APPENDIX 17.1: SHADOW FLICKER ASSESSMENT

Shadow Flicker Assessment

Tangy IV Wind Farm

SSE Renewables

12431-003
17 March 2018

COMMERCIAL IN CONFIDENCE

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Executive Summary

TNEI Services Ltd was commissioned by SSE Renewables to undertake an assessment of the potential for shadow flicker occurrence resulting from the installation of 16 wind turbines at the proposed Tangy IV Wind Farm. The shadow flicker assessment was used to assess the potential for shadow flicker occurrence resulting from the proposed development at the nearest receptors.

Under certain combinations of geographical position, time of day and year, wind speed and wind direction, the sun may pass behind the rotor and cast a shadow over neighbouring buildings' windows. When the blades rotate and the shadow passes a window, to a person within that room the shadow appears to flick on and off; this effect is known as shadow flicker. Where moving shadows are cast over the ground (rather than a building's windows), this is known as 'shadow throw'. There are no guidelines to quantify the effect and there is no requirement to assess 'shadow throw', therefore 'shadow throw' has not been considered further in this assessment.

In the United Kingdom, there is no standard for the assessment of shadow flicker and there are no guidelines which quantify what exposure levels would be acceptable. However some information specific to shadow flicker can be found in the Scottish Government's web based renewables advice on *'Onshore Wind Turbines'* which states: *'Under certain combinations of geographical position, time of day and time of year, the sun may pass behind the rotor and cast a shadow over neighbouring properties. When the blades rotate, the shadow flicks on and off; the effect is known as "shadow flicker". It occurs only within buildings where the flicker appears through a narrow window opening. The seasonal duration of this effect can be calculated from the geometry of the machine and the latitude of the potential site. Where this could be a problem, developers should provide calculations to quantify the effect. In most cases however, where separation is provided between wind turbines and nearby dwellings (as a general rule 10 rotor diameters), "shadow flicker" should not be a problem. However, there is scope to vary layout / reduce the height of turbines in extreme cases.'*

Sixteen 130 m rotor diameter wind turbines were modelled in this assessment. Seven shadow flicker assessment locations (SFAL's) located within 1,300 m (10 times rotor diameter) of the proposed wind turbines were assessed.

It has been shown that under worst case conditions, the maximum theoretical occurrence of shadow flicker amounts to 48.2 hours per year and a maximum of 0.51 hours per day which is experienced at Killarow Farm (SFAL2). The times of day when shadow flicker could occur at the Killarow Farm is between 04:40 and 06:30 (GMT) during the months of April through to August.

It should be noted that these are the theoretical maximum number of shadow flicker hours and do not take into account weather conditions (i.e. when there is total or partial cloud cover), local visual obstructions (such as trees, hedges or other structures), turbine orientation and turbine operation. In reality, the amount of time when shadow flicker occurs will be less than that predicted. Accordingly an assessment has also been undertaken to estimate the 'likely' number of shadow flicker hours taking into account typical sunshine hours for the region. Consideration of likely sunshine hours suggests likely occurrence of shadow flicker of 15.4 hour per year and a maximum of 0.16 hours per day at Killarow Farm (SFAL2).

The potential for cumulative effects with other nearby wind farm developments has been considered but no cumulative effects are predicted as there are no other wind farms within 10 rotor diameters of the SFALs.

If the Scottish Government are minded to grant planning consent for the proposed wind farm it may be appropriate to include a shadow flicker related planning condition to ensure that the amenity of local residents is protected. Inclusion of a condition requiring implementation of a shadow flicker control system would ensure that the turbines do not operate during periods where shadow flicker is predicted, the result of which would be that no shadow flicker would occur at any of the identified receptors.

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1 Introduction

1.1 Brief

1.1.1 To undertake a shadow flicker assessment for the proposed Tangy IV Wind Farm in order to quantify the potential shadow flicker occurrence that will be incident at sensitive dwellings located to the south / south-west of the site.

1.1.2 To present the results in the form of a report with reference to current Planning Policy and Guidance.

1.2 Background

1.2.1 TNEI Services Ltd was commissioned by SSE Renewables to undertake a shadow flicker assessment for the proposed Tangy IV Wind Farm (hereinafter referred to as the 'proposed development'). The proposed development is located approximately 8 km to the north west of Campbeltown in Argyll and Bute. The approximate Ordnance Survey grid reference for the proposed development is 167470, 628131.

1.2.2 This shadow flicker assessment models 16 wind turbines with a 130 m rotor diameter and an 84.9 m hub height (149.9m to tip). These dimensions have been used in the assessment to provide a worst case assessment area.

1.3 Conditions Required for Shadow Flicker

1.3.1 Under certain combinations of geographical position, time of day and year, wind speed and wind direction, the sun may pass behind the rotor and cast a shadow over neighbouring buildings' windows. When the blades rotate and the shadow passes a window, to a person within that room the shadow appears to flick on and off; this effect is known as shadow flicker. It occurs only within buildings where the flicker appears through a window aperture and only in buildings within 130 degrees either side of north relative to a turbine can be affected.

1.3.2 Where moving shadows are cast over the ground (rather than a building's windows), this is known as 'shadow throw'. There are no guidelines to quantify the effect and there is no requirement to assess 'shadow throw', therefore it has not been considered further in this assessment.

1.4 Potential Impacts associated with Shadow Flicker including Photosensitive Epilepsy

1.4.1 Shadow flicker can result in a degradation of amenity when people are within the rooms affected by the phenomenon.

1.4.2 The flickering effect caused by shadow flicker also has the potential to induce epileptic seizures through a condition known as photosensitive epilepsy. Around 1% of people in the UK have epilepsy although only 3% of these 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 Epilepsy, 2016 [(1)]). Most commercial scale (>1 MW) wind turbines in the UK rotate much slower than this, at between 0.3 and 1.0 Hz; therefore, health effects arising from shadow flicker will not have the potential to occur unless the operating frequency of a particular turbine is between 3 and 30 Hz and all other pre-conditions for shadow flicker effects to occur exist. The potential impacts associated with the proposed development are considered in Section 5.4 of this report.

1.5 Timestamps and Co-ordinates

1.5.1 Please note that unless otherwise stated, all times are presented in GMT (Greenwich Mean Time) and all grid coordinates refer to the British National Grid Survey grid using Eastings and Northings.

