Solar Photovoltaic Glint and Glare Study

Prepared for:

Savills (UK) Limited

Llanwern

December, 2017
<table>
<thead>
<tr>
<th>Issue</th>
<th>Date</th>
<th>Detail of Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>December, 2017</td>
<td>Initial issue</td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

Report Purpose
This report has assessed the potential glint and glare impacts of the proposed Llanwern solar development on residential amenity and road safety.

Guidance
There is limited formal guidance for the assessment of glint and glare in the UK. Pager Power has published a recommended methodology based on international guidance, independent studies and consultation with industry stakeholders including aviation authorities. This guidance has been referenced throughout the document and is available via the company website or on request.

Receptors
This report has modelled reflections throughout the year towards dwellings and road user locations within one kilometre of the proposed panel areas.

Conclusions
- All potential effects have an impact significance that is defined as ‘Low’ – which does not correspond to a mitigation requirement.
- Reflections are possible at 24 dwelling locations, based on computer modelling and a conservative desk-based assessment of available views.
- Residents that observe glare, by looking towards a reflecting panel, would also be looking towards the Sun. Direct sunlight is significantly more intense than a reflection from a solar panel.
- Reflections are possible towards three separate stretches of road. These are the local roads that run adjacent to the panel areas.
- Drivers would have to look away from their direction of travel to view a reflecting panel. Effects would be fleeting in nature for a moving vehicle. In some or all cases, panel visibility will be partially obscured by vegetation.

Next Steps
- No mitigation requirement has been identified because the potential impacts are small.
- Effects could be reduced further via the provision of additional or enhanced screening at the site boundaries. Further site survey work could ascertain the site visibility more accurately.
LIST OF CONTENTS

Administration Page ........................................................................................................... 2
Executive Summary ............................................................................................................... 3
    Report Purpose .............................................................................................................. 3
    Guidance ......................................................................................................................... 3
    Receptors ......................................................................................................................... 3
    Conclusions ....................................................................................................................... 3
    Next Steps ......................................................................................................................... 3
List of Contents ..................................................................................................................... 4
List of Figures ......................................................................................................................... 6
List of Tables .......................................................................................................................... 6
About Pager Power ............................................................................................................... 7
1 Introduction .......................................................................................................................... 8
    1.1 Introduction ................................................................................................................. 8
    1.2 Pager Power’s Experience ......................................................................................... 8
    1.3 Glint and Glare Definition ......................................................................................... 8
2 Proposed Solar Development Location and Details ......................................................... 9
    2.1 Llanwern Solar Development ............................................................................... 9
    2.2 Panel Details .............................................................................................................. 10
3 Glint and Glare Assessment Methodology ................................................................. 11
    3.1 Guidance and Studies ............................................................................................ 11
    3.2 Background ............................................................................................................... 11
    3.3 Pager Power Methodology .................................................................................... 11
    3.4 Assessment Limitations ......................................................................................... 11
4 Identification of Receptors ........................................................................................... 12
    4.1 Overview ............................................................................................................... 12
    4.2 Dwellings ............................................................................................................... 12
    4.3 Roads ......................................................................................................................... 13
5 Modelling the Solar Development ............................................................................... 14
    5.1 Resolution ............................................................................................................... 14
6 Glint and Glare Assessment ......................................................................................... 15
    6.1 Findings .................................................................................................................... 15
7 Results Discussion ......................................................................................................... 27
    7.1 Dwellings ............................................................................................................... 27
    7.2 Roads ....................................................................................................................... 30
8 Mitigation ......................................................................................................................... 32

Solar Photovoltaic Glint and Glare Study
LIST OF FIGURES

Figure 1 Panel areas (map) ................................................................. 9
Figure 2 Panel areas (aerial imagery) ................................................. 10
Figure 3 Nearby dwellings ................................................................. 12
Figure 4 Assessed dwellings ............................................................. 13
Figure 5 Assessed roads ................................................................. 13
Figure 6 Potentially affected dwellings ........................................... 27
Figure 7 Potentially affected dwellings (close-up 1 of 4) ..................... 28
Figure 8 Potentially affected dwellings (close-up 2 of 4) ..................... 28
Figure 9 Potentially affected dwellings (close-up 3 of 4) ..................... 29
Figure 10 Potentially affected dwellings (close-up 4 of 4) ................... 30
Figure 11 Potentially affected roads .................................................. 31

LIST OF TABLES

Table 1 Analysis results (dwellings) ............................................... 22
Table 2 Analysis results (roads) ....................................................... 26
Table 3 Analysis results summary .................................................... 33
ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 43 countries within Europe, Africa, America, Asia and Australia.

The company comprises a team of experts to provide technical expertise and guidance on a range of planning issues for large and small developments.

Pager Power was established in 1997. Initially the company focus was on modelling the impact of wind turbines on radar systems. Over the years, the company has expanded into numerous fields including:

- Renewable energy projects.
- Building developments.
- Aviation and telecommunication systems.

Pager Power prides itself on providing comprehensive, understandable and accurate assessments of complex issues in line with national and international standards. This is underpinned by its custom software, longstanding relationships with stakeholders and active role in conferences and research efforts around the world.

