
**THREE OAKS RENEWABLE
ENERGY PARK
EXTENSION**

**Environmental
Statement Appendix 10.2:
Shadow Flicker Assessment**

MAY 2026



Shadow Flicker Impact Assessment

Ridge Clean Energy Ltd

Three Oaks Renewable Energy Park Extension

February 2026



ADMINISTRATION PAGE

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Issue	Date	Details of Changes
1	12 January 2026	Initial issue
2	02 February 2026	Updated turbine coordinates
3	10 February 2026	Administrative revisions
4	16 February 2026	Administrative revisions

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been commissioned to investigate the potential impact of shadow flicker upon residential amenity in the surrounding area from the proposed Three Oaks Renewable Energy Park Extension wind development located in the East Riding of Yorkshire, United Kingdom.

This report contains the following:

- Proposed wind development and receptor details;
- Shadow flicker explanation;
- Shadow flicker assessment of receptors;
- Overall conclusions and mitigation.

Assessment Methodology

All assessed receptors are within 10-rotor diameters (1,170m) of a turbine, and 130 degrees either side of north of the turbines. The model assumes that each dwelling receptor has a single window of 1 metre by 1 metre dimension and has a centre that is 1.5 metres above ground and directed towards the closest turbine as part of the conservative assumptions for a worst-case assessment. A minimum sun elevation of 2 degrees has been considered. All results are with respect to the threshold limits of 30 minutes per day and/or 30 hours per year (Section 2.3 for further details).

Shadow flicker effects can occur only on clear sunny days. The geometric modelling assessment uses highly conservative parameters, such as constant operation of the turbine, constant clear skies with no cloud coverage, and no consideration of wind speeds; all of which could reduce shadow flicker effects. The geometric modelling assessment does not consider additional factors that could also diminish the effects of shadow flicker, such as the visibility from the receptor, cloud coverage, and low and high wind speeds.

It is therefore that the geometric modelling results are considered theoretical and the worst-case scenario.

No site survey has taken place at this stage. A desk-based assessment of the identified dwelling receptors that could potentially be impacted has been undertaken to further inform the likely impacts.

Assessment Conclusions

Shadow flicker impacts exceeding the threshold limit of 30 minutes per day and/or 30 hours per year are geometrically possible towards four of the five assessed dwelling receptors. The results are based solely on the geometric possibility of effects occurring considering the position of the sun, relative to the turbines and dwellings. The geometric modelling results do not consider external factors that could be considered to reduce the duration of effects,



including existing screening in the form of vegetation and buildings. Therefore, these results are considered theoretical and worst-case scenario.

The geometric modelling results predict that Turbine 6 is the only wind turbine that would potentially result in shadow flicker occurring. As such, mitigation by way of a temporary shutdown scheme for Turbine 6 during specific climatic conditions is recommended unless the conservative parameters of the assessment (such as the assumed worst-case window orientation at properties) are confirmed not to exist under baseline conditions.

Turbine Shutdown Times

A temporary shutdown scheme defines the times between which a turbine could be shut down to reduce shadow flicker effects on each receptor to acceptable levels, assuming clear sunny skies. The term 'shutdown' means that the rotating blade is not rotating for the period of time specified.

The dates and times when shadow flicker may occur by Turbine 6 are presented in Appendix D. The temporary shutdown scheme may be used to inform the reduction of the duration of shadow flicker effects to be at or below the threshold limits. The Applicant commits to the preparation of a Shadow Flicker Mitigation Strategy, to be submitted to and agreed in writing by the determining authority, to be secured by way of planning condition.

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ABOUT PAGER POWER

Pager Power is a specialist technical consultancy based in the United Kingdom and has been providing independent expertise on planning issues for solar, wind, and building developments for over 20 years.

Established in 1997, the company initially specialised in assessing the impact of wind turbines on radar systems. Pager Power has since expanded into a multidisciplinary technical planning consultancy that offers a comprehensive range of services and has supported renewable and building projects in more than 60 countries.

Pager Power's core competencies now include:

- Aviation and Radar;
- Daylight, Sunlight and Overshadowing;
- Glint and Glare;
- Shadow Flicker;
- Telecommunications.

Using proprietary modelling software, each study is tailored to the individual project, ensuring that results are relevant, defensible, and aligned with current national and international standards. The company also provides planning support and stakeholder consultation across all service areas, helping clients to understand constraints, explore potential mitigation options, and forge a path forward for their projects.

Pager Power's work helps clients identify potential risks, inform project design, and support the decision-making process. The company can provide support at any stage of a project, from initial feasibility through to completion. Pager Power's assessments – recognised for their objectivity, accuracy, and technical integrity – are designed to withstand legal scrutiny and are trusted by developers and stakeholders alike.



1 TURBINE AND RECEPTOR DETAILS

1.1 Turbine Details

Table 1 below presents the turbine details.

Turbine	Easting	Northing	Hub Height (m)	Tip Height (m)	Rotor Diameter (m)
1	510534	465648	91.4	149.9	117
2	511084	465710	91.4	149.9	117
3	511722	465975	91.4	149.9	117
4	510772	464846	91.4	149.9	117
5	511340	465110	91.4	149.9	117
6	511771	465303	91.4	149.9	117

Table 1 *Turbine details*

1.2 Receptor Details

Dwelling receptors have been identified considering a 10-rotor diameter assessment area from each turbine, and 130 degrees either side of north of the turbines (see Section 2.2 for further details).

The cumulative assessment area is shown in Figure 1 on the following page.