2 Planning Policy and Guidance

2.1 Overview of Shadow Flicker Policy and Guidance

2.1.1 There is no standard for the assessment of shadow flicker accepted in the whole of the UK and there are no guidelines which quantify what exposure levels would be acceptable. In assessing the potential shadow flicker impacts of the proposed development the following guidance and policy documents have been considered:

- Local Policy;
- National Planning Policy;
- Web Based Renewables Advice: *'Onshore Wind Turbines'* (6); and
- An update of the UK shadow flicker evidence base produced by the (former) Department for Energy and Climate Change (DECC) (8).

2.2 Local Planning Policy

2.2.1 The adopted Development Plan for the area comprises the Argyll and Bute Local Development Plan (LDP) which was adopted on 26 March 2015. The Local Plan sets out a settlement strategy and spatial framework for how the Council wants to see Argyll and Bute develop to 2024 and beyond.

2.2.2 The Plan contains a number of overarching polices, the aim of which is to deliver high standards of development. POLICY LDP STRAT 1 – Sustainable Development in relation to achieving sustainable development proposals states that developers should: *'Avoid having significant adverse impacts on land, air and water environment'*.

2.2.3 Policy LDP 6 – Supporting the Sustainable Growth of Renewables sets out the criteria to which all applications for wind turbine development will be assessed against including: *'Impacts on communities and individual dwellings, including visual impact, residential amenity, noise and shadow flicker'*.

2.2.4 Supplementary Guidance 2: Renewable Energy was adopted in December 2016 and contains a reference to the Policy LDP 6 and also states that shadow flicker is likely to be relevant to applications for micro scale wind. It can be assumed that the same applies for large scale wind farms. There are no further references made.

2.2.5 A new Local Development Plan is currently under production; however it is not due to be adopted until June 2020 and so has not been considered in this report.

2.3 National Planning Policy

2.3.1 Scottish Planning Policy (SPP) (2014) (8) is the statement of the Scottish Government's policy on nationally important land use planning matters. Paragraphs 161 to 166 relate to 'Onshore Wind' and provide guidance on the preparation of a spatial framework within the development plan for Local Authorities. Paragraph 169 relates to Development Management and sets out the criteria that are likely to be considered in deciding all applications for energy infrastructure developments. It states that proposals should take account of spatial frameworks for wind farms (where relevant) and that considerations may include visual impact, residential amenity, noise and shadow flicker on communities and individual dwellings.

2.4 Web Based Planning Advice - Onshore Wind Turbines

2.4.1 The 'Onshore Wind Turbines' web based document states that, as a general rule, flicker effects have been proven to occur only within ten rotor diameters of a wind turbine. The guidance states:

'Under certain combinations of geographical position, time of day and time of year, the sun may pass behind the rotor and cast a shadow over neighbouring properties. When the blades rotate, the shadow flicks on and off; the effect is known as "shadow flicker". It occurs only within buildings where the flicker appears through a narrow window opening. The seasonal duration of this effect can be calculated from the geometry of the machine and the latitude of the potential site.

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

2.4.2 Whilst it is possible to predict periods when shadow flicker could theoretically occur using industry standard software packages, within the UK there are no relevant guidelines to quantify what exposure levels would be acceptable.

2.5 Department of Energy and Climate Change (DECC) - Update of UK Shadow Flicker Evidence Base

2.5.1 In March 2011, the Department of Energy and Climate Change issued a report titled 'Update of UK Shadow Flicker Evidence Base.' The report was prepared for DECC by Parsons Brinckerhoff (PB). The report summarised the findings of research undertaken by PB with a view to enabling DECC to 'advance current understanding of the shadow flicker effect.' The 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.'

2.5.2 The PB report concludes that an assessment area of 10 rotor diameters, 130 degrees either side of north is appropriate whilst noting that an adjustment may be appropriate for sites with different latitudes. PB found that a worst-case scenario is usually reported but noted that this is sometimes accompanied by a more 'realistic' approximation which takes account of variables like sunshine hours. The report confirms that the industry software packages WindPro, WindFarm and WindFarmer provide similar outputs.

3 Methodology

3.1 Shadow Flicker Modelling

3.1.1 It is possible to calculate the total theoretical number of hours per year that shadow flicker may occur in a building from the relative position of the turbine to the building, the geometry of the wind turbines, the latitude of the wind turbine site and the size / orientation of the windows potentially affected.

3.1.2 The potential for shadow flicker to occur and the duration of such an effect depends upon the following factors:

- the location of the building relative to the turbines;
- the distance from the turbines;
- the turbine hub-height and rotor diameter;
- the time of year (which impacts the trajectory of sun's path across the sky);
- the proportion of daylight hours in which the turbines operate;
- the frequency of bright sunshine and cloudless skies (particularly at low elevations above the horizon); and
- the wind direction (which impacts on turbine orientation).

3.1.3 Several specialist software packages are available which can take account of the variables listed above to determine the maximum theoretical number of shadow flicker hours which could occur at each window location. For this assessment details regarding the turbine dimensions / locations and the size, position and orientation of the windows at the buildings being assessed were entered into the 'Windfarm' software which is produced by REsoft [(11)].

3.1.4 The Windfarm software was then used to predict all periods when shadow flicker can theoretically occur.

3.2 Consultation

3.2.1 The scoping opinion issued by the Energy Consents Unit (dated 16 October 2017) included a consultation response from Argyll and Bute Council in relation to shadow flicker. Argyll and Bute Council stated that the:

'Consequences for the occupiers of property and countryside users should be assessed in terms of noise, shadow flicker, air quality, lighting and private water supplies'

4 Baseline

4.1 Description

4.1.1 The immediate area surrounding the site is rural with only a few scattered buildings. There are a small number of residential buildings which would be theoretically susceptible to shadow flicker.

4.2 Study Area

4.2.1 The candidate wind turbines modelled in this assessment each have a rotor diameter of 130 m, therefore the study area has been limited to 1,300 m and 130 degrees either side of north around the proposed turbine locations, as shown on Figure A1.1 (Annex 1). Buildings located outside 130 degrees either side of north have been excluded from the analysis as no direct path between the sun, the turbine and these buildings resulting in shadow flicker could occur.

4.3 Identification of Potential Receptors

4.3.1 Initially, a desk based assessment was undertaken using Ordnance Survey mapping data and aerial photography to identify potentially sensitive receptors within the study area; twelve such receptors were identified. This information formed the basis for the site survey which was undertaken in order to assess the receptors.

