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Solar Photovoltaic Glint and Glare Study

Prepared for:

BE Renewables Limited

Fendyke Farm Solar Farm

February, 2014

www.pagerpower.com

NOTE BY BE RENEWABLES LIMITED

This planning application is a resubmission of the documents for planning application ref: H20-0017-14 which was unanimously rejected at the South Holland District Council (SHDC) Planning Committee Meeting under Decision Notice dated 11th July 2014.

Following the rejection of the application – BE Renewables Limited (BERL) held a meeting with SHDC's Mr Richard Fidler and Mr Paul Jackson. BERL proposed an amended development boundary. It was agreed that rather than proceed to an appeal against the rejection of the previous planning application, BERL would prepare a revised scheme based upon the amended boundary for consideration by SHDC Planning Department and subsequent Planning Committee.

This report was prepared to accompany and assess the area of land associated within the development land boundary area for the previously submitted application. As this is a resubmission, with an amended development boundary (a reduced area from within the original boundary) it is appropriate to retain the use of this Glint and Glare Survey.

Please note: BERL has **not** changed or amended any of the survey assessments or ALC conclusions.

The report is submitted simply to accompany the amended planning application as the overall findings are still relevant and applicable to the resubmission.

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1	February, 2014	Initial Issue

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EXECUTIVE SUMMARY

BE Renewables Limited is proposing the development of a solar photovoltaic (PV) installation called Fendyke Farm Solar Farm to be located 2.5km south west of Sutton St James, Lincolnshire, England. The site details are presented below:

- The proposed development is due to be located on agricultural land ranging between approximately 0m and 2m above mean sea level (amsl);
- All of the PV panels at the PV installation will be fixed at 20 degrees above the horizontal and orientated in a southward direction.

Glint and Glare Concern

There is a possibility that solar reflections from the panels could occur at ground level. Therefore ground based receptors have been identified and assessed. The chosen receptors include nearby dwellings and relevant roads.

A geometric assessment was completed which considered the location and heights of the panels, the receptors and the sun as it passes across the sky through the year. In total, 26 calculations have been undertaken from each of the 11 chosen example points within the PV installation.

Assessment Results- Ground Based Receptors

The results of the geometric calculations are as follows:

- Direct solar reflections from the panels could be experienced from the majority of assessed panel locations for various receptors;

- Reflections could be experienced by drivers on the road around the proposed development. Information regarding glare and road users is as follows:

    - Encountering glare whilst driving is not an unusual occurrence. Glare can occur via reflections of the sun off a wet road or from car headlights whilst driving at night time etc.;

    - Reflections from a solar panel will not be as bright as many other glare sources encountered whilst driving, mainly because the panels are designed to absorb the light rather than reflect it;

- Reflections would only occur at assessed dwellings in the morning before 06:00 GMT (dwelling 10) and in the evenings between 17:15 and 18:20 GMT (dwellings 1-9) on certain days of the year (full list in Appendix B);

- Reflections can only be experienced if line of sight to the reflecting panels exists. It is likely that some of the dwellings will not be able to see the reflecting panels;

- The reflections would only last for a short period of time (less than one hour) from each assessed receptor point;

- The solar panels are likely to absorb most of the incoming light (5%-30% reflected);

- The sun is a much greater source of light when compared to a reflection from a solar panel;

- In instances where a solar reflection was calculated, the direct sunlight would be incident from the same direction as the reflected light.

- Subsequently, any solar reflection would be of lower intensity and therefore produce less glare when compared to direct light from the sun.

Installation of shielding around the perimeter of the solar farm would significantly reduce the likelihood of a solar reflection being visible from the assessed receptors.

Overall Conclusions

Reflections from the solar installation could be experienced from a number of assessed receptors including local ground based receptors such as the road users and local dwellings. Reflections are however unlikely to be a significant concern because:

- Road users must, and do, cope safely with direct sunshine and alternative sources of glare on a day to day basis. These sources of glare are much more intense to that of a reflection from a solar panel.
- Any receptor experiencing reflections is also very likely to be able to see the sun in a very similar location to where the reflection originates;
- Obstructed line of sight to the reflecting panels is likely to significantly reduce the likelihood of any reflection being witnessed;
- The sun is significantly brighter source of light when compared to a reflection from a solar panel.

Overall, the geometric calculations have shown that reflections from the panels are likely however it is not thought that the reflection would be a significant safety concern for road users, nor will they cause a significant nuisance for local dwellings.

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1 INTRODUCTION

BE Renewables Limited is proposing the development of a solar photovoltaic (PV) installation called Fendyke Farm Solar Farm to be located 2.5km south west of Sutton St James, Lincolnshire, England.

The proposed development is due to be located on agricultural land ranging between approximately 0m and 2m above mean sea level (amsl).

The need for a glint and glare assessment has arisen due to the location of the proposed near to residential properties and roads. In detail, this report contains the following:

- PV installation details;
- Explanation of potential glint and glare impacts;
- Overview of relevant guidance;
- Overview of the sun's position;
- Identification of ground based receptors (e.g. residences and roads);
- Glint and glare assessment for ground based receptors;

Please note that any reference to visual impact made within this report should be read in the context of potential glint and glare. In addition, this report is solely desk based and no site visit has taken place.

The relevant technical analysis is presented in each section. Following the assessment, conclusions and recommendations are made.

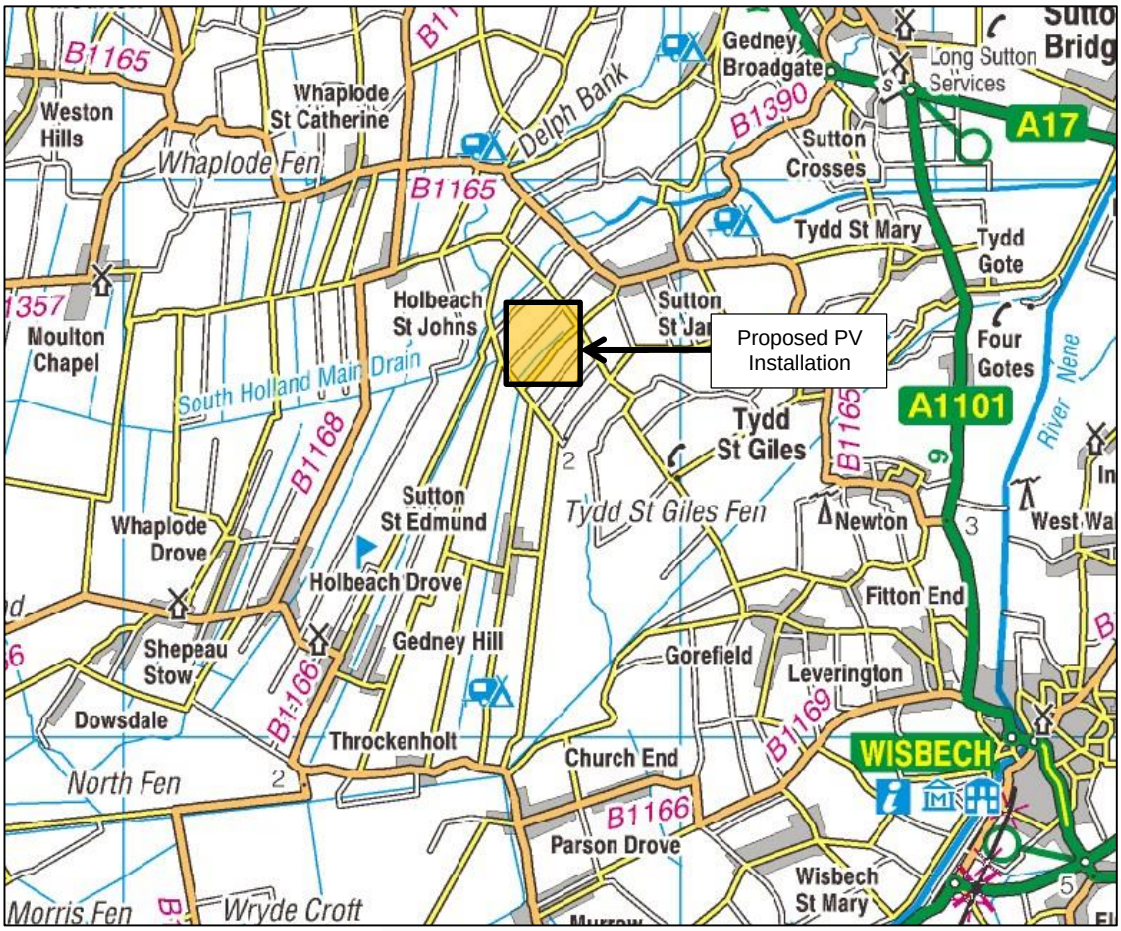


Figure 1 *Approximate location of Fendyke Farm Solar Farm*

2 FENDYKE FARM SOLAR FARM LOCATION

2.1 Fendyke Farm Solar Farm General Location

The general location of the proposed PV installation is illustrated on the map below:



Figure 2 Proposed PV installation layout aerial image (source: Google)

2.2 Fendyke Farm Solar Farm Aerial Image

The PV installation and associated infrastructure are due to be located as depicted on the following aerial image:


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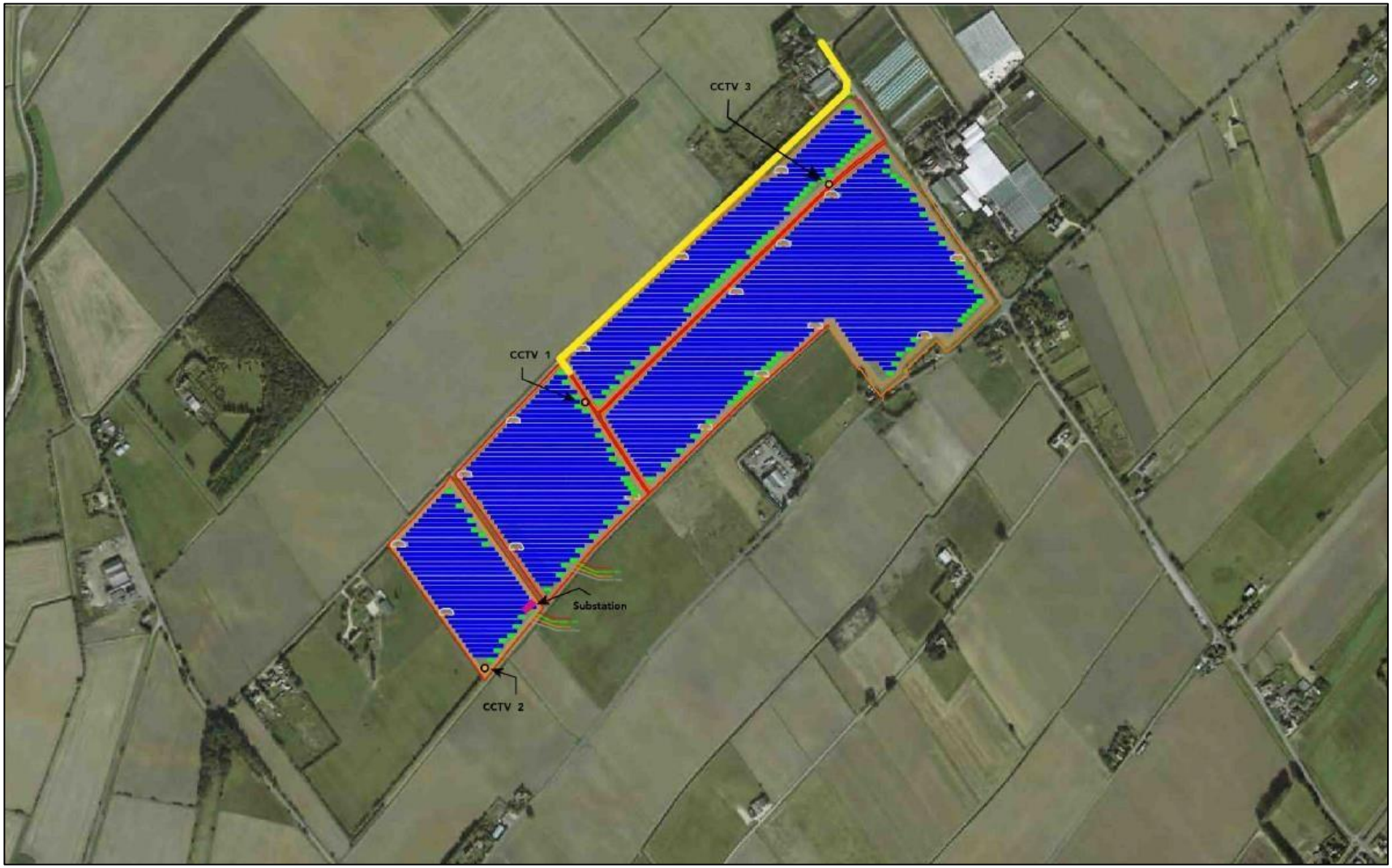


Figure 3 *Proposed PV installation site plan (Source: BE Renewables Limited)*

2.3 Fendyke Farm Solar Farm Site Plan

3 PHOTOVOLTAIC PANEL MOUNTING ARRANGEMENTS

The following section provides details regarding the solar panels.

3.1 Solar Panel Dimensions

The proposed PV installation will be mounted to ground via a metal frame with two layers of panels per row. The panels will be mounted at a height of between 0.60m and 1.94m above ground level (agl). The distance between each row will be between 7.5m and 9m depending on the topography.

3.2 Solar Panel Orientation

The panels are oriented to maximize electrical generation and will have a fixed position throughout the year. The intended panel angle is 20 degrees above the horizontal with the panels orientated facing southwards. The figure below shows the design.

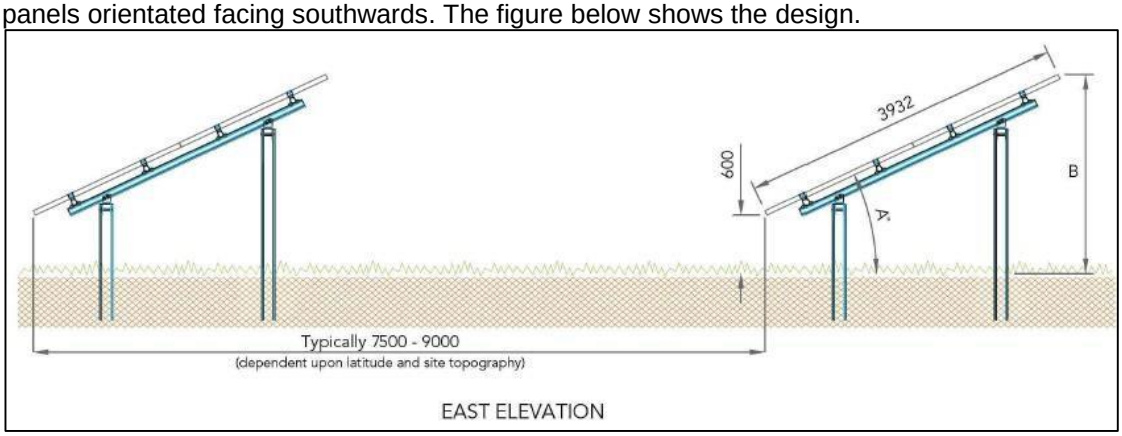


Figure 4 *Panel design*

4 GLINT AND GLARE OVERVIEW AND RELEVANT GUIDANCE

4.1 Overview

This section is intended to provide guidance on expected reflection effects exhibited by solar photovoltaic panels when in direct sunlight. The reflection of a surface is highly dependent on the angle of incidence and surface conditions. It is understood that as the angle of incidence increases, the amount of reflected light also increases.