Pager Power’s assessments withstand legal scrutiny and the company can provide support for a project at any stage.
1 INTRODUCTION

1.1 Introduction
Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar development known as Llanwern. The assessed receptors are residential dwellings and road users.

This report contains the following:
- Solar development details.
- Explanation of glint and glare.
- Overview of relevant guidance.
- Overview of relevant studies.
- Overview of Sun movement.
- Assessment methodology.
- Identification of receptors.
- Glint and glare assessment for identified receptors.
- Results.
- Mitigation discussion.

1.2 Pager Power’s Experience
Pager Power has conducted a comprehensive industry consultation exercise with developers and stakeholders. This has been carried out for specific developments and, in a wider context, in order to produce comprehensive guidelines for the assessment of solar glint and glare.

Pager Power has undertaken over 250 Glint and Glare assessments in the United Kingdom, Ireland, and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure, radar installations and other ground based receptors including roads and dwellings.

1.3 Glint and Glare Definition
The definition of glint and glare can vary however, the definition used by Pager Power is as follows:
- Glint – a momentary flash of bright light.
- Glare – a continuous source of bright light.

The term ‘solar reflection’ is used in this report to refer to both reflection types i.e. glint and glare.
2.1 Llanwern Solar Development

The proposed development comprises ground-mounted panels split over five separate areas, as shown in Figure 1 below\(^1\) and Figure 2 on the following page\(^2\).

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\(^1\) Provided to Pager Power by Savills (cropped)
\(^2\) ©2017 Google, Landsat, Copernicus
Figure 2. Panel areas (aerial imagery)

2.2 Panel Details

The panels will face south. Their vertical tilt angle will be 15 degrees above the horizontal.
3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies
Guidelines exist in the UK (produced by the Civil Aviation Authority) and in the USA (produced by the Federal Aviation Administration) with respect to solar developments and aviation activity. No specific guidelines have been produced pertaining to residential amenity and road safety.

Independent studies regarding the relative reflectivity of solar panels and other materials have been undertaken (see Appendices A and B).

Pager Power’s assessment methodology is based on compiled guidance from these sources, industry experience and consultation with the relevant bodies.

Key points from the literature are:

- Specular reflections of the Sun from solar panels are possible.
- The measured intensity of a reflection from solar panels can vary from 2% to 30% depending on the angle of incidence.
- The intensity of reflections from solar panels are equal to or less than those from water. Reflections from solar panels are significantly less intense than many other reflective surfaces which are common in an outdoor environment.

3.2 Background
Details of the Sun’s movements and solar reflections are presented in Appendix C.

3.3 Pager Power Methodology
The glint and glare assessment methodology has been derived from the information provided to Pager Power through consultation with stakeholders and by reviewing the available guidance. The methodology for the aviation glint and glare assessment is shown below.

- Identify receptors in the area surrounding the proposed solar development.
- Consider direct solar reflections from the proposed solar development towards the identified receptors by undertaking geometric calculations.
- Consider the visibility of the panels from the receptor’s location. If the panels are not visible from the receptor then no reflection can occur.
- Based on the results of the geometric calculations, determine whether a reflection can occur, and if so, at what time it will occur.
- Consider both the solar reflection from the proposed solar development and the location of the direct sunlight with respect to the receptor’s position.
- Consider the solar reflection with respect to the published studies and guidance.
- Determine whether a significant detrimental impact is expected in accordance with the methodology presented in Appendix D.

Within the Pager Power model, the solar development area is defined, as well as the relevant receptor locations. The result is a chart that shows whether a reflection can occur, the duration and the panels that can produce the solar reflection towards the receptor. See Appendix E for technical information regarding the methodology.

3.4 Assessment Limitations
The list of assumptions and limitations are presented in Appendix F.

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3 Pager Power has compiled its own guidance, and stakeholders do on occasion advise of criteria for particular developments. There is, however, no overarching guidance on how to quantify impacts from a government body or equivalent.
4 IDENTIFICATION OF RECEPTORS

4.1 Overview
There is no formal guidance with regard to the maximum distance at which glint and glare should be assessed. From a technical perspective, there is no maximum distance for potential reflections. However, the significance of a reflection decreases with distance. This is because the proportion of an observer’s field of vision that is taken up by the reflecting area diminishes as the separation distance increases. Terrain and shielding by vegetation are also more likely to obstruct an observer’s view at longer distances.

The above parameters and extensive experience over a significant number of glint and glare assessments undertaken shows that a 1km buffer is considered appropriate for glint and glare effects on local dwellings and road users. Receptors within this distance are identified based on mapping and aerial photography of the region. The initial judgement is made based on high-level consideration of aerial photography and mapping i.e. receptors are excluded if it is clear from the outset that no visibility would be possible. A more detailed assessment is made if the modelling reveals a reflection would be geometrically possible.

All coordinate data is shown in Appendix G.