4.3.2 The site survey was undertaken in March 2018. Following the site survey, all twelve residential dwellings were chosen for the detailed assessment. Where a number of receptors were located in very close proximity, they were modelled as a single shadow flicker assessment location (SFAL); consequently seven SFALs were included in the assessment. Details of the SFALs are provided in Table 4.1. The building survey results which include information on window size, number and orientation are included in Annex 2.

Table 4.1 – Shadow Flicker Assessment Locations (SFAL)

SFAL	Easting (m)	Northing (m)	Distance to nearest turbine* (m)
SFAL1 - Tangymoil	166244	628594	1,148
SFAL2 – Killarow Farm	166269	628025	1,053
SFAL3 – Tigh Na Mara	166079	628171	1,236
SFAL4 – Tangy Mill	166275	627740	1,117
SFAL5 - Tangylee	167489	627768	419
SFAL6 – Property north of Tangy Mill Croft	166067	627768	1,305
SFAL7 – Tangy Mill Croft	166125	627650	1,290

* *Please note the distance to nearest turbine quoted above is approximate and may differ from those reported elsewhere. Distances for the shadow flicker assessment are taken from the nearest turbine to the façade/window of the building.*

4.4 Information Gaps

4.4.1 The process has been as inclusive as possible with a total of twelve residential receptors buildings near to the proposed development being assessed. No information gaps have been identified.

5 Assessment Results

5.1 Prediction of the Likely Effects

5.1.1 Table 5.1 below details the shadow flicker modelling results and summarises the predicted frequency of occurrence of shadow flicker at the worst case window on each building (with respect to 'Theoretical Hours per Year'). A detailed listing of the potential for shadow flicker occurrence at each receptor is included in Annex 3. In addition Figures A1.3 to A1.9 (in Annex 1) show the potential shadow flicker occurrence at the most affected window of each receptor and illustrate the times of year and times of day when shadow flicker could theoretically occur.

Table 5.1 – Theoretical Predicted Levels of Shadow Flicker

SFAL/ Window	Frequency of Shadow Occurrence (days/ year)	Max Hours of Shadow per Day	Mean Hours of Shadow per Day	Total Theoretical Hours per Year
SFAL1/12	126	0.47	0.36	45
SFAL2/03	118	0.51	0.41	48.2
SFAL3/01	28	0.44	0.35	9.8
SFAL4/04	80	0.51	0.43	34.8
SFAL5/05	0	0	0	0
SFAL6/07	54	0.44	0.34	18.4
SFAL7/08	76	0.46	0.4	30.7

5.1.2 The calculations used to determine the numbers in Table 5.1 assume a 'worst case' scenario with the following assumptions:

- the sky is always clear (i.e. no account of climatic conditions such as clouds or precipitation has been made);
- there are no objects such as trees or buildings surrounding the windows that may block the view to turbines;
- the turbine rotors are always aligned face-on to the window, providing the maximum opportunity for shadow flicker; and
- the rotors are always turning (i.e. no account has been taken of calm winds or shut-down periods).

5.1.3 Similarly, when the sun is close to the horizon, at dawn and dusk, the intensity of the sun's rays is reduced and they are less likely to cast distinct shadows. It is generally considered that when the sun is lower than 2° above the horizon, that shadow flicker is unlikely to occur to any significant extent. This has been accounted for in the modelling by excluding periods where the sun is less than 2° above the horizon.

5.2 Evaluation of the Likely Effects

5.2.1 Under worst case conditions, the maximum theoretical occurrence of shadow flicker amounts to 48.2 hours per year, experienced at Killarow Farm (SFAL2). The times of day when shadow flicker is likely to occur varies between 04:40 and 06:30 (GMT) during the months of April to August.

5.2.2 It is important to note however that the instances of shadow flicker will always be less than that predicted by the model as these are 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 important to consider the following facts when making an assessment:

- Climatic conditions dictate that the sun is not always shining. Regional Met Office data gives actual sunshine hours for the Argyll and Bute region to be 32% of total daylight hours[1]. Cloud cover during other times may obscure the sun and prevent shadow flicker occurrence. While some shadow may still be cast under slightly overcast conditions, no shadow at all would be cast when heavy cloud cover prevails. It is considered that weather conditions will reduce actual occurrence of shadow flicker by at least half, compared to calculated levels;
- objects such as trees or walls may surround windows and obscure the view of the turbines and hence prevent shadow flicker; and
- during operation, the turbine rotors will automatically orientate themselves to face the prevailing wind direction. This means the turbine rotors will not always be facing the affected window and in fact will sometimes be 'side-on' to the window. Very little of the blade movement would be visible during such occurrences and therefore the potential for shadow flicker is reduced.

5.2.3 As detailed above, shadow flicker can only occur during daylight hours and when the sun is shining. The total theoretical hours per year given in Table 5.1 above assume all hours of daylight are sunny with clear skies. For the most affected SFAL, the total theoretical shadow flicker hours are 48.2 hours per year. Using historical data provided by the Met Office, the total theoretical hours can be re analysed to provide a more realistic estimate of the likely shadow flicker levels. Actual sunshine hours is given to be 32%* of all daylight hours therefore the potential 'likely' hours of shadow flicker per year would be 15.4 hours.

5.2.4 This figure does not take account of the other factors listed in Section 5.2.2 above which may reduce levels further.

5.2.5 The 'likely' hours of shadow flicker occurrence at Tangymoil (SFAL1), Tigh Na Mara (SFAL3), Tangy Mill (SFAL4), Tangylee (SFAL5), Property north of Tangy Mill Croft (SFAL6) and Tangy

* Calculated based on figures available at https://www.metoffice.gov.uk/public/weather/climate/ for Campbeltown, 1,412.5 hours of sunshine a year (1412.5/4380*100 = 32%) (last accessed 16/03/2018).

Mill Croft (SFAL7) are 14.4, 3.1, 11.1, 0, 5.9 and 9.8 per year respectively when considering the same methodology detailed in Section 5.2.3.

5.3 Potential Cumulative Effects

5.3.1 The nearest wind farm to the site of the proposed Tangy IV Wind Farm (except Tangy I and II, which would be decommissioned if Tangy IV were to be built), consented, operational or otherwise, is the Beinn an Tuirc Wind Farm (Phase 3), located approximately 4,000 m to the north east. Given the distance between the two schemes, and the respective hub heights (130 m and 90 m, giving a 10 rotor diameter study area of 1,300 m and 900 m respectively), the relative study areas will not cross as the distance between the schemes is too great. Accordingly no cumulative shadow flicker is predicted to occur.