Glare and dazzle effects due to reflection from solar panels are expected to be minimal and comparable to glass facades. Solar panels generally appear darker than glass in nearly all conditions. Typical soiling of the solar panel surface will further reduce the observed light reflection, and this also has an effect on the efficiency of the panel.

Photovoltaic panels are designed to absorb light and not reflect it. They have a smooth surface, however, which means that incident light from a specific direction is reradiated in a specific direction. This means that photovoltaic panels can cause reflections which are however considerably less intense than direct sunlight. Photovoltaic panels can reflect as low as 2% of incident light[1] however this level of reflectance increases as the angle of incidence increases.[2]

Direct solar reflections will not occur when the sun is obscured by cloud. At the location of the proposed solar development there is to be, on average, more than 1600 hours of sunshine per year[3]. When the sun is not shining there will be no reflection from the panel.

4.2 Reflectivity of Solar PV Panels

There are various sources of guidance with regard to glint and glare effects from solar panels. Notable sources and relevant extracts with regard to the reflectivity of panels are shown in the table below.

The table is by no means a comprehensive review of the data sources, rather it is intended to give an overview of the important parameters and considerations that have informed this assessment.

Source	Extract(s)	Remarks
UK Civil Aviation Authority - Interim guidance relating to Solar Photovoltaic Systems (SPV). This guidance was issued on 17 December 2010 and was subject to a CAA information alert 2010/53. It is believed that the formal policy was cancelled on September 7th, 2012[4] however the advisory is still applicable.	It is recommended that, as part of a planning application, the SPV developer provide safety assurance documentation (including risk assessment) regarding the full potential impact of the SPV installation on aviation interests.	The document emphasises the importance of considering the potential effects on aviation but does not provide specific parameters with regard to reflectivity.

doi:10.5402/2011/651857

[3] http://www.metoffice.gov.uk/climate/uk/averages/ukmapavge.html

[4] http://www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=4370

USA Federal Aviation Authority - *Technical Guidance for Evaluating Selected Solar Technologies on Airports* (issued 2010)	• Reflectivity from solar panels could cause flash blindness episodes on pilots or air traffic controllers when 7-11 W/m^2 reaches the eye. • Today's solar panels reflect as little as 2% of the incoming sunlight meaning roughly 20 W/m^2 are reflected off as typical PV panel. • PV solar panels reflect less light than other substances such as snow, vegetation and water.	-

Source	Extract(s)	Remarks
Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems," ISRN Renewable Energy, vol. 2011, Article ID 651857, 6 pages, 2011. doi:10.5402/2011/651857	The theoretical glare was estimated using published ocular safety metrics which quantify the potential for a postflash glare after-image. This was then compared to the postflash glare after-image caused by smooth water. The results show that the potential for hazardous glare from flatplate PV systems is similar to that of smooth water and not expected to be a hazard to air navigation. … Portland white cement concrete (which is a common concrete for runways), snow, and structural glass all have reflectivities greater than water and flat plate PV modules.	The study demonstrated that the reflectance of the solar cell varied with angle of incidence, with maximum values occurring at angles close to 90 degrees. The reflectance values varied from approximately 5% to 30%.

Table 1 *Guidance – Glint and Glare*

Whilst the guidance summarised in the table above is related to aviation interests, the general principles apply to any receptor that could be potentially affected by glint and glare effects.

5 GLINT AND GLARE ASSESSMENT METHODOLOGY

5.1 Overview of Assessment Methodology

A geometric assessment has been undertaken to determine whether any of the relevant identified receptors may be exposed to direct solar reflections from the proposed solar panels. The following section outlines details regarding the sun's positions and receptor locations for a 20° panel as proposed by the developer.

5.2 Sun's Position

The sun's position in the sky can be accurately described by its azimuth and elevation. Azimuth is a direction relative to true north (e.g. 160 degrees) and elevation describes the sun's vertical angle relative to the horizon (e.g. 20 degrees).

The sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

- Time;
- Date; Latitude;
- Longitude.

The following is true at the location of Fendyke Farm Solar Farm:

- The sun rises in the east (approximately[5]);
- The sun sets in the west (approximately[6]);
- The sun is at its highest around midday and is to the south at this time;
- The sun rises highest on June 21st reaching a maximum elevation of 60.70 degrees[7];
- On December 21st the maximum elevation reached by the sun is only 13.83 degrees[7].

Position parameters for selected dates in 2014 are shown in the table below:

Date	Solar elevation at Solar Noon	Azimuth at Sunrise	Azimuth at Sunset
21 March	37.58 degrees	88.54 degrees	271.79 degrees
21 June	60.70 degrees	47.46 degrees	312.54 degrees
21 September	37.89 degrees	87.70 degrees	271.96 degrees
21 December	13.83 degrees	129.62 degrees	230.37 degrees

Table 2 *Solar azimuth and elevation on specific days at the Fendyke Farm Solar Farm*

It is understood that the highest angle the sun ever reaches in the sky at this location is 60.70 degrees.

[5] In summer it is northeast and in winter southeast

[6] In summer it is northwest and in winter southwest [7]

In 2014

5.2.1 Sun Tracks- Elevation and Reflection

It is known in general terms that the sun rises in the east and sets in the west however this is not always strictly true throughout the year. The sun can rise in positions between north east and south east, with the sun setting in locations between the south west and north west in the UK. The location and angle of the sun in the sky will determine what angle reflections will occur at. The diagram below simply shows how to calculate the reflection angle for a panel mounted at 20 degrees with a sun positioned at 30 degrees above the horizontal due directly south of the panel.

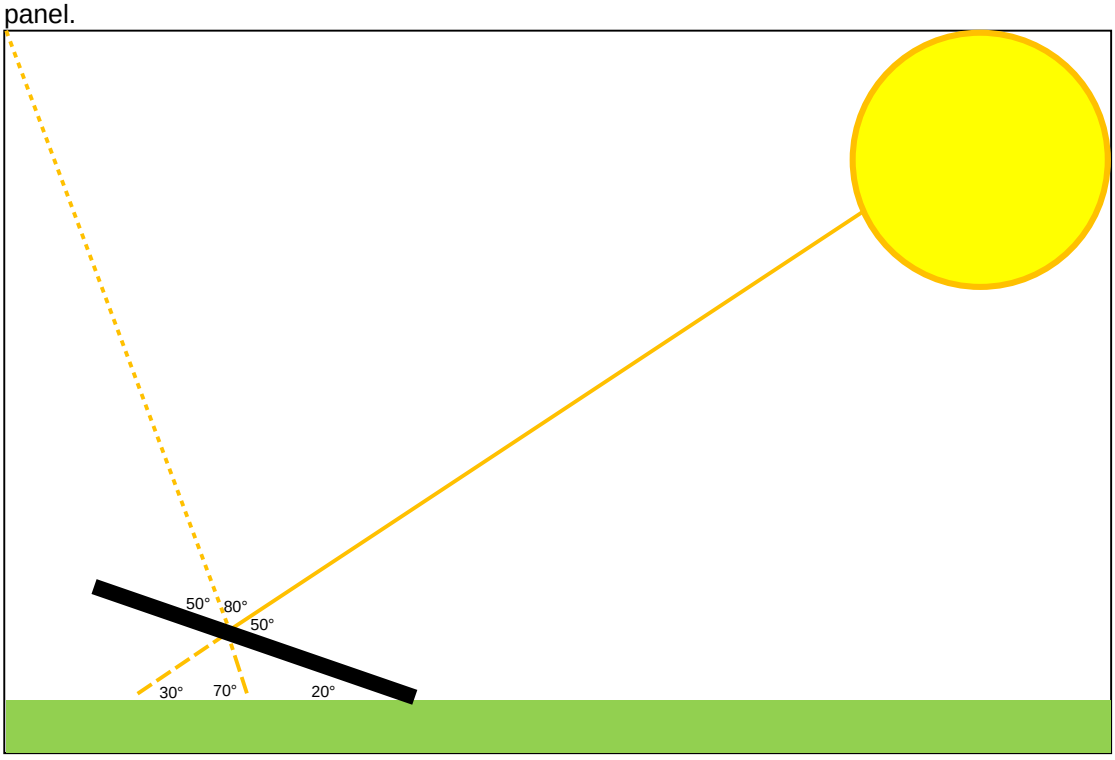


Figure 5 *Diagram showing geometry (when solar elevation is 30 degrees with a 20 degree panel)*

In this instance a reflection occurs at a steep angle directly behind the panel. With the sun's azimuth and elevation angle changing throughput the day, the direction and angle at which a reflection occurs will change constantly.