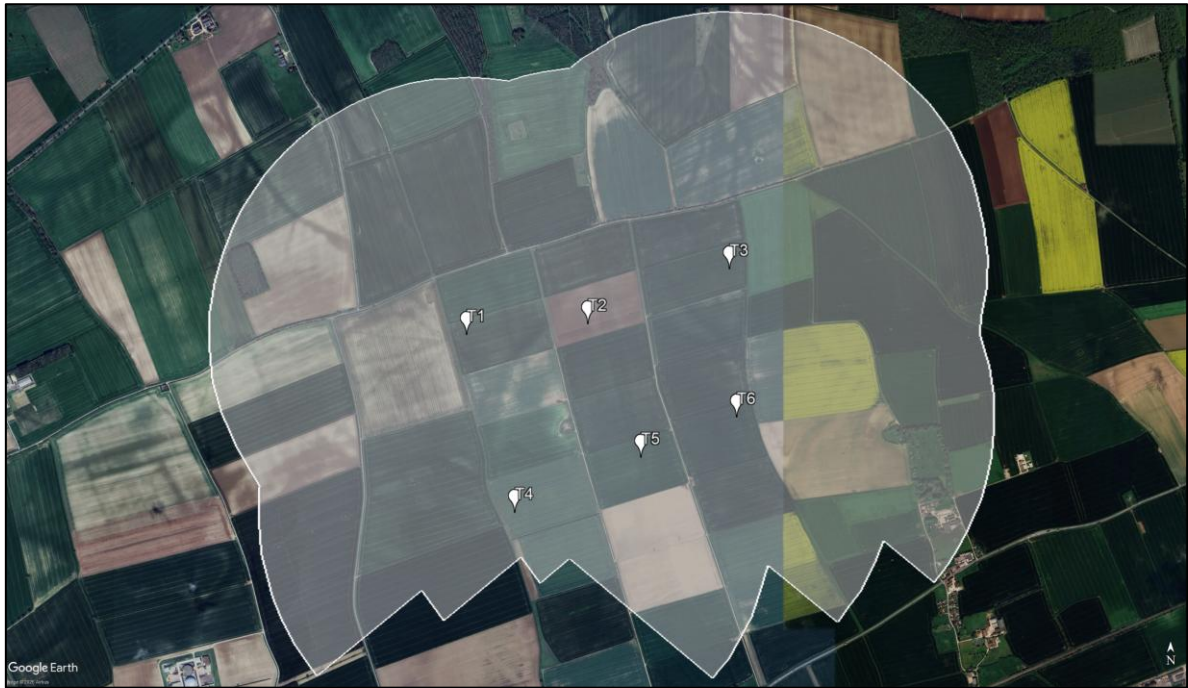


Figure 1 *Cumulative assessment area*

Figure 2 on the following page shows an overview of the assessed dwellings. In total, five dwelling receptors have been assessed as they fall within the 10-rotor diameter assessment area; the details of which are provided in Appendix A.

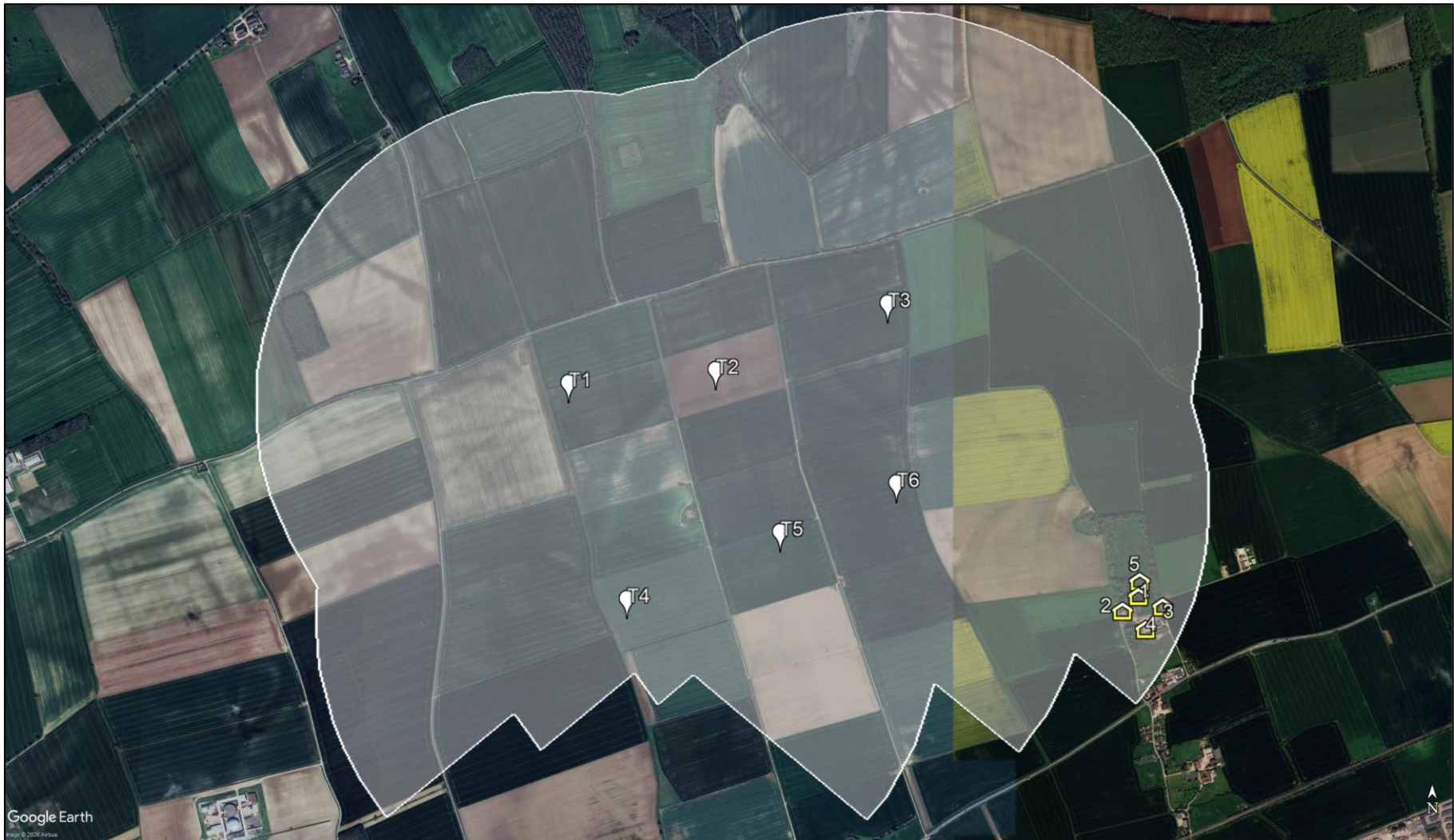


Figure 2 Assessed dwelling receptors

2 SHADOW FLICKER

2.1 Overview

Rotating wind turbine blades can cause brightness levels to vary periodically at locations where they obstruct the Sun's rays. This can result in a nuisance when the shadow is cast over the windows of residential properties. This intermittent shadow is described by the term 'shadow flicker' and it can be a cause of annoyance at residences near onshore wind turbines if it occurs for a significant period of time during the year¹.

2.2 Guidance Overview

There are various sources of guidance with regard to shadow flicker impacts caused by wind turbines. The most relevant extracts have been presented and summarised² in Table 2 on the following pages.