4.2 Dwellings
Dwellings within 1 km of any panel area are shown in Figure 3 below.

Figure 3 Nearby dwellings

©2017 Google, Landsat, Copernicus
Due to the large number of receptors, an initial investigation of predicted visibility was undertaken prior to the glint and glare modelling. This excluded dwellings 1-28, 35-98 and 132 since views of panels within a kilometre are highly unlikely from these locations. The remaining dwellings, for which modelling was undertaken, are shown in Figure 4 below.

![Figure 4 Assessed dwellings](image)

### 4.3 Roads

The analysis considers through roads only, individual receptor points are spaced at approximately 200 metre intervals. The assessed road receptor points are shown in Figure 5 below\(^5\). Note that reflections are not possible north of the northernmost panel, therefore these areas are excluded.

![Figure 5 Assessed roads](image)

\(^5\) ©2017 Google, Landsat, Copernicus
5 MODELLING THE SOLAR DEVELOPMENT

5.1 Resolution
A number of representative panel locations are selected within each of the modelled areas set out in Section 2. All ground heights have been taken from Pager Power’s database. Boundary coordinate data is shown in Appendix G.

A resolution of 10 metres has been chosen for this assessment. This means a geometric calculation is undertaken for each identified receptor every 10 metres from within each defined solar panel area. This resolution is sufficiently high to maximise the accuracy of the results – increasing the resolution further would not significantly change the modelling output. If a reflection is experienced from an assessed panel location, then it is likely that a reflection will be viewable from similarly located panels within the development.
6 GLINT AND GLARE ASSESSMENT

6.1 Findings
The tables in the following subsections summarise the months and times during which a solar reflection could be experienced by a receptor.

This does not mean that reflections would occur continuously between the times shown.

The range of times at which reflections are geometrically possible is generally greater than the length of time for any particular day. This is because the times of day at which reflections could start and stop vary throughout the days/months.

Appendix H presents the solar reflection charts.
<table>
<thead>
<tr>
<th>Receptor</th>
<th>Theoretical reflection times towards dwellings, GMT (approx.)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>am</strong></td>
<td><strong>pm</strong></td>
</tr>
</tbody>
</table>
| 1 – 28   | -      | -      | Excluded due to lack of potential views.  
No effects are predicted. |
| 29 – 30  | Between 05:30 and 06:30 for March-September | None | The majority of the predicted reflections are from panel areas more than 1 km from the dwellings.  
Partial visibility of the panel area to the northeast may remain.  
Some effects are possible. |
| 31 – 32  | Between 05:30 and 06:30 for March-September | None | Many of the predicted reflections are from panel areas more than 1 km from the dwelling. The nearest panel area is more than 800 metres from the dwellings.  
Some visibility of the panel area to the east may remain, however this area is more than 700 metres from the observers. |
| 33 – 34  | N/A    | None | All theoretical reflections are from areas that are more than 1 km from the dwellings.  
No effects are predicted. |
| 35 – 98  | -      | -      | Excluded due to lack of potential views.  
No effects are predicted. |
| 99       | Between 05:30 and 06:30 for March-September | N/A | Based on the available imagery, it appears unlikely that observers would have a view of the reflecting panels. A site survey would be required to confirm this.  
Theoretical reflections in the evening are from panels more than 1 km from the dwellings.  
Effects are considered possible. |
<table>
<thead>
<tr>
<th>Receptor</th>
<th>Theoretical reflection times towards dwellings, GMT (approx.)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>am</td>
</tr>
<tr>
<td>100 – 101</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>N/A</td>
</tr>
<tr>
<td>102</td>
<td>Between 05:30 and 06:10 for April-September</td>
<td>N/A</td>
</tr>
<tr>
<td>103</td>
<td>Between 05:30 and 06:10 for April-August</td>
<td>N/A</td>
</tr>
<tr>
<td>104</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>N/A</td>
</tr>
</tbody>
</table>
### Theoretical reflection times towards dwellings, GMT (approx.)

<table>
<thead>
<tr>
<th>Receptor</th>
<th>am</th>
<th>pm</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>105</td>
<td>Between 05:30 and 06:10 for April-August</td>
<td>N/A</td>
<td>Based on the available imagery, it appears unlikely that observers would have a view of the reflecting panels. A site survey would be required to confirm this. Theoretical reflections in the evening are from panels more than 1 km from the dwellings. Effects are considered possible.</td>
</tr>
<tr>
<td>106</td>
<td>Between 05:30 and 06:10 for May-July</td>
<td>N/A</td>
<td>The reflecting portion of the panel area nearest this dwelling is small, and almost a kilometre away. Visibility of the reflecting panels is not predicted. Theoretical reflections in the evening are from panels more than 1 km from the dwelling. No effects are predicted.</td>
</tr>
<tr>
<td>107</td>
<td>None</td>
<td>N/A</td>
<td>All theoretical reflections are from areas that are more than 1 km from the dwellings. No effects are predicted.</td>
</tr>
<tr>
<td>108 – 109</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Between 17:50 and 19:00 for March-May and July-September</td>
<td>Based on the available imagery, it appears unlikely that observers would have a view of the reflecting panels. A site survey would be required to confirm this. Effects are considered possible.</td>
</tr>
<tr>
<td>110</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Between 17:50 and 19:00 for March-September</td>
<td>Based on the available imagery, it appears unlikely that observers would have a view of the reflecting panels. A site survey would be required to confirm this. Effects are considered possible.</td>
</tr>
</tbody>
</table>
### Theoretical reflection times towards dwellings, GMT (approx.)