5.2.2 Sun Tracks- Azimuth and Elevation

The image below shows a simple diagram of the sun's movement across the sky as viewed by an observer facing south (in the northern hemisphere[7]). The orange lines show a simple illustration of the maximum and minimum elevation angle of the sun throughout one year as the

[7] The sun's azimuth angle is defined using 0° as north, heading clockwise so 180° is south and continuing round. This is reversed in the diagram as the perspective is as if viewed looking southwards.

sun travels through the sky each day. The high line illustrates the summer solstice (the longest day) and the lower line illustrates the winter solstice (the shortest day). For all other days in the year the sun would be between this maximum and minimum.

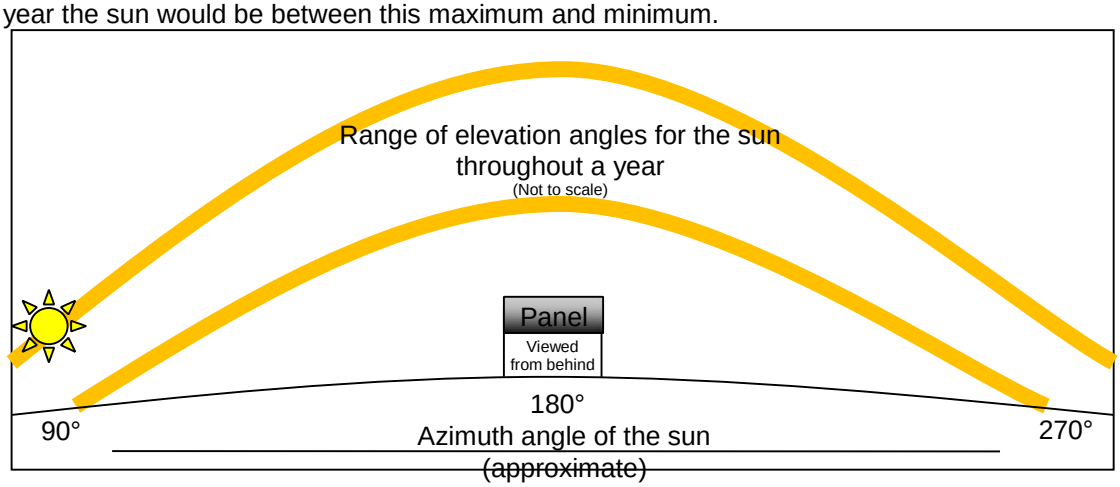


Figure 6 *Diagram showing how the azimuth and elevation change throughout a day/year)*

Calculating the direction and angle of a reflection from a solar panel requires a complex calculation. Further technical details relating to the methodology can be found in Appendix A.

5.3 Ground Based Assessment Methodology

The assessment methodology for a glint and glare assessment with respect to potential ground based receptors is as follows:

1. Identify ground based receptors. These may be from a nearby road, local residences or offices etc.

2. Determine whether the PV installation will be viewable from the identified receptor locations;

3. If it is calculated that a reflection will occur, consider the solar reflections from the PV installation with respect to the location of the sun in the sky, its angle above the horizontal and the time of day at which a reflection could occur.

4. Determine whether the solar reflection is likely to be a significant.

5. Consider mitigation such as shielding of the site.

6 IDENTIFICATION GROUND BASED RECEPTORS

The following section presents the process of identifying the relevant ground based receptors for the proposed Fendyke Farm Solar Farm.

The impact of glare due to solar reflections from the panels has been assessed by identifying locations at ground level which may be susceptible to such reflections. A direct solar reflection would only ever happen if there is direct line of sight between the panels and the receptor and therefore it is important to consider visibility when undertaking a glint and glare assessment. In the case of this assessment there are two categories of ground based receptors, this includes those driving along nearby roads and residences in the local area. If reflections can occur, it is important to determine when they will occur.

The map below shows the location of the assessed receptors with respect to the proposed PV installation.



Figure 7 *Identified ground based receptors*

6.1.1 Ground Based Receptor Details- Dwellings

A reflection calculation has been undertaken for each of the identified dwellings from the chosen points within the proposed PV installation. For a residence receptor, a height of 3.8m has been added to the ground height at that location (estimated height of a viewer from the 2nd floor). The details of the receptor points are presented in the table on the following page.

Location	Latitude (°)	Longitude (°)	Ground Height (m)	Assessed Height (m)

Location	Latitude (°)	Longitude (°)	Ground Height (m)	Assessed Height (m)
1	52.737625	0.042265	2	5.8
2	52.736386	0.043932	2	5.8
3	52.735253	0.044064	1	4.8
4	52.734881	0.042514	2	5.8
5	52.734259	0.040814	2	5.8
6	52.731532	0.042812	1	4.8
7	52.730494	0.042262	1	4.8
8	52.728116	0.037688	0	3.8
9	52.728389	0.031879	0	3.8
10	52.731255	0.022688	2	5.8

Table 3 *Information regarding identifed dwellings*

6.1.2 Ground Based Receptor Details- Roads

A reflection calculation has been undertaken for each of the identified road based receptors from the chosen points within the proposed PV installation. For a road receptor, a height of 1.5m has been added to the overall ground height at that location (estimated height of a road user). The details of the receptor points are presented in the table below.

Location	Latitude (°)	Longitude (°)	Ground Height (m)	Assessed Height (m)
1	52.732390	0.028947	1	2.5
2	52.733663	0.031029	1	2.5
3	52.734703	0.032762	1	2.5
4	52.735806	0.034778	1	2.5
5	52.736725	0.036615	1	2.5
6	52.737831	0.038549	1	2.5
7	52.738506	0.041099	2	3.5
8	52.737169	0.042584	2	3.5
9	52.735811	0.044015	1	2.5
10	52.734859	0.042861	1	2.5
11	52.734282	0.041304	2	3.5
12	52.733318	0.039689	1	2.5
13	52.732264	0.038217	2	3.5

14	52.731284	0.036538	1	2.5
Location	**Latitude (°)**	**Longitude (°)**	**Ground Height (m)**	**Assessed Height (m)**
15	52.730337	0.035025	0	1.5
16	52.728985	0.033254	1	2.5

Table 4 *Information regarding identifed roads*

The glint and glare assessment is presented in the following section.

7 GLINT AND GLARE ASSESSMENT

The following section presents the results of the geometric glint and glare assessment.

7.1 Panel Locations

Eleven locations have been chosen within the PV installation for assessment. The coordinates and heights are presented in the table below.

Location	Latitude	Longitude	Ground Height amsl[8]	Overall Panel Height amsl[9]
A	52.737564	0.041557	1	2
B	52.735460	0.043378	1	2
C	52.734572	0.041114	2	3
D	52.735497	0.039954	1	2
E	52.734796	0.038497	1	2
F	52.733137	0.035151	1	2
G	52.730516	0.031049	1	2
H	52.732331	0.029371	1	2
I	52.734670	0.033192	1	2
J	52.736683	0.036905	1	2
K	52.738107	0.039601	1	2

Table 5 *Reference panels for assessment*

A map showing the locations of the chosen panel locations is presented on the following page.

[8] Above mean sea level
[9] Additional panel height of 1m added for the reflector height.