¹ No significant negative health effects are anticipated. See Table 1

² The material regarding shadow flicker is quite extensive and not all aspects have been summarised here

Source	Extract	Remarks
Scottish Government Onshore wind turbines: Planning Advice	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.	This has been considered for technical context
Parsons Brinckerhoff, 2011 – Update of UK Shadow Flicker Evidence Base	This 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. Consultation (by means of a questionnaire) was carried out with stakeholders in the UK onshore wind farm industry including developers, consultants and Local Planning Authorities (LPAs). This exercise was used to gauge their opinion and operational experience with shadow flicker, current guidance and the mitigation strategies that can and have been implemented.	The report was read and understood by Pager Power and provides context for flicker reports
Parsons Brinckerhoff, 2011 – Update of UK Shadow Flicker Evidence Base	The three key computer models used by the industry are WindPro, WindFarm and Windfarmer. It has been shown that the outputs of these packages do not have significant differences between them. All computer model assessment methods use a “worst case scenario” approach and don’t consider “realistic” factors such as wind speed and cloud cover which can reduce the duration of the shadow flicker impact.	Pager Power uses WindFarm software for its analysis



Source	Extract	Remarks
Parsons Brinckerhoff, 2011 – Update of UK Shadow Flicker Evidence Base	Mitigation measures which have been employed to operational wind farms 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.	-
Parsons Brinckerhoff, 2011 – Update of UK Shadow Flicker Evidence Base	Companion Guide to PPS22 makes the following statements: - Shadow flicker only occurs inside buildings where the flicker appears through a narrow window opening; - Only properties within 130 degrees either side of north of the turbines can be affected at UK latitudes; - Shadow flicker has been proven to occur only within ten rotor diameters of a turbine position.	Note that this guidance was officially withdrawn as of March 2014 however the technical context pertaining to shadow flicker is still relevant for the purpose of this report
Parsons Brinckerhoff, 2011 – Update of UK Shadow Flicker Evidence Base	On health: ‘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 wind farms such as turbine shut down strategies, have proved very successful, to the extent that shadow flicker can not be considered to be a major issue in the UK.’	-
Parsons Brinckerhoff, 2011 – Update of UK Shadow Flicker Evidence Base	[Onshore Wind Energy Planning Conditions Guidance Note, Renewables Advisory Board and BERR (2007)] states that only dwellings within 130 degrees either side of north relative to a turbine can be affected and the shadow can be experienced only within 10 rotor diameters of the wind farm.	Secondary source presented within the Parson Brinckerhoff report



Source	Extract	Remarks
Department for Communities & Local Government (July 2013): Planning practice guidance for renewable and low carbon energy.	Under certain combinations of geographical position and time of day, the Sun may pass behind the rotors of a wind turbine and cast a shadow over neighbouring properties. When the blades rotate, the shadow flicks on and off; the impact is known as 'shadow flicker'. Only properties within 130 degrees either side of north, relative to the turbines.	This document replaced 'Planning for renewable energy: a companion guide to PPS22'.

Table 2 Summary of guidance pertaining to shadow flicker



2.3 Acceptable Limits

There is no formal limit on the amount of shadow flicker that is considered acceptable within the UK. Potentially significant effects are based on the available guidance, and other features of the modelling are highly conservative as set out in Tables 2 and 3. The results and conclusions made within this assessment consider the threshold limits of 30 minutes per day or 30 hours per year.

Other European countries do have limits, and these vary from one country to another. A typical limit, which has been utilised in Northern Ireland, Germany and Belgium, is 30 hours per year with a maximum of 30 minutes per day. Since there is no formal guidance on this subject in the UK, the discussion of the results relative to these limits is for reference purposes only.

If shadow flicker effects are predicted beyond this limit, mitigation may be required to eradicate the occurrence of shadow flicker. This is typically controlled by remote automatic wind turbine shutdown so that, in effect, no neighbouring property will experience the occurrence of shadow flicker beyond the limits specified above. There are two approaches to mitigation:

- Complete removal of effects;
- Reduction of any effects to the acceptable limit specified above.

Shadow flicker effects can only occur under specific conditions so, in reality, turbine shutdown may not be required to eliminate effects i.e. shadow flicker cannot occur if the weather at the time of predicted effects is not clear and sunny.

3 TECHNICAL ASSESSMENT

3.1 Methodology and Assumptions

The assessment has considered a 'viewing height' of 1.5 metres above ground level with each window having dimensions of 1m by 1m which is directly facing a wind turbine's position. The model considers terrain, the relative geometry of the turbine to the receptor, the dimensions of the wind turbine and the path of the Sun across the sky throughout a single year. The minimum Sun elevation at which shadow flicker effects could be deemed to materialise is 2 degrees above the horizon.

The geometric modelling assessment uses highly conservative parameters, such as constant operation of the turbine, constant clear skies with no cloud coverage, and no consideration of wind speeds; all of which could reduce shadow flicker effects. The geometric modelling assessment does not consider additional factors that could also diminish the effects of shadow flicker, such as the visibility from the receptor, cloud coverage and low and high wind speeds.

It is therefore that the geometric modelling results are considered theoretical and the worst-case scenario.

The main parameters of this assessment are presented in Table 3 below.

	Pager Power Assessment
Terrain Model	OS Panorama 50m DTM
Software	Windfarm R4
Turbines	6 Turbines are assumed constantly operational for the geometric modelled assessment
Assessment area	10 rotor diameters from each turbine, considered 130 degrees either side of the turbine
Assessed dwelling receptors	5 dwelling receptors
Minimum sun height over horizon	2 degrees
Meteorological assessment	The assessment considers constant clear skies Cloud coverage, and low and high wind speeds that could reduce the effects are not considered

	Pager Power Assessment
Windows	1 window per dwelling 1 metre by 1 metre with a centre that is 1.5 metres above ground level The orientation of windows is based on the conservative assumption that windows face the nearest proposed wind turbine. Screening in the form of existing vegetation and buildings that could obstruct views of the turbine (and therefore shadow flicker effects) are not considered in the geometric assessment
Viewing height	1.5m above ground level

Table 3 *Shadow flicker assessment parameters*



3.2 Shadow Flicker Results

A summary of the geometric modelling results is presented in Table 4 below and Table 5 on the following page. The results are based solely on the geometric possibility of effects occurring considering the position of the sun, relative to the turbines and dwellings. The geometric modelling results do not consider external factors that could be considered to reduce the duration of effects, such as weather conditions, cloud coverage, and existing screening in the form of vegetation and buildings. Therefore, these results are considered theoretical and worst-case scenario.

Time results are given as a decimal value, where 0.5 hours = 30 minutes. Results that exceed the threshold limits of 30 minutes per day or 30 hours per year are highlighted red for ease of reference.

3.2.1 Shadow Flicker Results – Per Dwelling

Dwelling	Days per year of potential shadow flicker	Maximum hours per day	Mean hours per day	Total hours per year
1	63	0.51	0.39	24.90
2	89	0.54	0.45	40.2
3	55	0.47	0.36	20.0
4	85	0.49	0.41	34.6
5	55	0.52	0.40	22.0

Table 4 Shadow flicker result per dwelling

3.2.2 Shadow Flicker Results – Per Turbine

Turbine	Days per year of potential shadow flicker	Maximum hours per day	Mean hours per day	Total hours per year
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	119	0.89	0.61	73.0

Table 5 Shadow flicker result per turbine

3.2.3 Date-Time Graph

Figure 3 on the following page illustrates the combined shadow flicker times for all dwelling receptors from the wind development (red hatched areas). The red lines illustrate the sunrise and sunset times. The geometric results suggest that shadow flicker effects are most prominent when the Sun is low in the sky, which is to be expected since this equates to the longest shadows.