<table>
<thead>
<tr>
<th>Receptor</th>
<th>am</th>
<th>pm</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>111</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Between 17:50 and 19:00 for March-September</td>
<td>Based on the available imagery, it is unlikely that observers would have a view of the panels to the east (morning reflections). Partial visibility of the panels to the west (afternoon reflections) may remain. Effects are considered possible.</td>
</tr>
<tr>
<td>112</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Between 18:00 and 19:00 for March-September</td>
<td>It is possible that views of the reflecting panels would be available, particularly from the upper floors of this receptor. Effects are considered possible.</td>
</tr>
<tr>
<td>113</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Between 18:00 and 19:00 for March-September</td>
<td>Views of the panels to the west (afternoon reflections) are unlikely. Based on the available imagery, it appears unlikely that observers would have a view of the reflecting panels to the east (morning reflections). A site survey would be required to confirm this. Effects are considered possible.</td>
</tr>
<tr>
<td>114 – 118</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Between 18:00 and 19:00 for March-September</td>
<td>Based on the available imagery, views of the panels from these locations are likely to be partially or entirely obstructed by existing trees. Partial visibility may remain, a site survey would be required to confirm this. Effects are considered possible.</td>
</tr>
<tr>
<td>Receptor</td>
<td>Theoretical reflection times towards dwellings, GMT (approx.)</td>
<td>Comment</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>-------------------------------------------------------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>am</strong></td>
<td><strong>pm</strong></td>
<td></td>
</tr>
<tr>
<td>119 – 121</td>
<td><strong>Between 05:30 and 06:30 for March-September</strong></td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>122</td>
<td><strong>Between 05:30 and 06:30 for March-May and July-September</strong></td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>123</td>
<td><strong>Between 05:30 and 06:30 for March-September</strong></td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>124</td>
<td><strong>Between 05:30 and 06:30 for March-September</strong></td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The reflecting panels to the west (evening reflections) are unlikely to be significantly visible due to the separation distance, intervening vegetation and the small size of the reflecting area.

The reflecting panels to the east are more than 1km from observers.

No effects are predicted.

Based on the available imagery, significant views of reflecting panels to the west (evening reflections) are unlikely. This is due to the separation distance, the restricted size of the reflecting area and intervening vegetation.

Theoretical reflections in the morning are from panels more than 1 km from the dwelling.

No effects are predicted.
<table>
<thead>
<tr>
<th>Receptor</th>
<th>Theoretical reflection times towards dwellings, GMT (approx.)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>am</td>
<td>pm</td>
</tr>
<tr>
<td>125</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>N/A</td>
</tr>
<tr>
<td>126</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Between 18:00 and 19:00 for March-June and August-September</td>
</tr>
<tr>
<td>127</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Between 18:00 and 19:00 for March-May and July-September</td>
</tr>
</tbody>
</table>
### Receptor Theoretical reflection times towards dwellings, GMT (approx.) Comment

<table>
<thead>
<tr>
<th>Receptor</th>
<th>am</th>
<th>pm</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>128 – 131</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Between 18:00 and 19:00 for March-September</td>
<td>Based on the available imagery, significant views of reflecting panels to the west (evening reflections) are unlikely. This is due to the separation distance and the reflecting area and intervening vegetation. Potential views of the panels to the east (morning reflections) cannot be readily ascertained based on the available imagery. Effects are considered possible</td>
</tr>
<tr>
<td>132</td>
<td>-</td>
<td>-</td>
<td>Excluded due to lack of potential views. No effects are predicted.</td>
</tr>
<tr>
<td>133</td>
<td>None</td>
<td>Between 17:50 and 18:30 for March-April and August-September</td>
<td>Based on the available imagery, observers are not predicted to have views of the reflecting panels. No effects are predicted.</td>
</tr>
</tbody>
</table>