5.4 Photosensitive Epilepsy

5.4.1 The possibility that shadow flicker could induce photosensitive epilepsy has also been considered. Whilst the exact turbine to be used on site is not yet known, information provided by the manufacturer for an indicative candidate turbine, the Nordex N131, details that the turbine has a maximum r.p.m. of 13.6[2]. Given the turbine will have three blades, the frequency at which a blade will pass a particular point will be in the order of 40.8 times per minute, which equates to 0.68 flashes per second (hertz). This is significantly less than the 3 to 30 hertz frequency range commonly considered to induce photosensitive epilepsy (The National Society for Epilepsy, 2016 [(1)]). Consequently, shadow flicker caused by the proposed development is predicted to have no adverse health effects. While some people are sensitive at higher frequencies, it is uncommon to have photosensitivity below 3 hertz and consequently shadow flicker caused by this development is predicted to have no adverse health effects.

5.4.2 The potential for cumulative shadow flicker occurrence has been investigated. Shadow flicker is predicted to occur from no more than one turbine at a given time and as such there are no predicted cumulative effects.

5.5 Mitigation Measures

5.5.1 There are no relevant UK guidelines which quantify what exposure levels of shadow flicker are acceptable. Where particular combinations of circumstances arise which increase the potential for nuisance, mitigation may be required to reduce the level of exposure to acceptable levels.

5.5.2 Mitigation measures are available to counteract shadow flicker occurrence to reduce the possibility of nuisance. These include planting tree belts between the affected window and the turbines and shutting down the turbines using turbine control systems during periods when shadow flicker could occur.

5.5.3 Inclusion of a condition requiring implementation of a shadow flicker control system would ensure that the turbines do not operate during periods where shadow flicker is predicted, the result of which would be that no shadow flicker would occur at any of the identified receptors.

[2] Available at http://www.nordex-online.com/fileadmin/MEDIA/Produktinfos/EN/Nordex_Delta_Broschuere_en.pdf (last accessed 16/03/2018)

6 Conclusions

6.1.1 A shadow flicker assessment has been undertaken for the seven Shadow Flicker Assesment Locations (SFALs) within 1,300 m of the proposed wind turbine locations. The turbines modelled in this assessment each have a rotor diameter of 130 m.

6.1.2 It has been shown that under worst case conditions, the maximum occurrence of shadow flicker amounts to 48.2 hours per year experienced at Killarow Farm (SFAL2). The times of day when shadow flicker could theoretically occur at this location is in the early morning time from April to August.

6.1.3 It is important however to note that these are the theoretical maximum number of shadow flicker hours per year. They do not take into account weather conditions (i.e. no sun or partial cover), local visual obstructions (such as trees, hedges or other structures), turbine orientation and turbine operation. In reality, the amount of time when shadow flicker occurs will be less than that predicted. It is also important to note that affected windows may well be in rooms that are not generally in use at the times when the effect may occur. The 'likely' occurrence of shadow flicker at the worst affected property, Killarow Farm (SFAL2), is predicted to be 15.4.

6.1.4 If the Scottish Government are minded to grant planning consent for the proposed wind farm it may be appropriate to include a shadow flicker related planning condition to ensure that the amenity of local residents is protected. Inclusion of a condition requiring implementation of a shadow flicker control system would ensure that the turbines do not operate during periods where shadow flicker is predicted, the result of which would be that no shadow flicker would occur at any of the identified receptors.

7 Glossary of Terms

Shadow Flicker: The term 'shadow flicker' refers to the flickering effect caused when rotating wind turbine blades periodically cast shadows over neighbouring properties as they turn, through constrained openings such as windows.

Shadow Throw: Shadow throw occurs when a shadow is cast by turbine(s) across the ground at frequent intervals.

Photosensitive Epilepsy: is a form of epilepsy in which seizures are triggered by visual stimuli that form patterns in time or space, such as flashing lights, bold, regular patterns, or regular moving patterns.

8 References

1. **Epilepsy Society.** https://www.epilepsysociety.org.uk/photosensitive-epilepsy#.Wo1uz6jFLcs.

2. **Scottish Government.** Web Bases Renewables Advice 'Onshore Wind Turbines'. *Scottish Government.* [Online] 2014. http://www.gov.scot/Topics/Built-Environment/planning/Policy/Subject-Policies/Utilities/Delivering-heat-electricity/renewables-advice.

3. Parsons Brinckerhoff prepared for the Department of Energy and Climate Change, Update of UK Shadow Flicker Evidence Base, March 2011. [Online] http://webarchive.nationalarchives.gov.uk/20110405153950/http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/planning/on_off_wind/shadow_flicker/shadow_flicker.aspx.

4. **Scottish Government.** Scottish Planning Policy. *Scottish Government.* [Online] http://www.gov.scot/Publications/2014/06/5823.

5. **ReSoft Ltd.** WindFarm Release 4.2.1.9. (1997-2014).