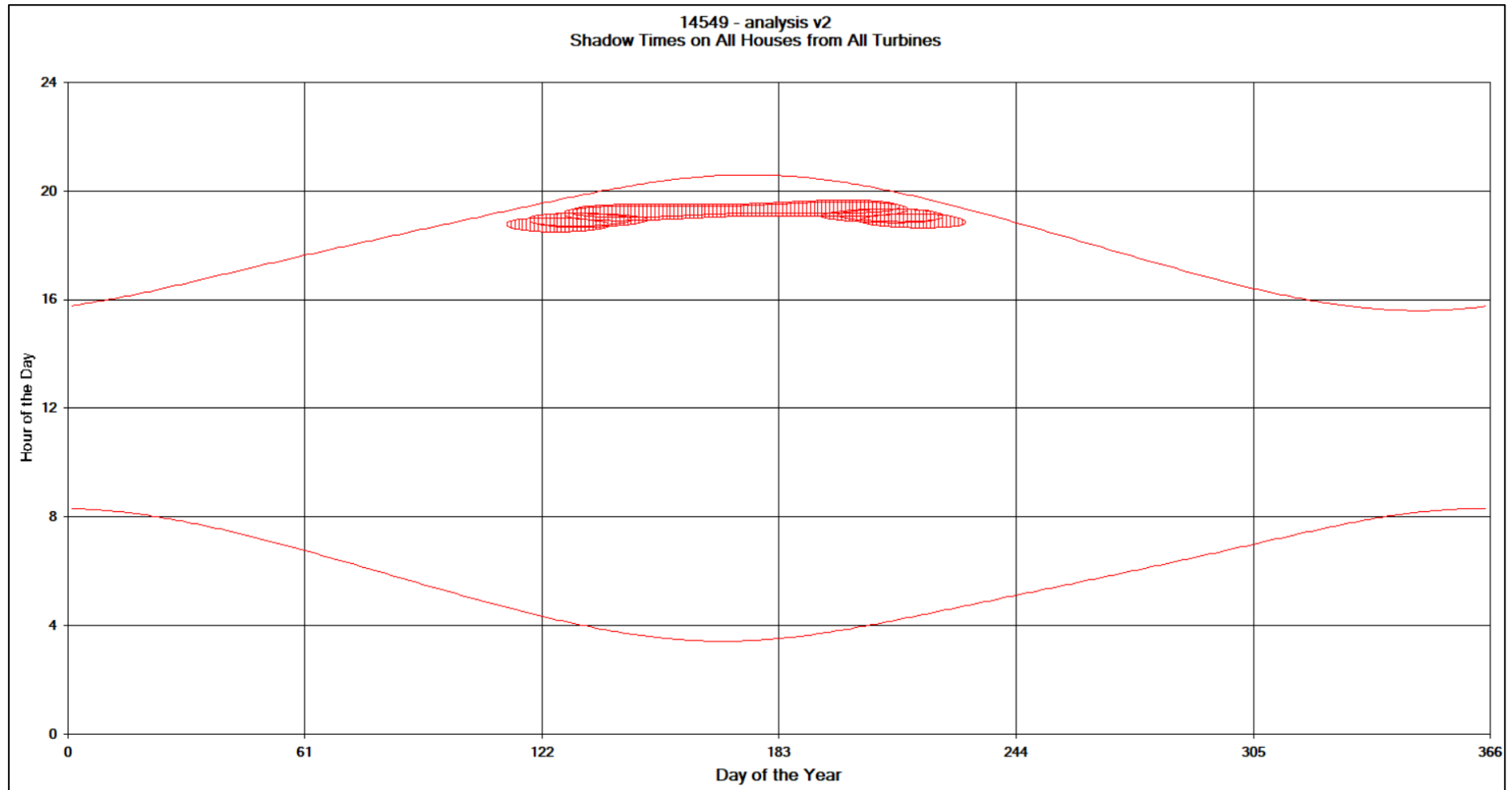


Figure 3 Date-time graph



3.3 Assessment Conclusions

Shadow flicker impacts exceeding the threshold limit of 30 minutes per day and/or 30 hours per year are geometrically possible towards four of the five assessed dwelling receptors. The results are based solely on the geometric possibility of effects occurring considering the position of the sun, relative to the turbines and dwellings. The geometric modelling results do not consider external factors that could be considered to reduce the duration of effects, including existing screening in the form of vegetation and buildings. Therefore, these results are considered theoretical and worst-case scenario.

The geometric modelling results predict that Turbine 6 is the only wind turbine that would potentially result in shadow flicker occurring. As such, mitigation by way of a temporary shutdown scheme for Turbine 6 during specific climatic conditions is recommended unless the conservative parameters of the assessment (such as the assumed worst-case window orientation at properties) are confirmed not to exist under baseline conditions.