Table 1 Analysis results (dwellings)
<table>
<thead>
<tr>
<th>Receptor</th>
<th>Theoretical reflection times towards road, GMT (approx.)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 2</td>
<td>Between 05:30 and 06:30 for March-May and August-September</td>
<td>Observers are not predicted to have a view of the reflecting panels. No effects are predicted.</td>
</tr>
<tr>
<td>3 – 4</td>
<td>Between 05:30 and 06:30 for March-April and August-September</td>
<td>Observers are not predicted to have a view of the reflecting panels. No effects are predicted.</td>
</tr>
<tr>
<td>5</td>
<td>Between 06:00 and 06:30 for March and September</td>
<td>Observers are not predicted to have a view of the reflecting panels. No effects are predicted.</td>
</tr>
<tr>
<td>6</td>
<td>None</td>
<td>No effects are possible.</td>
</tr>
<tr>
<td>7</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Observers are not predicted to have a view of the reflecting panels. No effects are predicted.</td>
</tr>
<tr>
<td>8</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Partial visibility of the panels to the east may be available. Effects are considered possible.</td>
</tr>
<tr>
<td>9</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Partial visibility of the panels to the east may be available. Effects are considered possible.</td>
</tr>
<tr>
<td>10</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Partial visibility of the panels to the east may be available. Effects are considered possible.</td>
</tr>
<tr>
<td>11</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Partial visibility of the panels to the east may be available. Effects are considered possible.</td>
</tr>
<tr>
<td>Receptor</td>
<td>Theoretical reflection times towards road, GMT (approx.)</td>
<td>Comment</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>12 – 13</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Visibility of the panels to the east may be available. Effects are considered possible.</td>
</tr>
<tr>
<td>14 - 17</td>
<td>N/A</td>
<td>All theoretical reflections are from panels more than 1 km from the receptor location. No effects are predicted.</td>
</tr>
<tr>
<td>18</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Based on the available imagery, visibility of the panels is not predicted from this location. No effects are predicted.</td>
</tr>
<tr>
<td>19 – 29</td>
<td>N/A</td>
<td>All theoretical reflections are from panels more than 1 km from the receptor location. No effects are predicted.</td>
</tr>
<tr>
<td>30</td>
<td>Between 05:30 and 06:00 for June-July</td>
<td>Based on the separation distance, the restricted size of the reflecting area and intervening vegetation, views of the reflecting panels are unlikely to be available. No effects are predicted.</td>
</tr>
<tr>
<td>31</td>
<td>None</td>
<td>No effects are possible.</td>
</tr>
<tr>
<td>32</td>
<td>Between 05:30 and 06:00 for March-May and July-September</td>
<td>Based on the available imagery, potential views are likely to be screened by existing vegetation. No effects are predicted.</td>
</tr>
<tr>
<td>33</td>
<td>Between 05:30 and 06:00 for March-September</td>
<td>Based on the available imagery, potential views are likely to be screened by existing vegetation. No effects are predicted.</td>
</tr>
<tr>
<td>Receptor</td>
<td>Theoretical reflection times towards road, GMT (approx.)</td>
<td>Comment</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td><strong>am</strong></td>
<td><strong>pm</strong></td>
</tr>
<tr>
<td>34 – 35</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Between 18:00 and 19:00 for March-September</td>
</tr>
<tr>
<td>36</td>
<td>N/A</td>
<td>Between 18:30 and 19:00 for May-August</td>
</tr>
<tr>
<td>37</td>
<td>N/A</td>
<td>Between 18:00 and 19:00 for March-September</td>
</tr>
<tr>
<td>38</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Between 18:00 and 19:00 for March-May and July-September</td>
</tr>
<tr>
<td>39 – 41</td>
<td>Between 05:30 and 06:30 for March-September</td>
<td>Between 18:00 and 19:00 for March-September</td>
</tr>
<tr>
<td>42</td>
<td>Between 05:30 and 06:30 for April-September</td>
<td>Between 18:00 and 19:00 for April-August</td>
</tr>
<tr>
<td>Receptor</td>
<td>Theoretical reflection times towards road, GMT (approx.)</td>
<td>Comment</td>
</tr>
<tr>
<td>----------</td>
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</tr>
<tr>
<td></td>
<td>am</td>
<td>pm</td>
</tr>
<tr>
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<td>Between 18:30 and 19:00 for May-July</td>
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<tr>
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<td>Between 18:00 and 19:00 for March-April and August-September</td>
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Table 2 Analysis results (roads)
7 RESULTS DISCUSSION

7.1 Dwellings

Effects are possible at twenty-four dwelling locations. This is based on computer modelling combined with a conservative assessment of potential panel visibility.

In the event that survey data or proposed screening plans reduce the panel visibility, the results of the assessment may change.

Figure 6 below shows the potentially affected dwellings on a map of the area\[^6\].

Figure 6 Potentially affected dwellings

Figures 7 – 10 on the following pages\[^7\] show close-up views of the potentially affected dwellings.

\[^6\] ©2017 Google, Landsat, Copernicus

\[^7\] As above
Figure 7 Potentially affected dwellings (close-up 1 of 4)

Figure 8 Potentially affected dwellings (close-up 2 of 4)
Figure 9 Potentially affected dwellings (close-up 3 of 4)
In cases where reflections are possible, it should be considered that:

- Reflections would coincide with direct sunlight. An observer looking towards the reflecting panels would also be looking towards the Sun.
- The intensity of reflections from solar panels is relatively low compared to other common surfaces, including glass.

Potential effects would last for less than 60 minutes per day under worst-case conditions. In practice, noticeable effects would most likely have a duration of less than this.

Overall, in accordance with the methodology set out in Appendix D, the impact significance is Low.

### 7.2 Roads

Effects are possible at ten road locations. This is based on computer modelling combined with a conservative assessment of potential panel visibility.

Figure 11 on the following page\(^8\) shows the potentially affected road locations.