7.2 Assessed Panel Locations

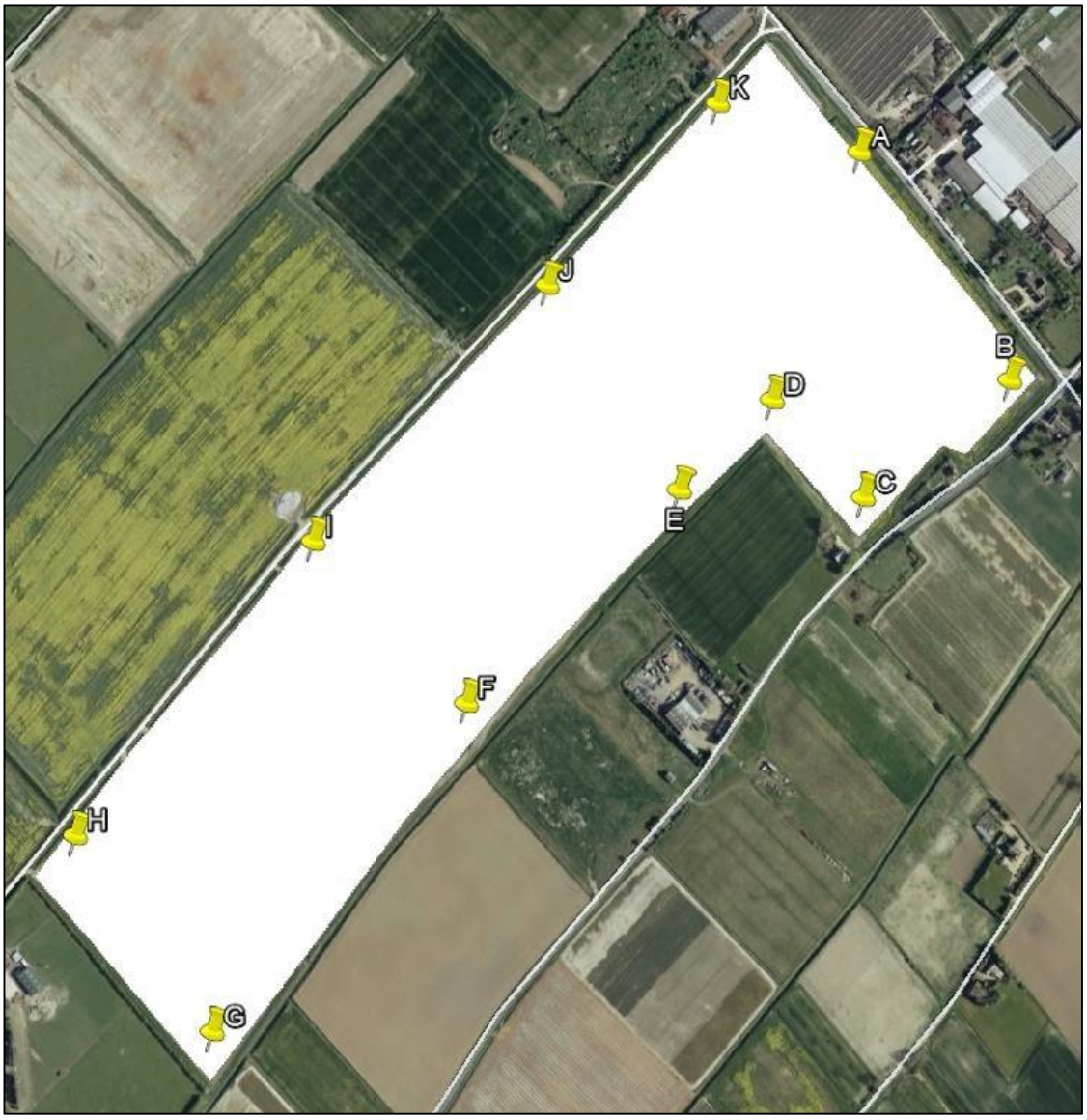


Figure 8 *Assessed reflector locations*

7.3 Assessment Limitations

The results of this analysis are considered conservative. The analysis does not incorporate the terrain profile of the horizon which may obscure the sun at its lowest angle (when a reflection may occur). In addition, any screening in the form of trees, building etc. which are not immediately next to the solar farm have not been considered, this again may obscure the sun at its lowest elevation. Finally, whilst line of sight to the development from receptors has been considered, only available street view imagery and satellite mapping has been used. This

imagery may not be up to date and is unlikely to give the full perspective of the installation from the location of the assessed receptor.

8 GEOMETRIC ASSESSMENT CALCULATIONS DISCUSSION

The tables below provide comments with regard to the results of the geometric assessments. The full calculation sheet results are presented in Appendix B.

8.1 Ground Based Receptors- Dwellings

Location	Comment
1	Reflections possible from panels in the region of reflectors A and K (to the north of the development). Reflections would occur between approximately 17:00 and 18:15 GMT in the months of March, May, August and October. At this time the sun would be due north west, at a low elevation in the sky and incident to the reflection location.
2	Reflections possible from panels in the region of reflector J. Reflections would occur around 18:00 GMT in March and September. At this time the sun would be due west, at a low elevation in the sky and incident to the reflection location.
3	Reflections possible from panels in the region of reflectors D and J. Reflections would occur between approximately 18:00 and 18:30 GMT in April May, August and September. At this time the sun would be due west to north west, at a low elevation in the sky and incident to the reflection location.
4	Reflections possible from panels in the region of reflectors D and E. Reflections would occur between approximately 17:45 and 18:30 GMT in March, May, July and September. At this time the sun would be due west to north west, at a low elevation in the sky and incident to the reflection location.
5	Reflections possible from panels in the region of reflectors E and I. Reflections would occur between approximately 18:00 and 18:30 GMT in March, May, July and September. At this time the sun would be due west to north west, at a low elevation in the sky and incident to the reflection location.
6	Reflections possible from panels in the region of reflectors F and H. Reflections would occur between approximately 18:00 and 18:30 GMT in April, May, July and September. At this time the sun would be due north west, at a low elevation in the sky and incident to the reflection location. A view of the panels is expected to be very much limited at this location.

Location	Comment
7	There will be no view of the panels from this location. No reflection is therefore possible.
8	No reflection is geometrically possible from any of the assessed receptors at this location.
9	No reflection is geometrically possible from any of the assessed receptors at this location.
10	Reflections possible from panels in the region of reflectors B, C, D, E F and H. Reflections would occur between approximately 18:00 and 18:30 GMT in April, May, July and August. At this time the sun would be due east to south east, at a low elevation in the sky and incident to the reflection location. A view of the panels is expected to be very much limited at this location.

Table 6 *Dwelling receptors reflection results discussion*

8.1 Ground Based Receptors- Roads

Location	Comment
1	Reflections possible from panels in the region of reflectors B, C, E and F. Reflections would occur between approximately 05:30 and 06:00 GMT in April, May, July and August. At this time the sun would be due north east to east, at a low elevation in the sky and incident to the reflection location.
2	Reflections possible from panels in the region of reflectors B, C, D and E. Reflections would occur between approximately 05:30 and 06:00 GMT in April, May, July, August and September. At this time the sun would be due north east to south east, at a low elevation in the sky and incident to the reflection location.
3	Reflections possible from panels in the region of reflectors B, D, E and I. Reflections would occur between approximately 05:45 and 06:30 GMT in March, April, August, September and October. At this time the sun would be due north east to east, at a low elevation in the sky and incident to the reflection location.
4	Reflections possible from panels in the region of reflector A. Reflections would occur between approximately 05:30 and 06:00 GMT in June and July. At this time the sun would be due north east, at a low elevation in the sky and incident to the reflection location.