APPENDIX A – DWELLING RECEPTOR DATA

Dwellings

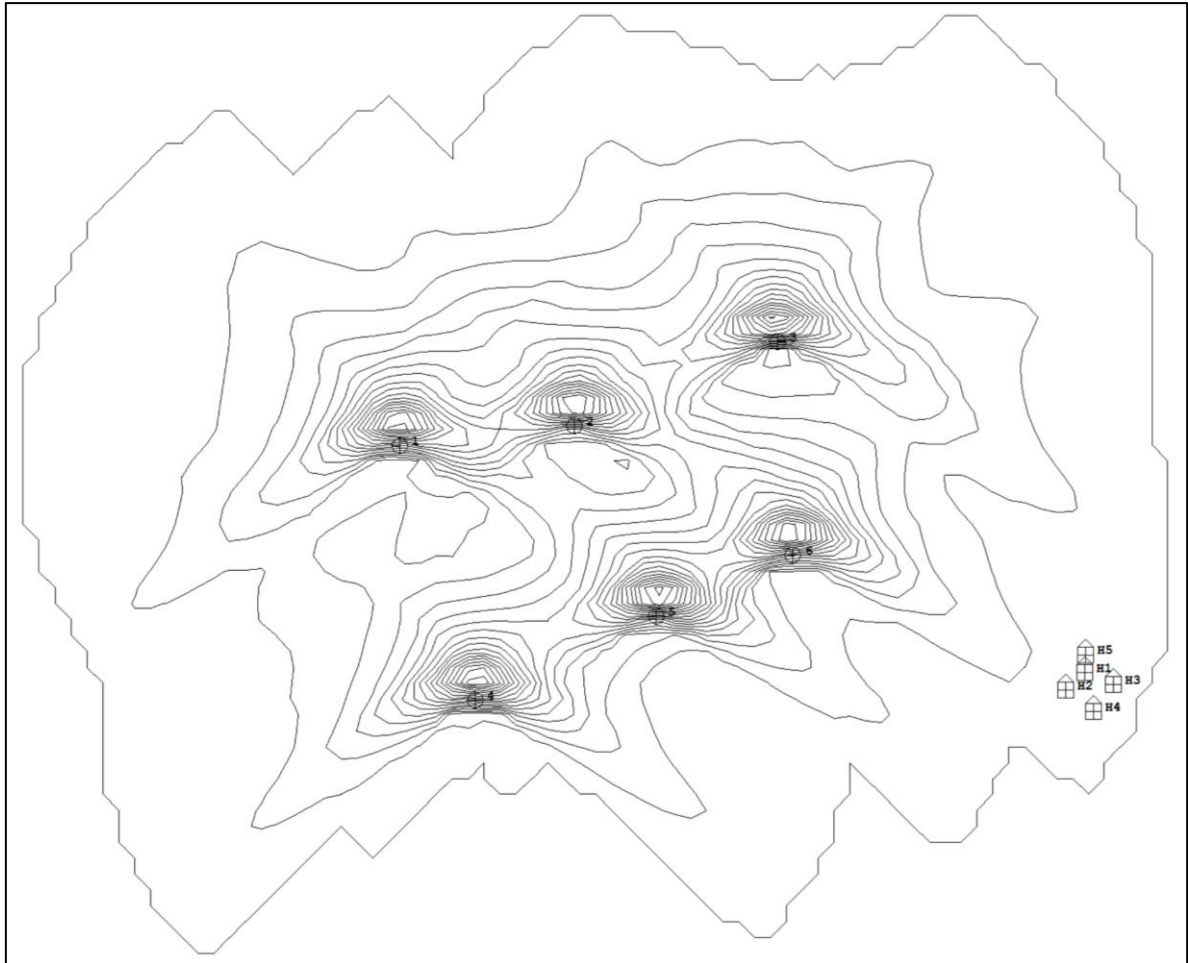
Receptor	Easting	Northing	Distance to nearest Turbine (m)	Bearing of Window to nearest Turbine (°)
1	512687	464934	987.75 (T06)	291.91
2	512629	464879	956.87 (T06)	296.33
3	512779	464898	1086.07 (T06)	291.90
4	512717	464812	1065.89 (T06)	297.44
5	512690	464990	971.11 (T06)	288.78

Assessed dwelling receptor details

APPENDIX B – CONTOUR MAP

Overview

The figure below shows the shadow flicker contours associated with the proposed wind development relative to the receptor locations. The contour spacing is 50 hours per year.



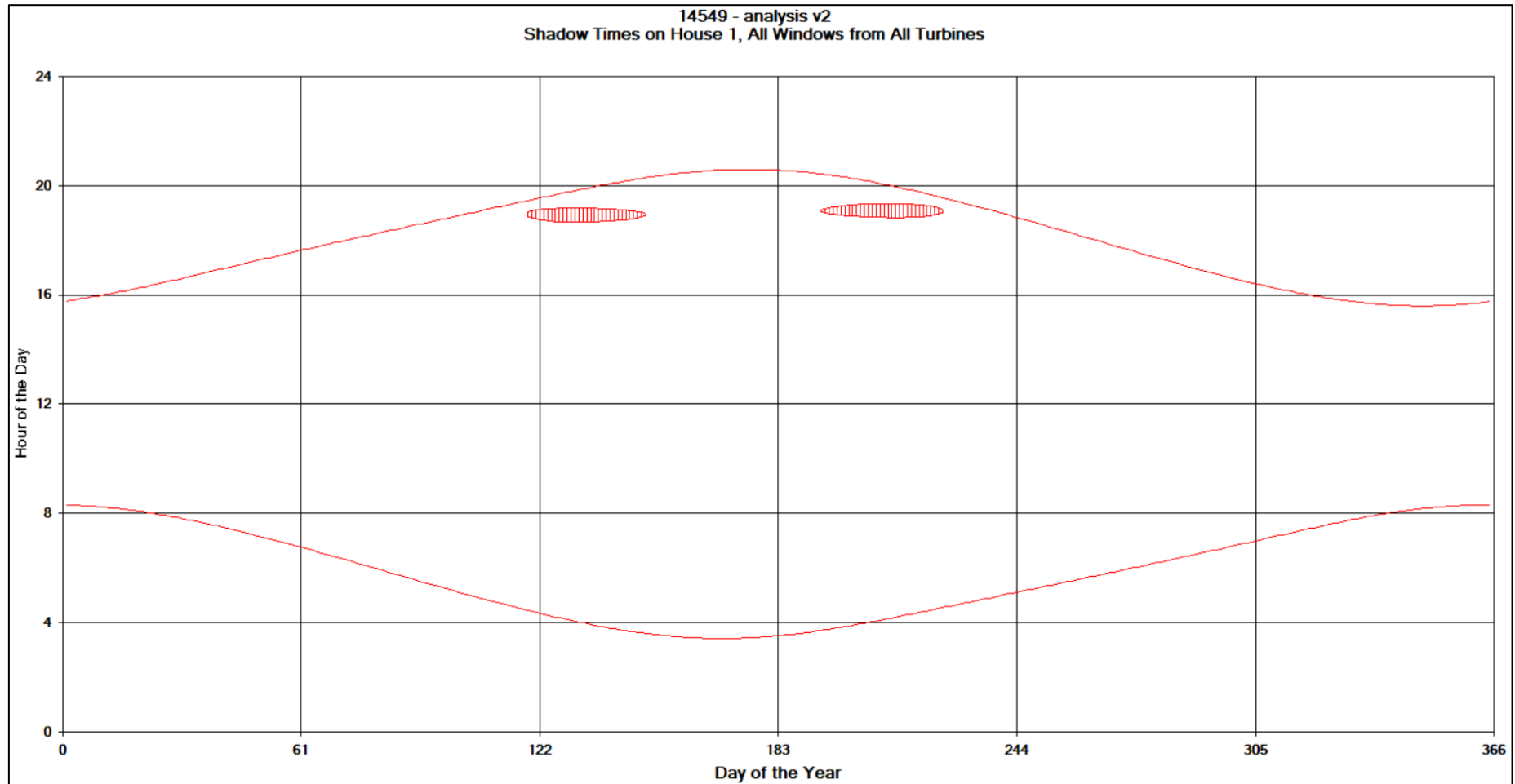
Contour map

APPENDIX C – SHADOW FLICKER CHARTS

The charts for the assessed dwelling receptors are presented on the following page. The charts shows:

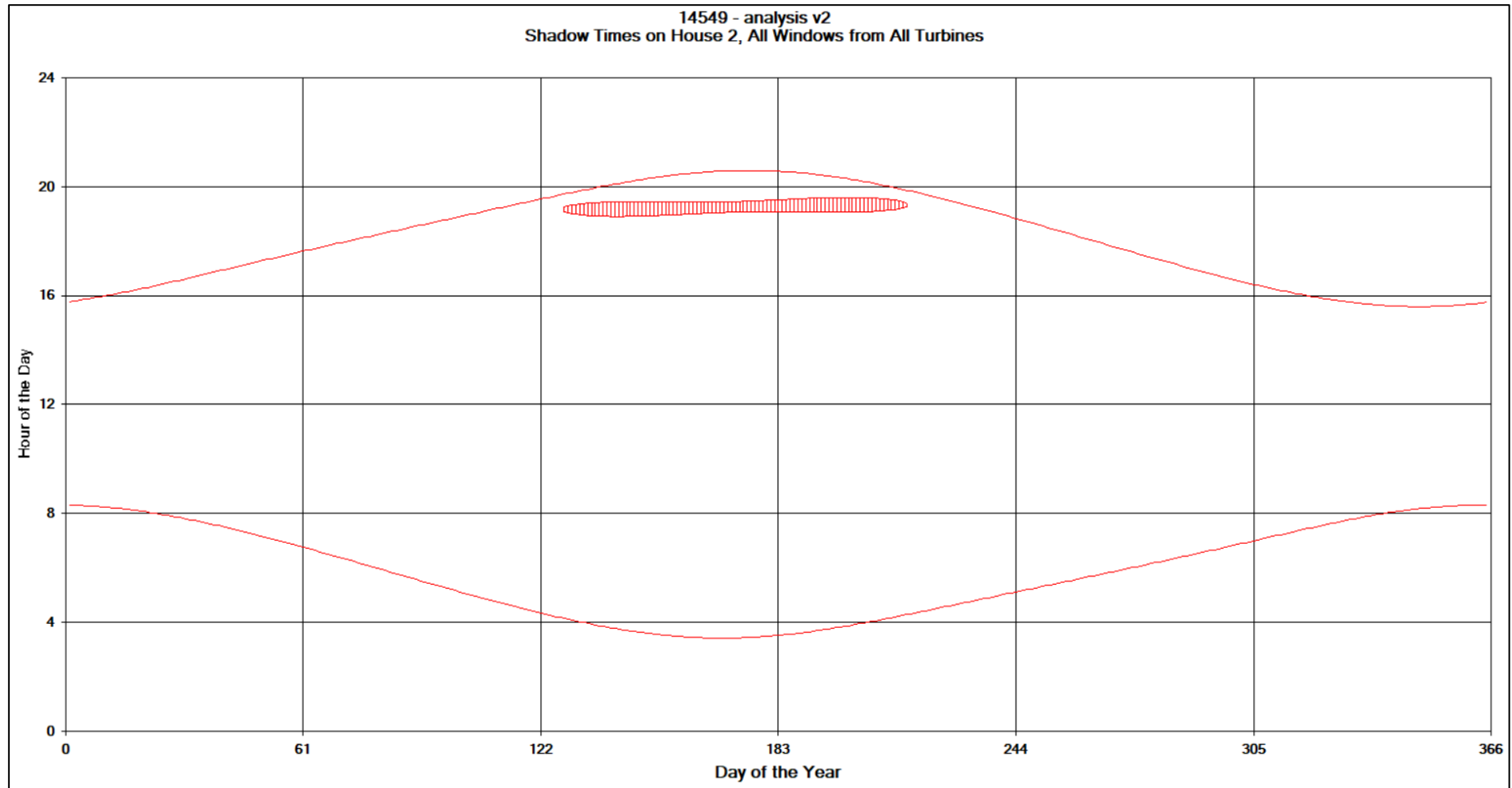
- The sunrise and sunset times throughout the year (thin red lines at the top and bottom of the chart;
- The days/times at which effects could occur (red hatched area).