\(^8\)©2017 Google, Landsat, Copernicus
In cases where reflections are possible, it should be considered that:

- Reflections would coincide with direct sunlight. An observer looking towards the reflecting panels would also be looking towards the Sun.
- The intensity of reflections from solar panels is relatively low compared to other common surfaces, including glass.
- Effects would be fleeting for a moving receptor such as a car.
- Reflections would occur from a direction outside the main direction of travel, such that a driver would have to look sideways in order to look directly at a reflection.
- The potentially affected roads are local, they are unlikely to experience high volumes of fast-moving traffic.

Overall, in accordance with the methodology set out in Appendix D, the impact significance is Low.
8 MITIGATION

8.1 Overview
No mitigation requirement pertaining to the development has been identified because no significant impacts are predicted.

Potential effects could be further reduced, or eliminated, via the provision of further screening at the site boundaries.

In some or all cases, this could amount to ‘gap-filling’ in order to bolster existing hedgerows.

8.2 Process
If further mitigation measures are to be progressed, it is recommended that a site survey is carried out to accurately record views that are currently available from potentially affected dwellings.
9 OVERALL CONCLUSIONS

9.1 Analysis Results

Table 4 below summarises the results of this assessment.

<table>
<thead>
<tr>
<th>Receptor</th>
<th>Technical Effects</th>
<th>Likely Impact</th>
<th>Conclusion</th>
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<tbody>
<tr>
<td>Dwellings.</td>
<td>Reflections towards 24 individual dwellings.</td>
<td>Low – based on the restricted duration of effects and their coinciding with direct sunlight.</td>
<td>No significant impacts are predicted.</td>
</tr>
<tr>
<td>Roads.</td>
<td>Reflections are predicted towards 10 road receptor locations.</td>
<td>Low – based on the type of road, the level of predicted effect and the bearing of incoming reflections.</td>
<td>No significant impacts are predicted.</td>
</tr>
</tbody>
</table>

Table 3 Analysis results summary

9.2 Mitigation Requirement

No mitigation requirement has been identified.
APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

This section presents details regarding the relevant guidance and studies with respect to the considerations and effects of solar reflections from solar panels, known as ‘Glint and Glare’.

This is not 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.

UK Planning Policy

UK National Planning Practice Guidance dictates that in some instances a glint and glare assessment is required however, there is no specific guidance with respect to the methodology for assessing the impact of glint and glare.

The planning policy from the Department for Communities and Local Government (paragraph 27) states:

‘Particular factors a local planning authority will need to consider include… the effect on landscape of glint and glare and on neighbouring uses and aircraft safety.’

The National Planning Policy Framework for Renewable and Low Carbon Energy (specifically regarding the consideration of solar farms) states:

‘What are the particular planning considerations that relate to large scale ground-mounted solar photovoltaic Farms?

The deployment of large-scale solar farms can have a negative impact on the rural environment, particularly in undulating landscapes. However, the visual impact of a well-planned and well-screened solar farm can be properly addressed within the landscape if planned sensitively.

Particular factors a local planning authority will need to consider include:

- the proposal’s visual impact, the effect on landscape of glint and glare (see guidance on landscape assessment) and on neighbouring uses and aircraft safety;
- the extent to which there may be additional impacts if solar arrays follow the daily movement of the sun;

The approach to assessing cumulative landscape and visual impact of large scale solar farms is likely to be the same as assessing the impact of wind turbines. However, in the case of ground-mounted solar panels it should be noted that with effective screening and appropriate land topography the area of a zone of visual influence could be zero.’

Assessment Process

No process for determining and contextualising the effects of glint and glare are, however, provided. Therefore, the Pager Power approach is to determine whether a reflection from the proposed solar development is geometrically possible and then to compare the results against the relevant guidance/studies to determine whether the reflection is significant.

---

Overview
Studies have been undertaken assessing the type and intensity of solar reflections from various surfaces including solar panels. An overview of these studies is presented below.

There are no specific studies for determining the effect of reflections from solar panels with respect to roads and dwellings. The guidelines presented are related to aviation safety. The results are applicable for the purpose of this analysis.

Reflection Type from Solar Panels
Based on the surface conditions reflections from light can be specular and diffuse. A specular reflection has a reflection characteristic similar to that of a mirror; a diffuse will reflect the incoming light and scatter it in many directions. The figure below\(^\text{11}\), taken from the FAA guidance, illustrates the difference between the two types of reflections. Because solar panels are flat and have a smooth surface most of the light reflected is specular, which means that incident light from a specific direction is reradiated in a specific direction.

![Specular and diffuse reflections](image)

Solar Reflection Studies
An overview of content from identified solar panel reflectivity studies is presented in the subsections below.

Evan Riley and Scott Olson, “A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems”

Evan Riley and Scott Olson published in 2011 their study titled: A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems\(^\text{12}\). They researched the potential glare that a pilot could experience from a 25 degree fixed tilt PV system located outside of Las Vegas, Nevada. 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 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%. This is shown on the figure on the following page.