Annex 1 – Figures

Figure A1.3 – Predicted Shadow Flicker Times at SFAL1

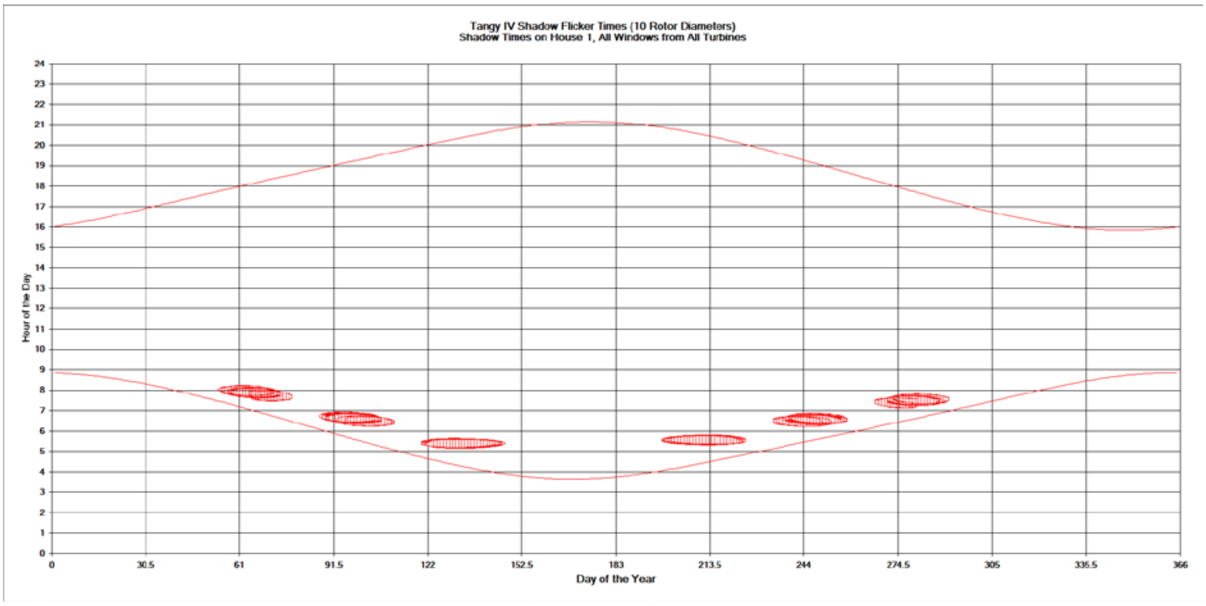


Figure A1.4 – Predicted Shadow Flicker Times at SFAL2

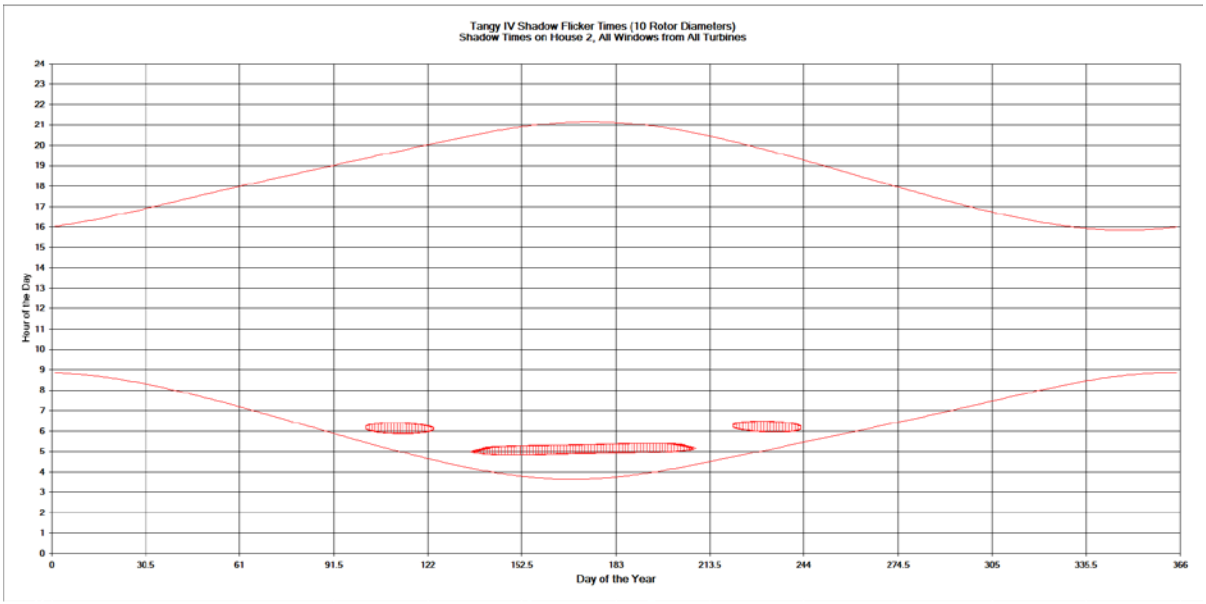


Figure A1.5 – Predicted Shadow Flicker Times at SFAL3

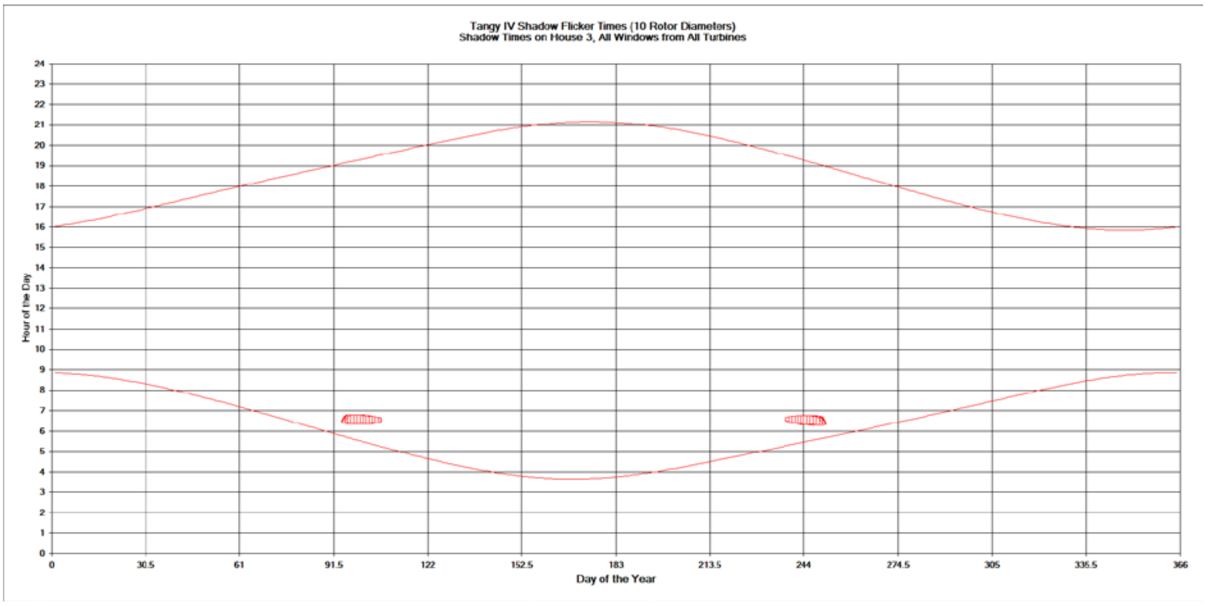


Figure A1.6 – Predicted Shadow Flicker Times at SFAL4

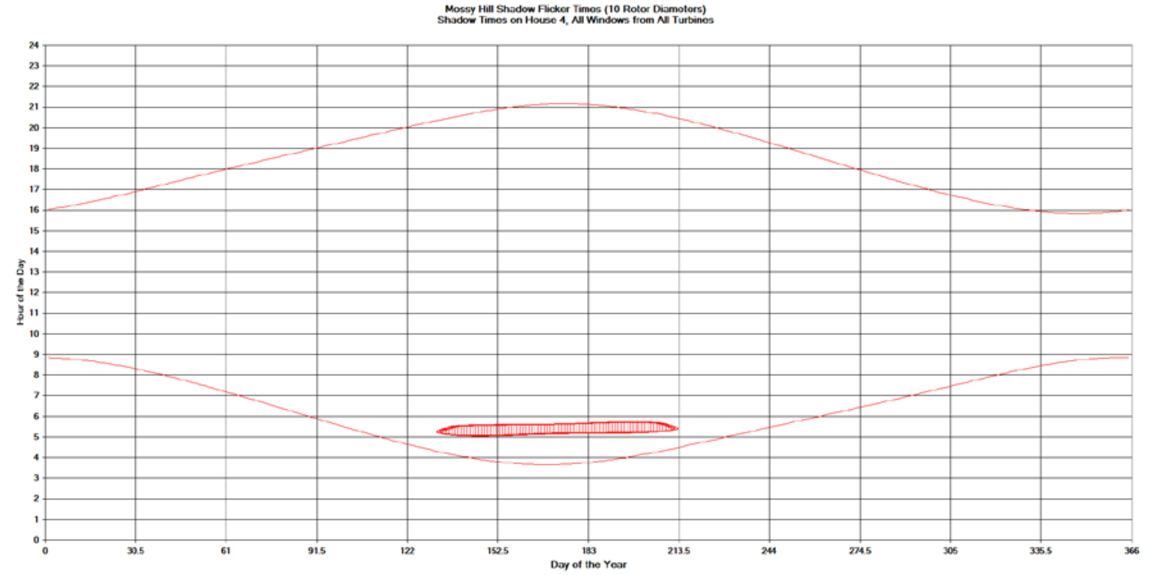


Figure A1.7 – Predicted Shadow Flicker Times at SFAL5

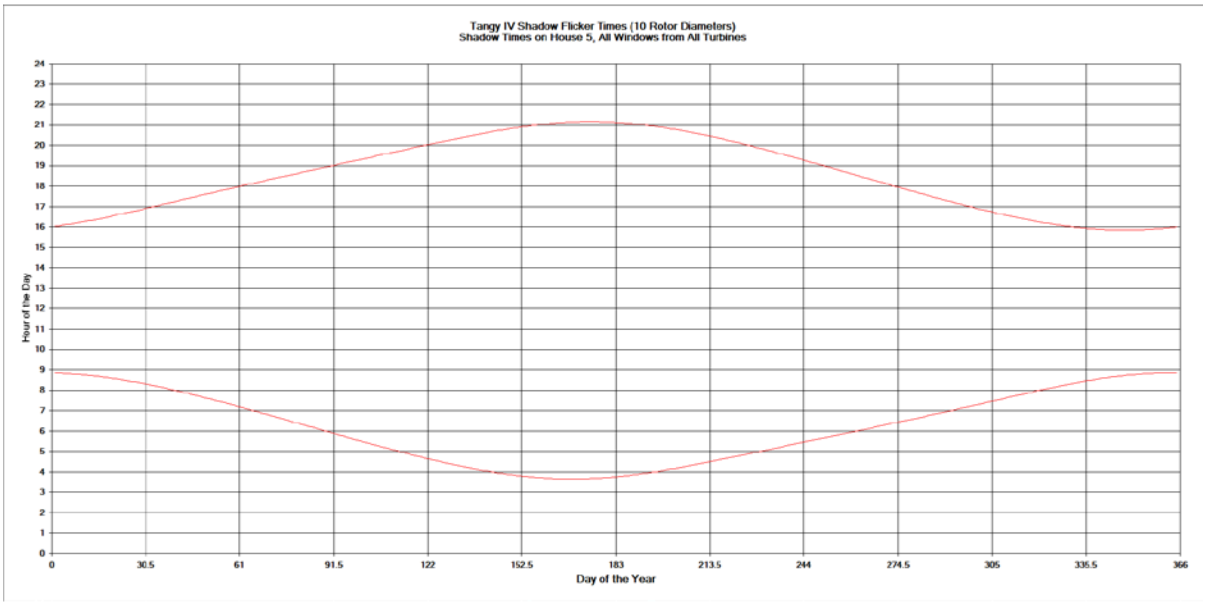


Figure A1.8 – Predicted Shadow Flicker Times at SFAL6

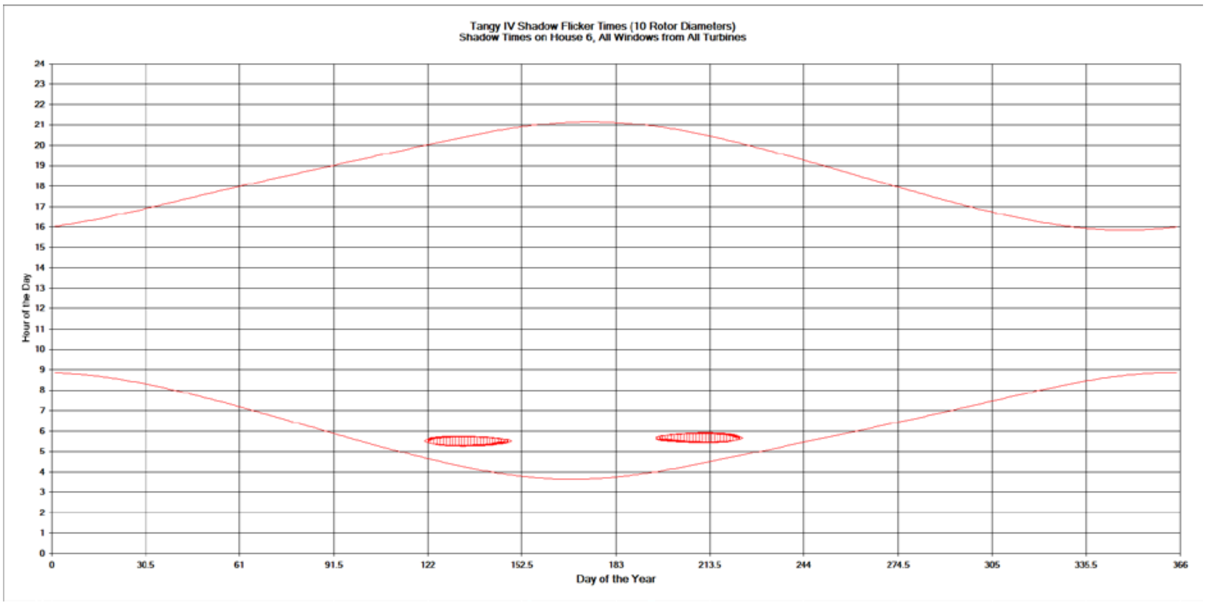
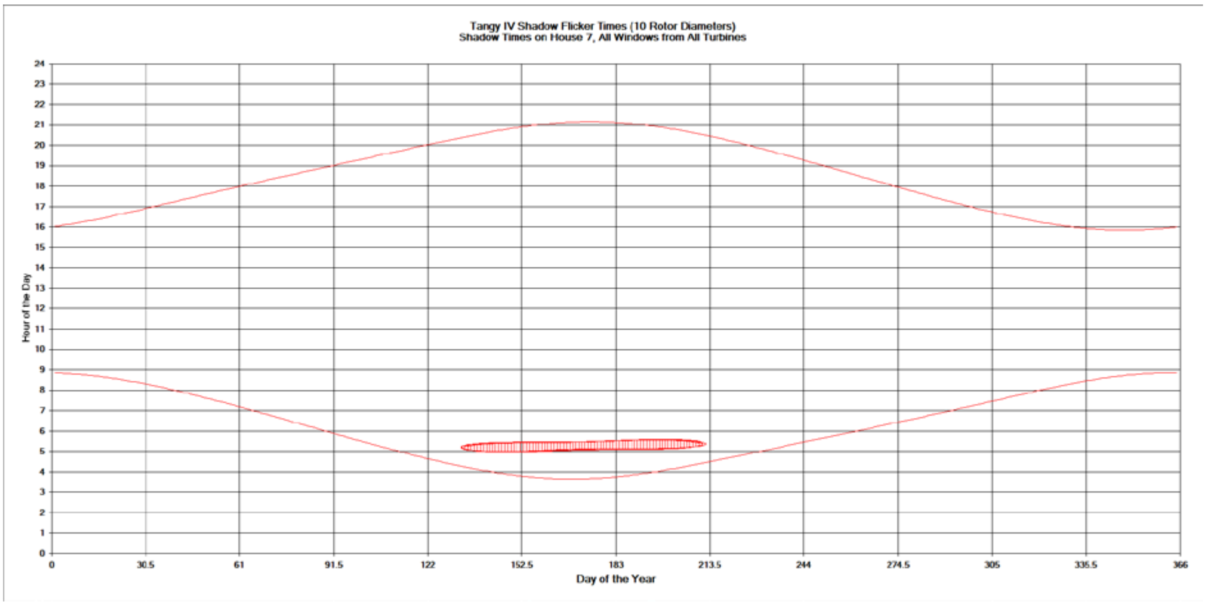


Figure A1.9 – Predicted Shadow Flicker Times at SFAL7



Annex 2 – Building Survey Results

SFAL	Window	Easting (relative to building location coordinates)	Northing (relative to building location coordinates)	Windows					Approach taken to with regards to window size for modelling
				Width (m)	Height (m)	Elevation (m.agl)	Aspect (° from north)	Tilt (° from vertical; top backwards positive)	
1	1	-26	-45	12	2.2	1.2	70	0	Informed by Site Survey
1	2	-22	-50	1	2	1.5	340	0	Informed by Site Survey