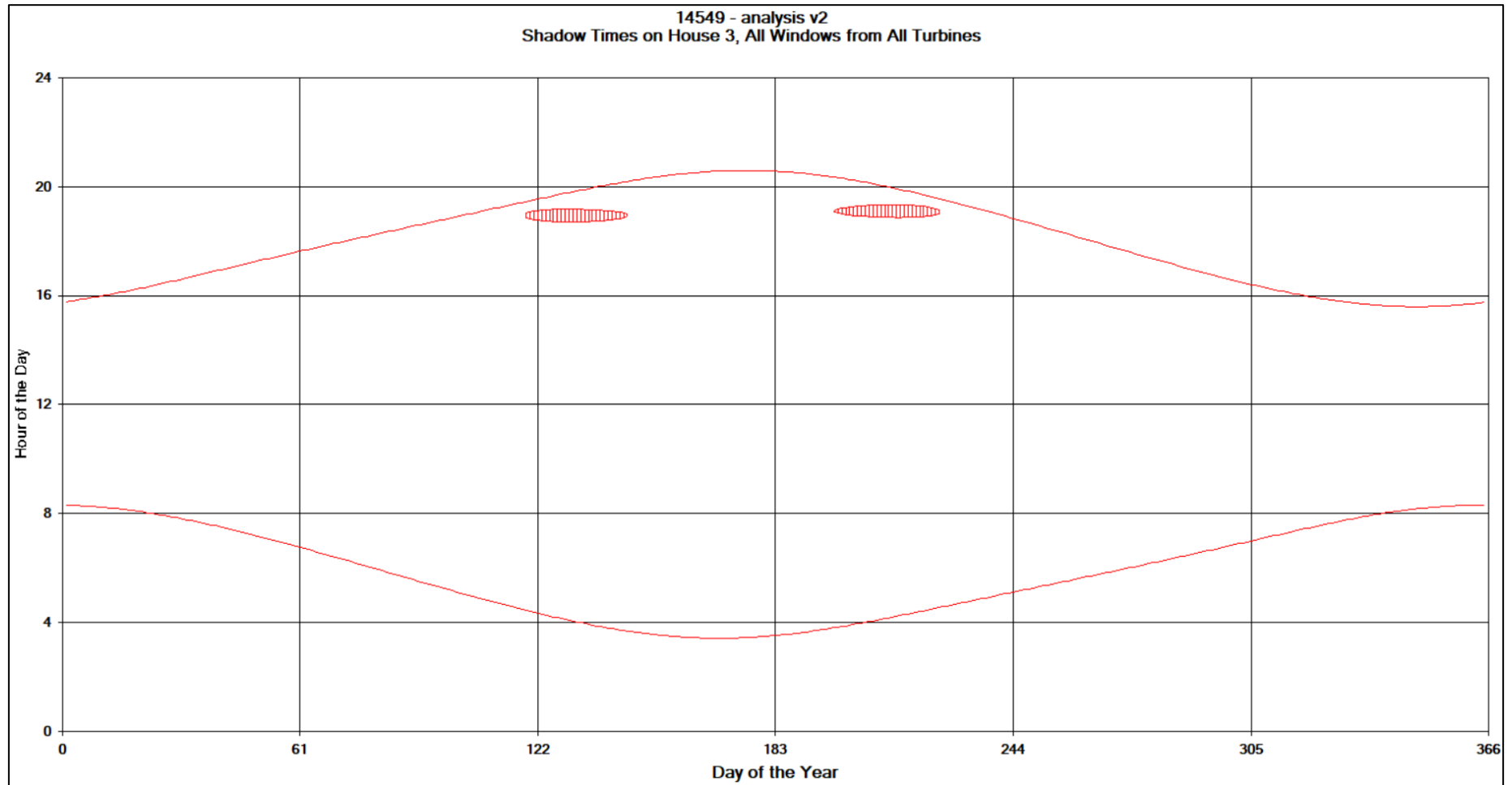
Predicted shadow flicker – Dwelling 1



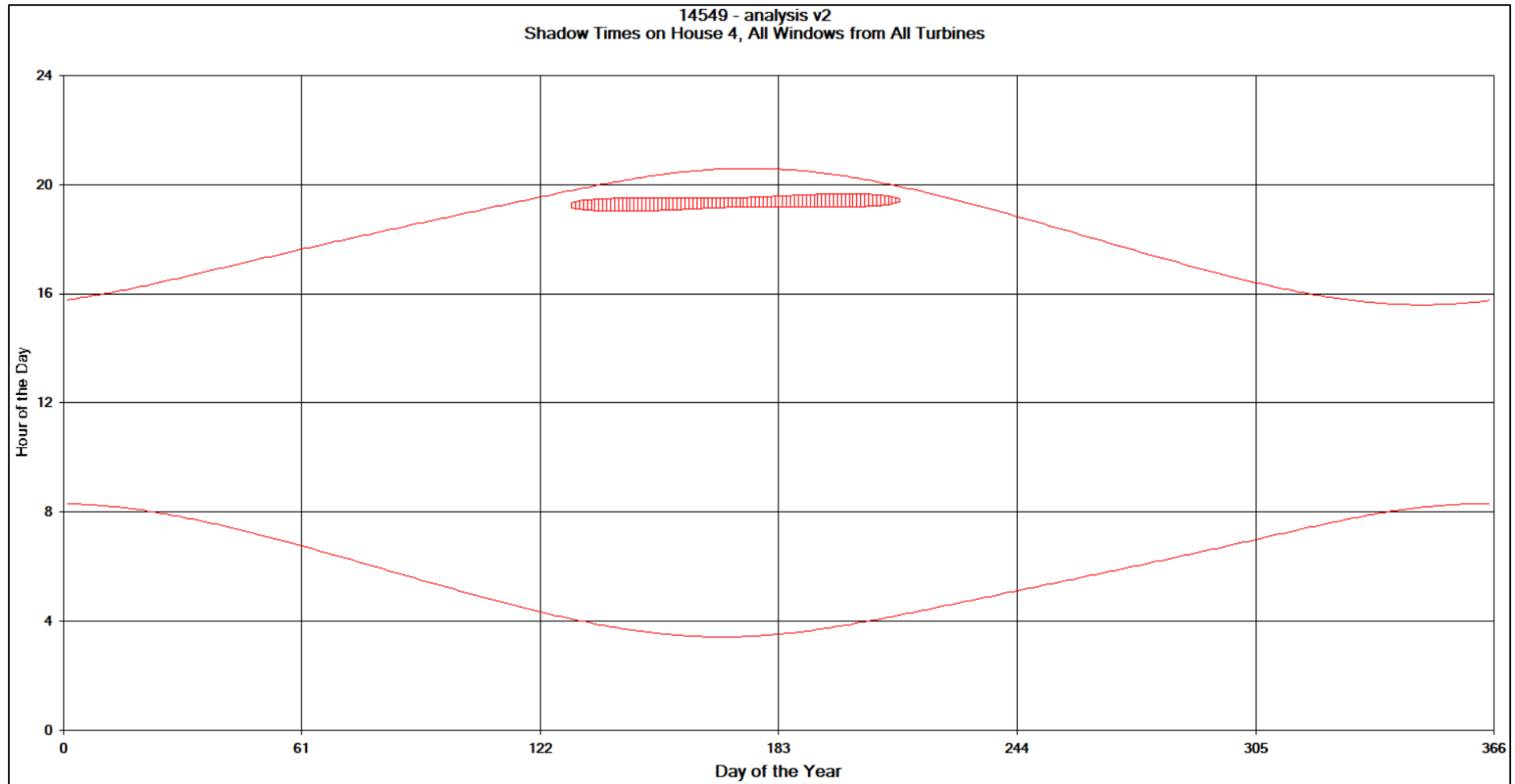


Predicted shadow flicker – Dwelling 2



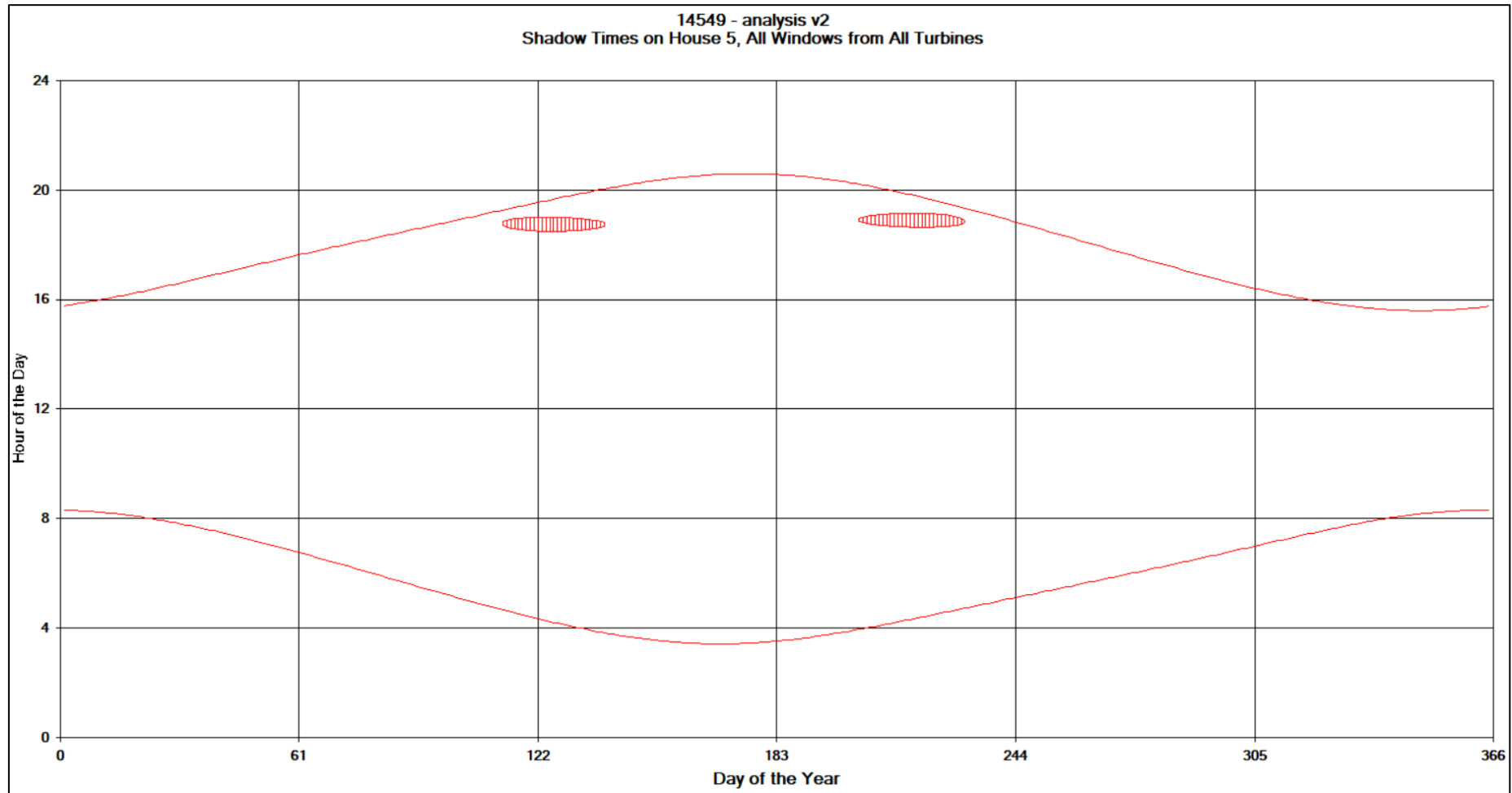


Predicted shadow flicker – Dwelling 3



Predicted shadow flicker – Dwelling 4





Predicted shadow flicker – Dwelling 5



APPENDIX D – SHADOW FLICKER DETAILED RESULTS

The dates and times when shadow flicker may theoretically occur at all assessed dwellings are presented in the table below and on the following pages. If the turbine is shutdown during all the times in the tables, then shadow flicker effects would be eliminated completely throughout the year for all dwellings (subject to climatic conditions also being present). This information should be used to guide the shutdown scheme recommended as part of this report to mitigate shadow flicker effects to be at or below the threshold limits. It is important to note that the duration should be less than 30 minutes per day and 30 hours per year.

The Applicant commits to the preparation of a Shadow Flicker Mitigation Strategy, to be submitted to and agreed in writing by the determining authority, to be secured by way of planning condition.

Turbine 6

Theoretical Dates and Times when Shadow Flicker is Geometrically Possible, subject to climatic conditions also being present

Date (DD/MM)	Start Time	End Time
23/04	18:41	18:51
24/04	18:38	18:54
25/04	18:36	18:56
26/04	18:34	18:57
27/04	18:33	18:58
28/04	18:32	18:59
29/04	18:31	19:03
30/04	18:30	19:05
10/05	18:30	19:07
20/05	18:29	19:08
30/05	18:29	19:09
40/05	18:29	19:10
50/05	18:29	19:10
60/05	18:29	19:10

Date (DD/MM)	Start Time	End Time
70/05	18:29	19:11
80/05	18:29	19:16
90/05	18:29	19:18
10/05	18:30	19:21
11/05	18:30	19:23
12/05	18:31	19:25
13/05	18:31	19:26
14/05	18:32	19:27
15/05	18:33	19:28
16/05	18:34	19:28
17/05	18:36	19:29