---

\(^{11}\) [http://www.faa.gov/airports/environmental/policy_guidance/media/airport_solar_guide_print.pdf](http://www.faa.gov/airports/environmental/policy_guidance/media/airport_solar_guide_print.pdf)

The conclusions of the research study were:

- The potential for hazardous glare from flat-plate PV systems is similar to that of smooth water;
- Portland white cement concrete (which is a common concrete for runways), snow, and structural glass all have a reflectivity greater than water and flat plate PV modules.


The 2010 FAA Guidance (discussed in section 4) included a diagram which illustrates the relative reflectance of solar panels compared to other surfaces. The figure shows the relative reflectance of solar panels compared to other surfaces. Surfaces in this figure produce reflections which are specular and diffuse. A specular reflection (those made by most solar panels) has a reflection characteristic similar to that of a mirror. A diffuse reflection will reflect the incoming light and scatter it in many directions. A table of reflectivity values, sourced from the figure within the FAA guidance, is presented on the following page.

---

<table>
<thead>
<tr>
<th>Surface</th>
<th>Approximate Percentage of Light Reflected&lt;sup&gt;15&lt;/sup&gt;</th>
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</thead>
<tbody>
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<td>Snow</td>
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<tr>
<td>White Concrete</td>
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<tr>
<td>Bare Aluminium</td>
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<td>Vegetation</td>
<td>50</td>
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<tr>
<td>Bare Soil</td>
<td>30</td>
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<tr>
<td>Wood Shingle</td>
<td>17</td>
</tr>
<tr>
<td>Water</td>
<td>5</td>
</tr>
<tr>
<td>Solar Panels</td>
<td>5</td>
</tr>
<tr>
<td>Black Asphalt</td>
<td>2</td>
</tr>
</tbody>
</table>

Relative reflectivity of various surfaces

Note that the data above does not appear to consider the reflection type (specular or diffuse).

An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

**SunPower Technical Notification (2009)**

SunPower published a technical notification<sup>16</sup> to ‘*increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment*’. The study revealed that the reflectivity of a solar panel is considerably lower than that of ‘*standard glass and other common reflective surfaces*’. With respect to aviation and solar reflections observed from the air, SunPower has developed several large installations near airports or on Air Force bases. It is stated that these developments have all passed FAA or Air Force standards with all developments considered “No Hazard to Air Navigation”. The note suggests that developers discuss any possible concerns with stakeholders near proposed solar farms.

Figures within the document show the relative reflectivity of solar panels compared to other natural and manmade materials including smooth water, standard glass and steel. The results, similarly to those from Riley and Olsen study (2011) and the FAA (2010), show that solar panels produce a reflection that is less intense than those produced from these surfaces.

---

<sup>15</sup> Extrapolated data, baseline of 1,000 W/m<sup>2</sup> for incoming sunlight.

<sup>16</sup> Technical Support, 2009. **SunPower Technical Notification- Solar Module Glare and Reflectance.**
APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

The Sun’s position in the sky can be accurately described by its azimuth and elevation. Azimuth is a direction relative to true north (horizontal angle i.e. from left to right) and elevation describes the Sun’s angle relative to the horizon (vertical angle i.e. up and down).

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 combination of the Sun’s azimuth angle and vertical elevation will affect the direction and angle of the reflection from a solar panel.
APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview
The significance of glint and glare will vary for different receptors. The following section presents a general overview of the significance criteria with respect to experiencing a solar reflection.

Impact significance definition
The table below presents the recommended definition of ‘impact significance’ in glint and glare terms and the requirement for mitigation under each.

<table>
<thead>
<tr>
<th>Impact Significance</th>
<th>Definition</th>
<th>Mitigation Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Impact</td>
<td>A solar reflection is not geometrically possible or will not be visible from the assessed receptor.</td>
<td>No mitigation required.</td>
</tr>
<tr>
<td>Low</td>
<td>A solar reflection is geometrically possible however any impact is considered to be small such that mitigation is not required e.g. intervening screening will limit the view of the reflecting solar panels.</td>
<td>No mitigation required.</td>
</tr>
<tr>
<td>Moderate</td>
<td>A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case.</td>
<td>Whilst the impact may be acceptable, consultation and/or further analysis should be undertaken to determine the requirement for mitigation.</td>
</tr>
<tr>
<td>Major</td>
<td>A solar reflection is geometrically possible and visible under conditions that will produce a significant impact. Mitigation and consultation is recommended.</td>
<td>Mitigation will be required if the proposed solar development is to proceed.</td>
</tr>
</tbody>
</table>
Assessment process for road receptors

The flow chart presented below has been followed when determining the mitigation requirement for road receptors.

**Road receptor mitigation requirement flow chart**

1. **Start**
   - Is a solar reflection geometrically possible and unscreened?
     - No: Mitigation not required
     - Yes: Proceed to next step.

2. Is the solar reflection towards a Major National, National or Regional road?
   - No: A solar reflection is predicted toward a Local road
   - Yes: Proceed to next step.

3. Does the solar reflection originate in front of the road user?
   - No: Mitigation not required but could be considered
   - Yes: Mitigation should be implemented
Assessment process for dwelling receptors

The flow chart presented below has been followed when determining the mitigation requirement for dwelling receptors.

