D. A Case of Shadow Flicker/Flashing: Assessment and Solution, British Wind Energy Association Annual Conference, 1981

[3] NHS Choices - http://www.nhs.uk/CONDITIONS/EPILEPSY/Pages/Introduction.aspx

[4] http://www.scotland.gov.uk/Topics/Built-Environment/planning/National-Planning-Policy/themes/renewables/Onshore (updated October 24 2012)

[5] Update of UK Shadow Flicker Evidence Base. DECC, 2011.

[6] BBC Weather Country Guide – Great Britain available at: http://www.bbc.co.uk/weather/features/18025528

[7] Sun Earth Tools Sunrise and Sunset times 2013 - *http://www.sunearthtools.com/dp/tools/pos_sun.php*

[8] Met Office Historic Station Data – Lerwick 1930 – 2015 - *http://www.metoffice.gov.uk/climate/uk/stationdata/index.html*