Location	Comment
5	Reflections possible from panels in the region of reflector A. Reflections would occur between approximately 05:30 and 06:00 GMT in May and August. At this time the sun would be due north east, at a low elevation in the sky and incident to the reflection location.
6	Reflections possible from panels in the region of reflector K. Reflections would occur between approximately 05:30 and 06:00 GMT in June. At this time the sun would be due north east, at a low elevation in the sky and incident to the reflection location.
7	No reflection is geometrically possible from any of the assessed receptors at this location.
8	No reflection is geometrically possible from any of the assessed receptors at this location.
9	Reflections possible from panels in the region of reflector J. Reflections would occur between approximately 18:00 and 18:30 GMT in April and August. At this time the sun would be due north west, at a low elevation in the sky and incident to the reflection location.
10	Reflections possible from panels in the region of reflector D. Reflections would occur between approximately 18:00 and 18:30 GMT in May and July. At this time the sun would be due north west, at a low elevation in the sky and incident to the reflection location.
11	Reflections possible from panels in the region of reflectors E and I. Reflections would occur between approximately 18:00 and 18:30 GMT in March, May, June and September. At this time the sun would be due west to north west, at a low elevation in the sky and incident to the reflection location.
12	Reflections possible from panels in the region of reflector I. Reflections would occur between approximately 18:00 and 18:30 GMT in May and July. At this time the sun would be due north west, at a low elevation in the sky and incident to the reflection location.
Location	**Comment**

13	Reflections possible from panels in the region of reflector H. Reflections would occur between approximately 17:45 and 18:15 GMT in March and September. At this time the sun would be due west, at a low elevation in the sky and incident to the reflection location.
14	Reflections possible from panels in the region of reflector H. Reflections would occur between approximately 18:00 and 18:30 GMT in April and August. At this time the sun would be due north west, at a low elevation in the sky and incident to the reflection location.
15	Reflections possible from panels in the region of reflector G. Reflections would occur between approximately 18:00 and 18:15 GMT in March and September. At this time the sun would be due west, at a low elevation in the sky and incident to the reflection location.
16	No reflection is geometrically possible from any of the assessed receptors at this location.

Table 7 *Road receptors reflection results discussion*

8.2 Geometric Assessment Results Overview

Reflections have been calculated to occur for some of the identified ground based receptors in the vicinity of the proposed solar farm. In all of the locations where a reflection from the panels could be experienced by a ground based receptor, direct sunlight would be incident from a low elevation from the same direction as the reflected light.

Solar reflections have been calculated to occur at road locations around the proposed PV installation. Encountering glare whilst driving is not an unusual occurrence. This may be via reflections of the sun off a wet road, or night time driving with the headlights on. It is something that a driver must safely cope with. Reflections from a solar panel will not be as bright as many of the driving glare effects encountered mainly because they are designed to absorb the light rather than reflect it. Again, direct sunlight would be incident from the same direction as the reflected light.

8.3 Mitigation

Any shielding put up around the perimeter of the field will significantly reduce the likelihood of any reflection occurring and being visible to one of the assessed receptors. It is recommended that the height of the shielding is equal or similar to the maximum height of the panels above ground level.

9 OVERALL CONCLUSIONS

All of the PV panels at the Fendyke Farm Solar Farm will be fixed at 20 degrees above the horizontal and orientated in a southward direction.

There is a possibility that solar reflections from the panels could occur at ground level. Therefore ground based receptors have been identified and assessed. The chosen receptors include nearby dwellings and relevant roads.

A geometric assessment was completed which considered the location and heights of the panels, the receptors and the sun as it passes across the sky through the year. In total, 26 calculations have been undertaken from each of the 11 chosen example points within the PV installation.

9.1 Assessment Results- Ground Based Receptors

- Direct solar reflections from the panels could be experienced from the majority of assessed panel locations for various receptors;
- Reflections could be experienced by drivers on the road around the proposed development. Information regarding glare and road users is as follows:
    - Encountering glare whilst driving is not an unusual occurrence. Glare can occur via reflections of the sun off a wet road or from car headlights whilst driving at night time etc.;
    - Reflections from a solar panel will not be as bright as many other glare sources encountered whilst driving, mainly because the panels are designed to absorb the light rather than reflect it;
- Reflections would only occur at assessed dwellings in the morning before 06:00 GMT (dwelling 10) and in the evenings between 17:15 and 18:20 GMT (dwellings 1-9) on certain days of the year (full list in Appendix B);
- Reflections can only be experienced if line of sight to the reflecting panels exists. It is likely that some of the dwellings will not be able to see the reflecting panels;
- The reflections would only last for a short period of time (less than one hour) from each assessed receptor point;
- The solar panels are likely to absorb most of the incoming light (5%-30% reflected);
- The sun is a much greater source of light when compared to a reflection from a solar panel;
- In instances where a solar reflection was calculated, the direct sunlight would be incident from the same direction as the reflected light.
- Subsequently, any solar reflection would be of lower intensity and therefore produce less glare when compared to direct light from the sun.

Installation of shielding around the perimeter of the solar farm would significantly reduce the likelihood of a solar reflection being visible from the assessed receptors.

9.2 Overall Conclusions

Reflections from the solar installation could be experienced from a number of assessed receptors including local ground based receptors such as the road users and local dwellings. Reflections are however unlikely to be a significant concern because:

- Road users must, and do, cope safely with direct sunshine and alternative sources of glare on a day to day basis. These sources of glare are much more intense to that of a reflection from a solar panel.
- Any receptor experiencing reflections is also very likely to be able to see the sun in a very similar location to where the reflection originates;
- Obstructed line of sight to the reflecting panels is likely to significantly reduce the likelihood of any reflection being witnessed;
- The sun is significantly brighter source of light when compared to a reflection from a solar panel.

Overall, the geometric calculations have shown that reflections from the panels are likely however it is not thought that the reflection would be a significant safety concern for road users, nor will they cause a significant nuisance for local dwellings.

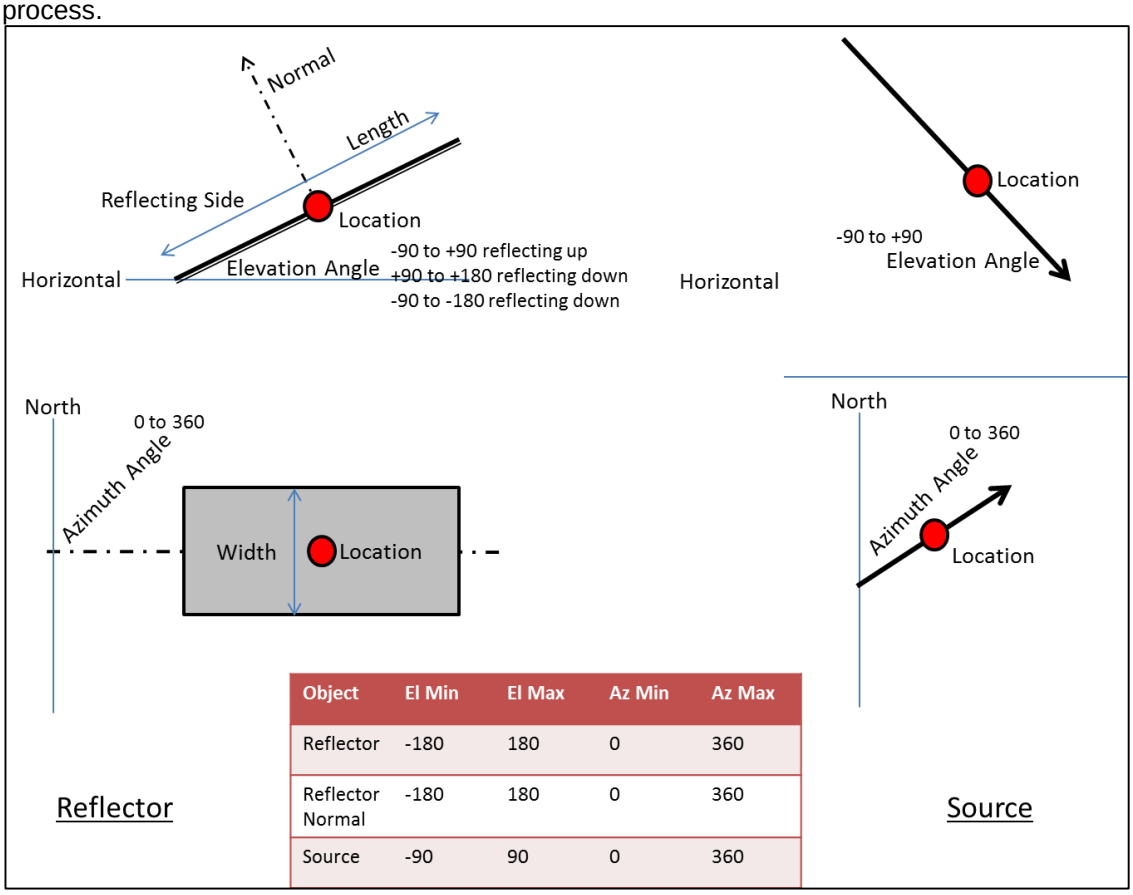
APPENDIX A- REFLECTION CALCULATIONS

The calculations are three dimensional and complex, accounting for:

- The Earth's orbit around the Sun;
- The Earth's rotation;
- The Earth's orientation;
- The reflector's location;
- The reflector's 3D Orientation.