1	3	-18	-51	2	1.5	5	340	60	Informed by Site Survey
1	4	-12	-53	1.5	2	1.2	70	0	Informed by Site Survey
1	5	-29	-46	12	5	2.3	70	80	Informed by Site Survey
1	6	-4	7	0.5	1	2	80	0	Informed by Site Survey
1	7	-4	5	0.5	1	4.5	80	0	Informed by Site Survey
1	8	-2	-1	0.5	1	2	80	0	Informed by Site Survey
1	9	-2	1	0.3	1	2	170	0	Informed by Site Survey
1	10	-1	-7	0.5	1	2	80	0	Informed by Site Survey
1	11	-2	-3	0.5	1	2	80	0	Informed by Site Survey
1	12	-2	-6	0.5	1	4	80	30	Informed by Site Survey

SFAL	Window	Easting (relative to building location coordinates)	Northing (relative to building location coordinates)	Windows					Approach taken to with regards to window size for modelling
				Width (m)	Height (m)	Elevation (m.agl)	Aspect (° from north)	Tilt (° from vertical; top backwards positive)	
1	13	-2	-9	1	1.2	2	170	0	Informed by Site Survey
1	14	48	12	0.5	0.5	1.8	165	0	Informed by Site Survey
1	15	45	13	0.5	0.5	2.3	165	0	Informed by Site Survey
1	16	47	16	0.5	0.5	4	165	0	Informed by Site Survey
1	17	45	15	0.5	0.5	3.8	165	60	Informed by Site Survey
1	18	0	0	1	1	2	0	0	Informed by Site Survey
2	1	-11	4	0.4	0.7	4.3	2	0	Informed by Site Survey