Dwelling receptor mitigation requirement flow chart
APPENDIX E – PAGER POWER’S REFLECTION CALCULATIONS METHODOLOGY

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 below may be used to aid understanding of the reflection calculation process.

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

- Use the Latitude and Longitude of reflector as the reference 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 F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power’s Model

It is assumed that the panel elevation angle provided by the developer represents the elevation angle for all of the panels within the solar development.

It is assumed that the panel azimuth angle provided by the developer represents the azimuth angle for all of the panels within the solar development.

Only a reflection from the face of the panel has been considered. The frame or the reverse of the solar panel has not been considered.

The model assumes that a receptor can view the face of every panel within the proposed solar development area whilst in reality this, in the majority of cases, will not occur.

Therefore any predicted reflection from the face of a solar panel that is not visible to a receptor will not occur.

A finite number of points within the proposed solar development are chosen based on an assessment resolution so we can build a comprehensive understanding of the entire development. This will determine whether a reflection could ever occur at a chosen receptor. The calculations do not incorporate all of the possible panel locations within the development outline.

A single reflection point on the panel has been chosen for the geometric calculations. This will suitably determine whether a reflection can be experienced at a location and the general time of year and duration of this reflection. Increased accuracy could be achieved by increasing the number of heights assessed however this would only marginally change the results and is not considered significant.

Whilst line of sight to the development from receptors has been considered, only available street view imagery and satellite mapping has been used. In some cases this imagery may not be up to date and may not give the full perspective of the installation from the location of the assessed receptor.

Any screening in the form of trees, buildings etc. that may obstruct the Sun from view of the solar panels is not considered unless stated.
### APPENDIX G – COORDINATE DATA

#### Panel Areas

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<th>ID</th>
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APPENDIX H – GEOMETRIC CALCULATION RESULTS

The charts for relevant receptors are shown on the following pages. Each chart shows:

- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;

- The reflecting panels – bottom right image. The reflecting area is shown in yellow. If the yellow panels are not visible from the observer location, no issues will occur in practice. Additional obstructions which may obscure the panels from view are considered separately within the analysis;

- The reflection date/time graph – left hand side of the page. The blue line indicates the dates and times at which geometric reflections are possible. This relates to reflections from the yellow areas.

Charts are shown for scenarios where effects are predicted in practice.

Dwellings

Observer 29 Results

Reflection Date/Time (GMT) Graph

Observer Location
Sun azimuth range is 67.4° - 90.4° (yellow)

Reflecting panels (yellow)
Solar Photovoltaic Glint and Glare Study

Observer 30 Results

Min observer difference angle: 0°
Max observer difference angle: 13°

Observer 31 Results

Min observer difference angle: 0°
Max observer difference angle: 13°
Observer 32 Results

Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13°

Observer 99 Results

Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13.1°
Observer 104 Results
Reflection Date/Time (GMT) Graph

Min observer difference angle: 0.2°
Max observer difference angle: 12.9°

Observer 105 Results
Reflection Date/Time (GMT) Graph

Min observer difference angle: 4.8°
Max observer difference angle: 13.2°
**Observer 108 Results**

Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13.2°

**Observer 109 Results**

Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13.2°
Solar Photovoltaic Glint and Glare Study

Observer 110 Results

Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13.5°

Observer 111 Results

Reflection Date/Time (GMT) Graph

Min observer difference angle: 0.1°
Max observer difference angle: 14.7°
Observer 112 Results

Min observer difference angle: 0°
Max observer difference angle: 13.5°

Observer 113 Results

Min observer difference angle: 0°
Max observer difference angle: 13.1°
Observer 114 Results
Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13.2°

Observer 115 Results
Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13.2°
Observer 116 Results

Min observer difference angle: 0°
Max observer difference angle: 13.1°

Observer 117 Results

Min observer difference angle: 0°
Max observer difference angle: 13°
Observer 118 Results

Min observer difference angle: 0°
Max observer difference angle: 13°

Observer 126 Results

Min observer difference angle: 0°
Max observer difference angle: 13°
Observer 127 Results

Min observer difference angle: 0°
Max observer difference angle: 13°

Observer 128 Results

Min observer difference angle: 0°
Max observer difference angle: 13.1°
Observer 129 Results
Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13.2°

Observer 130 Results
Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13.1°
Observer 131 Results

Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13.2°
**Observer 8 Results**

Min observer difference angle: 0°
Max observer difference angle: 12.8°

**Observer 9 Results**

Min observer difference angle: 0°
Max observer difference angle: 13.2°
### Observer 10 Results

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Min observer difference angle: 0°
Max observer difference angle: 12.9°

### Observer 11 Results

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Min observer difference angle: 0°
Max observer difference angle: 13°
Observer 12 Results
Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13.2°

Observer 13 Results
Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13°
Observer 34 Results
Reflection Data/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13.5°

Observer 35 Results
Reflection Data/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 13°
**Observer 47 Results**

Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 5.5°

**Observer 48 Results**

Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 10°