Reflections from a flat reflector are calculated by considering the normal which is an imaginary line that is perpendicular to the reflective surface and originates from it.

The diagram on the following page may be used to aid understanding of the reflection calculation process.



Object	El Min	El Max	Az Min	Az Max
Reflector	-180	180	0	360
Reflector Normal	-180	180	0	360
Source	-90	90	0	360

The following process is used to determine the 3D Azimuth and Elevation of a reflection:

- Use the Latitude and Longitude of the reflector as the reference point for calculation purposes;
- Calculate the Azimuth and Elevation of the normal to the reflector;
- Calculate the 3D angle between the source and the normal;

- If this angle is less than 90 degrees a reflection will occur. If it is greater than 90 degrees no reflection will occur because the source is behind the reflector;
- Calculate the Azimuth and Elevation of the reflection in accordance with the following:
    - The angle between source and normal is equal to angle between normal and reflection; ○ Source, Normal and Reflection are in the same plane

APPENDIX B- GEOMETRIC CALCULATION RESULTS

Geometric Assessment Results- Dwellings

The following table presents an overview of the results of the analysis for dwelling receptors.

Location	Panel Reflector Location										
	A	B	C	D	E	F	G	H	I	J	K
1	**Reflections Possible** Earlier date: Date: 03/03/2014 Time: 17:38:57 [GMT] Later date: Date: 10/10/2014 Time: 17:14:07 [GMT] Sun Elevation: 0.09° Sun Azimuth: 259.4°	No Reflection Possible[10]	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	**Reflections Possible** Earlier date: Date: 05/05/2014 Time: 18:04:34 [GMT] Later date: Date: 06/08/2014 Time: 18:13:45 [GMT] Sun Elevation: 12.0° Sun Azimuth: 281.7°

Location	Panel Reflector Location										
	A	B	C	D	E	F	G	H	I	J	K

[10] Location does not have a view of the panel face and therefore a reflection could never occur.

2	No Valid Reflection [12]	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	**Reflections Possible** Earlier date: Date: 30/03/2014 Time: 18:05:36 [GMT] Later date: Date: 12/09/2014 Time: 17:57:23 [GMT] Sun Elevation: 3.1° Sun Azimuth: 272.6°	No Valid Reflection
3	No Valid Reflection	No Reflection Possible	No Reflection Possible	**Reflections Possible** Earlier date: Date: 03/04/2014 Time: 18:04:36 [GMT] Later date: Date: 08/09/2014 Time: 17:58:58 [GMT] Sun Elevation: 4.3° Sun Azimuth: 273.6°	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	**Reflections Possible** Earlier date: Date: 10/05/2014 Time: 18:10:50 [GMT] Later date: Date: 01/08/2014 Time: 18:20:46 [GMT] Sun Elevation: 12.0° Sun Azimuth: 283.8°	No Valid Reflection

[12]

Location	Panel Reflector Location										
	A	B	C	D	E	F	G	H	I	J	K

Location could have a view of the panel face however the sun's position in the sky at any point does not allow for a reflection at the assessed location.

4	No Valid Reflection	No Valid Reflection	No Reflection Possible	**Reflections Possible** Earlier date: Date: 27/05/2014 Time: 18:09:42 [GMT] Later date: Date: 15/07/2014 Time: 18:18:31 [GMT] Sun Elevation: 15.1° Sun Azimuth: 285.8°	**Reflections Possible** Earlier date: Date: 14/03/2014 Time: 18:04:07 [GMT] Later date: Date: 28/09/2014 Time: 17:45:27 [GMT] Sun Elevation: -0.3° Sun Azimuth: 267.7°	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Valid Reflection	No Valid Reflection
5	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	**Reflections Possible** Earlier date: Date: 24/05/2014 Time: 18:07:52 [GMT] Later date: Date: 19/07/2014 Time: 18:17:20 [GMT] Sun Elevation: 14.8° Sun Azimuth: 285.0°	No Reflection Possible	No Reflection Possible	No Reflection Possible	**Reflections Possible** Earlier date: Date: 02/04/2014 Time: 18:05:50 [GMT] Later date: Date: 10/09/2014 Time: 17:59:15 [GMT] Sun Elevation: 3.8° Sun Azimuth: 273.5°	No Valid Reflection	No Valid Reflection

Location	Panel Reflector Location										
	A	B	C	D	E	F	G	H	I	J	K
6	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Reflection Possible	**Reflections Possible** Earlier date: Date: 13/05/2014 Time: 18:11:44 [GMT] Later date: Date: 29/07/2014 Time: 18:21:52 [GMT] Sun Elevation: 12.5° Sun Azimuth: 284.5°	No Reflection Possible	**Reflections Possible** Earlier date: Date: 03/04/2014 Time: 18:07:20 [GMT] Later date: Date: 08/09/2014 Time: 18:01:43 [GMT] Sun Elevation: 3.8° Sun Azimuth: 274.1°	No Valid Reflection	No Valid Reflection	No Valid Reflection
7	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	**Reflections Possible** Earlier date: Date: 20/03/2014 Time: 18:07:08 [GMT] Later date: Date: 23/09/2014 Time: 17:52:11 [GMT] Sun Elevation: 0.4° Sun Azimuth: 269.9°	**Reflections Possible** Earlier date: Date: 24/04/2014 Time: 18:08:51 [GMT] Later date: Date: 18/08/2014 Time: 18:14:33 [GMT] Sun Elevation: 8.7° Sun Azimuth: 280.0°	No Valid Reflection	No Valid Reflection	No Valid Reflection
8	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection

9	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection
Location	**Panel Reflector Location**										
	A	B	C	D	E	F	G	H	I	J	K
10	No Valid Reflection	**Reflections Possible** Earlier date: Date: 12/05/2014 Time: 05:40:02 [GMT] Later date: Date: 01/08/2014 Time: 05:50:02 [GMT] Sun Elevation: 11.9° Sun Azimuth: 75.8°	**Reflections Possible** Earlier date: Date: 04/05/2014 Time: 05:42:30 [GMT] Later date: Date: 08/08/2014 Time: 05:51:24 [GMT] Sun Elevation: 10.7° Sun Azimuth: 77.4°	**Reflections Possible** Earlier date: Date: 28/05/2014 Time: 05:37:37 [GMT] Later date: Date: 15/07/2014 Time: 05:46:20 [GMT] Sun Elevation: 14.2° Sun Azimuth: 72.9°	**Reflections Possible** Earlier date: Date: 19/05/2014 Time: 05:38:44 [GMT] Later date: Date: 25/07/2014 Time: 05:48:48 [GMT] Sun Elevation: 13.1° Sun Azimuth: 74.4°	**Reflections Possible** Earlier date: Date: 26/04/2014 Time: 05:46:27 [GMT] Later date: Date: 16/08/2014 Time: 05:52:57 [GMT] Sun Elevation: 9.2° Sun Azimuth: 79.5°	No Reflection Possible	**Reflections Possible** Earlier date: Date: 29/04/2014 Time: 05:46:32 [GMT] Later date: Date: 13/08/2014 Time: 05:54:04 [GMT] Sun Elevation: 10.0° Sun Azimuth: 79.0°	No Valid Reflection	No Valid Reflection	No Valid Reflection

Geometric Assessment Results- Roads

The following table presents an overview of the results of the analysis for road receptors.