2	2	-9	4	0.5	0.7	1.3	2	0	Informed by Site Survey
2	3	-8	4	1	1.5	3.5	2	0	Informed by Site Survey
2	4	-5	4	0.5	0.7	4.3	2	0	Informed by Site Survey
2	5	-5	4	1	1.3	1.5	2	0	Informed by Site Survey
2	6	-1	4	1	1.3	1.5	2	0	Informed by Site Survey

SFAL	Window	Easting (relative to building location coordinates)	Northing (relative to building location coordinates)	Windows					Approach taken to with regards to window size for modelling
				Width (m)	Height (m)	Elevation (m.agl)	Aspect (° from north)	Tilt (° from vertical; top backwards positive)	
2	7	-1	2	0.5	0.5	4.3	2	45	Informed by Site Survey
3	1	11	0	1	1.3	2	170	0	Informed by Site Survey
3	2	8	-1	0.6	0.8	2.3	170	0	Informed by Site Survey
3	3	6	-1	1	1.3	2	170	0	Informed by Site Survey
3	4	3	-2	0.5	1.9	1.1	170	0	Informed by Site Survey
3	5	1	-4	1	1.3	2	170	0	Informed by Site Survey
3	6	0	-4	1	1.3	2	170	0	Informed by Site Survey
4	1	8	3	0.8	1	3.5	92	0	Informed by Site Survey
4	2	4	7	0.8	0.5	0.3	2	0	Informed by Site Survey
4	3	7	7	0.8	1.2	2	2	0	Informed by Site Survey
4	4	7	7	0.8	0.5	0.3	2	0	Informed by Site Survey
4	5	8	1	0.8	1.2	2	92	0	Informed by Site Survey