18/05	18:37	19:29
19/05	18:40	19:30
20/05	18:42	19:30
21/05	18:42	19:30
22/05	18:43	19:31
23/05	18:44	19:31
24/05	18:45	19:31
25/05	18:46	19:31
26/05	18:47	19:31
27/05	18:49	19:31
28/05	18:50	19:31
29/05	18:53	19:31
30/05	18:55	19:31
31/05	18:56	19:31

Date (DD/MM)	Start Time	End Time
10/06	18:56	19:31
20/06	18:56	19:31
30/06	18:57	19:31
40/06	18:57	19:31
50/06	18:57	19:31
60/06	18:58	19:31
70/06	18:58	19:31
80/06	18:59	19:31
90/06	18:59	19:31
10/06	19:00	19:31
11/06	19:00	19:30
12/06	19:00	19:30
13/06	19:01	19:30
14/06	19:01	19:31
15/06	19:02	19:31
16/06	19:02	19:31
17/06	19:02	19:31
18/06	19:02	19:31
19/06	19:03	19:31
20/06	19:03	19:31
21/06	19:03	19:31
22/06	19:03	19:32
23/06	19:04	19:32
24/06	19:04	19:32
25/06	19:04	19:33

Date (DD/MM)	Start Time	End Time
26/06	19:04	19:33
27/06	19:04	19:33
28/06	19:04	19:34
29/06	19:04	19:34
30/06	19:04	19:35
01/07	19:04	19:35
02/07	19:04	19:35
03/07	19:04	19:36
04/07	19:04	19:36
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10/07	19:03	19:39
11/07	19:03	19:39
12/07	19:03	19:39
13/07	19:02	19:40
14/07	18:59	19:40
15/07	18:58	19:40
16/07	18:56	19:40
17/07	18:55	19:40
18/07	18:55	19:40
19/07	18:54	19:40
20/07	18:53	19:40

Date (DD/MM)	Start Time	End Time
21/07	18:52	19:40
22/07	18:52	19:40
23/07	18:51	19:40
24/07	18:48	19:40
25/07	18:46	19:39
26/07	18:45	19:39
27/07	18:44	19:38
28/07	18:43	19:37
29/07	18:42	19:36
30/07	18:41	19:35
31/07	18:40	19:34
01/08	18:40	19:32
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05/08	18:38	19:20
06/08	18:38	19:19
07/08	18:38	19:19
08/08	18:38	19:18
09/08	18:38	19:17
10/08	18:38	19:16
11/08	18:38	19:14
12/08	18:38	19:12
13/08	18:39	19:09
14/08	18:40	19:06

Date (DD/MM)	Start Time	End Time
15/08	18:40	19:05
16/08	18:41	19:03
17/08	18:43	19:01
18/08	18:45	18:59
19/08	18:49	18:54

Shutdown scheme



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