Location	Panel Reflector Location										
	A	B	C	D	E	F	G	H	I	J	K
1	No Valid Reflection	**Reflections Possible** Earlier date: Date: 15/05/2014 Time: 05:38:53 [GMT] Later date: Date: 29/07/2014 Time: 05:49:02 [GMT] Sun Elevation: 12.4° Sun Azimuth: 75.1°	**Reflections Possible** Earlier date: Date: 04/05/2014 Time: 05:42:12 [GMT] Later date: Date: 08/08/2014 Time: 05:51:05 [GMT] Sun Elevation: 10.6° Sun Azimuth: 77.4°	No Valid Reflection	**Reflections Possible** Earlier date: Date: 31/05/2014 Time: 05:37:15 [GMT] Later date: Date: 12/07/2014 Time: 05:45:13 [GMT]" Sun Elevation: 14.4° Sun Azimuth: 72.5°	**Reflections Possible** Earlier date: Date: 18/04/2014 Time: 05:50:18 [GMT] Later date: Date: 25/08/2014 Time: 05:53:03 [GMT] Sun Elevation: 7.4° Sun Azimuth: 81.6°	No Reflection Possible	No Reflection Possible	No Valid Reflection	No Valid Reflection	No Valid Reflection
2	No Valid Reflection	**Reflections Possible** Earlier date: Date: 25/04/2014 Time: 05:46:09 [GMT] Later date: Date: 18/08/2014 Time: 05:52:03 [GMT] Sun Elevation: 8.7° Sun Azimuth: 79.7°	**Reflections Possible** Earlier date: Date: 11/04/2014 Time: 05:53:56 [GMT] Later date: Date: 01/09/2014 Time: 05:52:54 [GMT] Sun Elevation: 5.6° Sun Azimuth: 83.6°	**Reflections Possible** Earlier date: Date: 12/05/2014 Time: 05:39:51 [GMT] Later date: Date: 31/07/2014 Time: 05:49:55 [GMT] Sun Elevation: 12.1° Sun Azimuth: 75.6°	**Reflections Possible** Earlier date: Date: 27/04/2014 Time: 05:45:48 [GMT] Later date: Date: 16/08/2014 Time: 05:52:26 [GMT] Sun Elevation: 9.2° Sun Azimuth: 79.3°	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Valid Reflection	No Valid Reflection	No Valid Reflection

Location	Panel Reflector Location										
	A	B	C	D	E	F	G	H	I	J	K
3	No Valid Reflection	**Reflections Possible** Earlier date: Date: 06/04/2014 Time: 05:56:44 [GMT] Later date: Date: 06/09/2014 Time: 05:52:41 [GMT] Sun Elevation: 4.5° Sun Azimuth: 85.0°	No Reflection Possible	**Reflections Possible** Earlier date: Date: 16/04/2014 Time: 05:51:22 [GMT] Later date: Date: 27/08/2014 Time: 05:53:06 [GMT] Sun Elevation: 6.8° Sun Azimuth: 82.3°	**Reflections Possible** Earlier date: Date: 24/03/2014 Time: 06:05:27 [GMT] Later date: Date: 20/09/2014 Time: 05:52:29 [GMT] Sun Elevation: 1.3° Sun Azimuth: 89.1°	No Reflection Possible	No Reflection Possible	No Reflection Possible	**Reflections Possible** Earlier date: Date: 04/03/2014 Time: 06:35:24 [GMT] Later date: Date: 10/10/2014 Time: 06:10:40 [GMT] Sun Elevation: -0.9° Sun Azimuth: 98.7°	No Valid Reflection	No Valid Reflection
4	**Reflections Possible** Earlier date: Date: 05/06/2014 Time: 05:37:48 [GMT] Later date: Date: 07/07/2014 Time: 05:44:14 [GMT] Sun Elevation: 14.9° Sun Azimuth: 72.1°	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Valid Reflection	No Valid Reflection

Location	Panel Reflector Location										
	A	B	C	D	E	F	G	H	I	J	K
5	**Reflections Possible** Earlier date: Date: 02/05/2014 Time: 05:44:11 [GMT] Later date: Date: 11/08/2014 Time: 05:52:25 [GMT] Sun Elevation: 10.3° Sun Azimuth: 78.2°	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Valid Reflection
6	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	**Reflections Possible** Earlier date: Date: 12/06/2014 Time: 05:45:31 [GMT] Later date: Date: 30/06/2014 Time: 05:49:20 [GMT] Sun Elevation: 16.2° Sun Azimuth: 72.9°
7	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible

8	No Valid Reflection	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Valid Reflection

Location	Panel Reflector Location										
	A	B	C	D	E	F	G	H	I	J	K
9	No Valid Reflection	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	**Reflections Possible** Earlier date: Date: 18/04/2014 Time: 18:08:29 [GMT] Later date: Date: 24/08/2014 Time: 18:11:30 [GMT] Sun Elevation: 7.5° Sun Azimuth: 278.6°	No Valid Reflection

10	No Valid Reflection	No Valid Reflection	No Reflection Possible	**Reflections Possible** Earlier date: Date: 17/05/2014 Time: 18:11:49 [GMT] Later date: Date: 25/07/2014 Time: 18:21:57 [GMT] Sun Elevation: 13.2° Sun Azimuth: 285.0°	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Reflection Possible	No Valid Reflection	No Valid Reflection

Location	Panel Reflector Location										
	A	B	C	D	E	F	G	H	I	J	K
11	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	**Reflections Possible** Earlier date: "Date: 06/05/2014 Time: 18:07:45 [GMT] Later date: Date: 06/08/2014 Time: 18:17:02 [GMT] Sun Elevation: 11.5° Sun Azimuth: 282.4°	No Reflection Possible	No Reflection Possible	No Reflection Possible	**Reflections Possible** Earlier date: Date: 31/03/2014 Time: 18:07:05 [GMT] Later date: Date: 11/09/2014 Time: 17:59:31 [GMT] Sun Elevation: 3.2° Sun Azimuth: 273.2°	No Valid Reflection	No Valid Reflection

12	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Reflection Possible	No Reflection Possible	No Reflection Possible	**Reflections Possible** Earlier date: Date: 13/05/2014 Time: 18:12:25 [GMT] Later date: Date: 30/07/2014 Time: 18:22:31 [GMT] Sun Elevation: 12.3° Sun Azimuth: 284.5°	No Valid Reflection	No Valid Reflection

Location	Panel Reflector Location										
	A	B	C	D	E	F	G	H	I	J	K
13	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Reflection Possible	**Reflections Possible** Earlier date: Date: 21/03/2014 Time: 18:07:24 [GMT] Later date: Date: 21/09/2014 Time: 17:53:13 [GMT] Sun Elevation: 0.71° Sun Azimuth: 270.3°	No Valid Reflection	No Valid Reflection	No Valid Reflection

14	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Reflection Possible	**Reflections Possible** Earlier date: Date: 24/04/2014 Time: 18:09:14 [GMT] Later date: Date: 17/08/2014 Time: 18:15:09 [GMT]" Sun Elevation: 8.9° Sun Azimuth: 280.3°	No Valid Reflection	No Valid Reflection	No Valid Reflection

Location	Panel Reflector Location										
	A	B	C	D	E	F	G	H	I	J	K
15	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	**Reflections Possible** Earlier date: Date: 30/03/2014 Time: 18:07:22 [GMT] Later date: Date: 12/09/2014 Time: 17:59:10 [GMT] Sun Elevation: 3.0° Sun Azimuth: 273.0°	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection
16	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection	No Valid Reflection



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