SFAL	Window	Easting (relative to building location coordinates)	Northing (relative to building location coordinates)	Windows					Approach taken to with regards to window size for modelling
				Width (m)	Height (m)	Elevation (m.agl)	Aspect (° from north)	Tilt (° from vertical; top backwards positive)	
4	6	8	-3	0.8	1	2	92	0	Informed by Site Survey
5	1	-37	-27	1	1.8	4.3	55	0	Informed by Site Survey
5	2	-37	-27	1	1.8	2	55	0	Informed by Site Survey
5	3	-35	-30	1	1.2	4.5	55	0	Informed by Site Survey
5	4	-36	-27	1	1	1.5	325	0	Informed by Site Survey
5	5	-34	-26	0.8	0.8	4	325	45	Informed by Site Survey
5	6	-34	-26	0.8	1.2	1.5	325	0	Informed by Site Survey
5	7	-30	-23	0.8	1.2	1.5	325	0	Informed by Site Survey
5	8	-25	-20	0.8	1.2	1.5	325	0	Informed by Site Survey
5	9	-25	-20	0.8	1.2	1.5	325	45	Informed by Site Survey
5	10	-23	-18	0.8	0.8	4	325	45	Informed by Site Survey
5	11	-23	-18	0.8	0.8	4	325	45	Informed by Site Survey

SFAL	Window	Easting (relative to building location coordinates)	Northing (relative to building location coordinates)	Windows					Approach taken to with regards to window size for modelling
				Width (m)	Height (m)	Elevation (m.agl)	Aspect (° from north)	Tilt (° from vertical; top backwards positive)	
6	1	4	6	0.8	1	1.5	10	0	Informed by Site Survey
6	2	8	2	1	1.2	1.5	100	0	Informed by Site Survey
6	3	10	1	0.5	1.3	1.5	10	0	Informed by Site Survey
6	4	10	-3	1	1.5	1.5	100	0	Informed by Site Survey
6	5	7	-5	1	1.2	1.5	100	0	Informed by Site Survey
6	6	9	-7	0.8	1.3	1.5	10	0	Informed by Site Survey
6	7	10	-10	1	1.5	1.5	100	0	Informed by Site Survey
6	8	9	-14	1	1.5	1.5	100	0	Informed by Site Survey
6	9	4	-18	1	1	1.5	100	0	Informed by Site Survey
6	10	3	-21	1	1	1.5	100	0	Informed by Site Survey
6	11	7	-26	1	1	1.5	100	0	Informed by Site Survey
6	12	11	-32	0.8	0.8	1.5	100	0	Informed by Site Survey

SFAL	Window	Easting (relative to building location coordinates)	Northing (relative to building location coordinates)	Windows					Approach taken to with regards to window size for modelling
				Width (m)	Height (m)	Elevation (m.agl)	Aspect (° from north)	Tilt (° from vertical; top backwards positive)	
7	1	-2	6	1	1.5	2	15	0	Informed by Site Survey
7	2	0	5	0.3	0.5	2	15	0	Informed by Site Survey
7	3	1	5	0.8	1.3	2	15	0	Informed by Site Survey
7	4	5	7	1	1	1.5	15	0	Informed by Site Survey
7	5	6	5	1	1	1.5	105	0	Informed by Site Survey
7	6	7	4	1	1	1.5	15	0	Informed by Site Survey
7	7	8	4	0.3	0.5	2	15	0	Informed by Site Survey

Annex 3 – Detailed Listings

House/ Window	Days per year	Max hours per day	Mean hours per day	Total hours
01/01	68	0.49	0.39	26.2
01/02	0	0	0	0
01/03	0	0	0	0
01/04	60	0.47	0.38	22.9
01/05	70	0.49	0.38	26.7
01/06	123	0.47	0.36	44.2
01/07	124	0.47	0.36	44.5
01/08	125	0.47	0.36	44.7
01/09	73	0.47	0.36	26.6
01/10	125	0.47	0.36	44.9
01/11	126	0.47	0.36	44.8
01/12	126	0.47	0.36	45
01/01	74	0.47	0.36	26.7
01/01	74	0.49	0.39	28.6
01/01	75	0.49	0.38	28.6
01/01	77	0.49	0.37	28.8
01/01	130	0.49	0.37	48
01/01	52	0.45	0.34	17.9
02/01	118	0.51	0.41	47.9
02/02	118	0.51	0.4	47.4
02/03	118	0.51	0.41	48.2
02/04	118	0.51	0.41	48
02/05	118	0.51	0.4	47.7
02/06	117	0.52	0.41	47.6
02/07	118	0.51	0.41	47.9
03/01	28	0.44	0.35	9.8
03/02	28	0.44	0.34	9.6
03/03	28	0.44	0.34	9.5
03/04	26	0.44	0.34	8.8
03/05	26	0.44	0.36	9.4
03/06	26	0.44	0.36	9.4
04/01	82	0.52	0.45	36.6
04/02	80	0.51	0.43	34.7
04/03	82	0.52	0.44	36.4
04/04	80	0.51	0.43	34.8
04/05	81	0.52	0.45	36.4
04/06	80	0.52	0.45	36.2

House/ Window	Days per year	Max hours per day	Mean hours per day	Total hours
05/01	0	0	0	0
05/02	0	0	0	0
05/03	0	0	0	0
05/04	0	0	0	0
05/05	0	0	0	0
05/06	0	0	0	0
05/07	0	0	0	0
05/08	0	0	0	0
05/09	0	0	0	0
05/10	0	0	0	0
05/11	0	0	0	0
06/01	52	0.44	0.33	17.4
06/02	52	0.44	0.34	17.8
06/03	53	0.44	0.34	17.9
06/04	54	0.44	0.34	18.2
06/05	54	0.44	0.33	18.1
06/06	54	0.44	0.34	18.2
06/07	54	0.44	0.34	18.4
06/08	0	0	0	0
06/09	0	0	0	0
06/10	0	0	0	0
06/11	0	0	0	0
06/12	0	0	0	0
07/01	80	0.45	0.38	30.5
07/02	79	0.45	0.38	30.3
07/03	79	0.45	0.39	30.5
07/04	79	0.45	0.39	30.6
07/05	78	0.45	0.39	30.6
07/06	78	0.45	0.39	30.6
07/07	78	0.45	0.39	30.4
07/08	76	0.46	0.4	30.7