6 GLINT AND GLARE ASSESSMENT – TECHNICAL RESULTS

6.1 Evaluation of Effects

The tables in the following subsections present the results of the technical analysis. The final column summarises the predicted impact considering the level of identified screening based on a desk-based review of the available imagery.

The significance of the predicted effects has been evaluated in accordance with Pager Power's published guidance document[13].

The flowcharts setting out the impact characterisation and presented in Appendix D[14]. The list of assumptions and limitations are presented in Appendix F. The modelling output for key receptors can be found in Appendix H.

When evaluating visibility in the context of glint and glare, it is only the *reflecting* panel area that must be considered. For example, if the western half of the development is visible, but reflections would only be possible from the eastern half, it can be concluded that the reflecting area is not visible and no impacts are predicted. This is why there can be instances where visibility of the development is predicted, but glint and glare issues are screened.

Receptors are included within the assessment based on the potential visibility of the development as a whole, among other factors. Once the modelling output has been generated, the assessment can be refined to evaluate the visibility of the reflecting area specifically.

[13] Solar Photovoltaic Development – Glint and Glare Guidance Issue 3.1, April 2021.

[14] There is no standard methodology for evaluating effects on ground-based receptors beyond a kilometre. These receptors have been considered based on first principles and the general methodology for ground-based receptors, keeping in mind the relative safety/amenity implications for differing receptor types.

6.2 Aviation - Overview

The Pager Power and Forge models have been used to determine whether reflections are possible. Where solar reflections have been predicted, intensity calculations in line with the Sandia National Laboratories methodology have been undertaken for reference purposes. These calculations are routinely required for solar photovoltaic developments on or near aerodromes.

The intensity model calculates the expected intensity of a reflection with respect to the potential for an after-image (or worse) occurring. The designation used by the model is presented in Table 2 below along with the associated colour coding.

Coding Used	Intensity Key
Glare beyond 50°	Glare beyond 50 deg from pilot line-of-sight
Low potential	Low potential for temporary after-image
Potential	Potential for temporary after-image
Potential for permanent eye damage	Potential for permanent eye damage

Table 2 *Glare intensity designation*

This coding has been used in the table where a reflection has been calculated and is in accordance with Sandia National Laboratories' methodology.

In addition, the intensity model allows for assessment of a variety of solar panel surface materials. In the first instance, a surface material of 'smooth glass without an anti-reflective coating' has been assessed. Surfaces that can be modelled include:

- Smooth glass with an ARC;
- Light textured glass without an ARC;
- Light textured glass with an ARC;
- Deeply textured glass.

6.3 Summary of Results

The tables in the following subsections summarise the results of the assessment. The predicted glare times are based solely on bare-earth terrain i.e. without consideration of screening from buildings and vegetation. The final column summarises the glare intensity designation defined in the previous sub-section.

The significance of any predicted impact from the Proposed Development is discussed in the subsequent report sections. The modelling output showing the precise predicted times and the reflecting panel area is shown in Appendix H.

6.4 Geometric Calculation Results –-Burn Airfield Circuits

The results of the geometric calculations for the ~~runway approach~~circuits are presented in Table 3 below. A discussion of the results is presented in Section 7.1.

Circuit	Geometric Modelling Result	Glare Intensity	Comment
~~07/25~~Runway 01 RH and LH – short, mid and long approach	Solar reflections are geometrically possible towards ~~the~~almost the entiriety of the modelled circuit ~~for runway 07/25~~path.		Solar reflections with a 'yellow' glare intensity are possible towards ~~the 07/25 circuit.~~ ~~A moderate impact is predicted~~from panels areas northwest 1, northwest 2 and ~~mitigation is recommended~~mid 1.
~~01/19~~Runway 19 RH and LH – short, mid and long approach	Solar reflections are geometrically possible towards ~~the~~almost the entiriety of the modelled circuit ~~for runway 01/19~~path.		Solar reflections with a 'yellow' glare intensity are possible towards ~~the 01/19 circuit.~~ ~~A moderate impact is predicted~~from panels areas northwest 1 and ~~mitigation is recommended~~northwest 2.
Runway 25 RH and LH – short, mid and long approach	Solar reflections are geometrically possible towards almost the entiriety of the modelled circuit path.		Solar reflections with a 'yellow' glare intensity are possible towards from panels areas northwest 1 and northwest 2.
~~15/33~~Runway 33 RH and LH – short, mid and long approach	Solar reflections are geometrically possible towards ~~the~~almost the entiriety of the modelled circuit ~~for runway 15/33~~path.		Solar reflections with a 'yellow' glare intensity are possible towards ~~the 15/33 circuit.~~ ~~A moderate impact is predicted~~from panels areas northwest 1, northwest 2 and ~~mitigation is recommended~~mid 1.

Table 3~~3~~ *Geometric calculation results overview – additional circuits*

~~6.5 Geometric Calculation Results – Burn Airfield Splayed Approaches~~

~~The results of the geometric calculations for the splayed approaches are presented in Table 4 below and on the following pages.~~

~~Approach~~	~~Geometric Modelling Result~~	~~Glare Intensity~~	~~Comment~~
~~07~~	~~Solar reflections are geometrically possible towards the splayed approach for runway 07~~		~~Solar reflections with a 'yellow' glare intensity are geometrically possible.~~ ~~Solar reflections occur outside of the stated operational hours for Burn Airfield (10am – 30 minutes after sunset) and are therefore predicted to be operationally accommodatable.~~ ~~A low impact is predicted and mitigation is not recommended.~~
~~25~~	~~Solar reflections are geometrically possible towards the splayed approach for runway 25~~		~~Solar reflections with a 'yellow' glare intensity are geometrically possible.~~ ~~Solar reflections originating from the two most northern panel areas require mitigation.~~ ~~Solar reflections originating from the remaining panel areas occur outside of the stated operational hours for Burn Airfield (10am – 30 minutes after sunset) and are therefore predicted to be operationally accommodatable.~~ ~~A moderate impact is predicted and mitigation is recommended.~~
~~01~~	~~Solar reflections are geometrically possible towards the splayed approach for runway 25~~		~~Solar reflections with a 'yellow' and 'green' glare intensity are geometrically possible.~~ ~~Solar reflections originating from the two most southern panel areas require mitigation.~~ ~~Solar reflections originating from the remaining panel areas occur outside of the stated operational hours for Burn Airfield (10am – 30 minutes after sunset) and are therefore predicted to be operationally accommodatable.~~ ~~A moderate impact is predicted and mitigation is recommended.~~

~~Approach~~	~~Geometric Modelling Result~~	~~Glare Intensity~~	~~Comment~~
~~19~~	~~Solar reflections are geometrically possible towards the splayed approach for runway 19~~		~~Solar reflections with a 'yellow' and 'green' glare intensity are geometrically possible.~~ ~~Solar reflections occurring within a pilot's primary field of view (50 degrees horizontally either side of the direction of travel) occur outside of the stated operational hours for Burn Airfield (10am – 30 minutes after sunset) and are therefore predicted to be operationally accommodatable.~~ ~~Any solar reflections geometrically possible within the stated operational hours are predicted to occur directly behind a pilot.~~ ~~A low impact is predicted and mitigation is not recommended.~~
~~15~~	~~Solar reflections are geometrically possible towards the splayed approach for runway 15~~		~~Solar reflections with a 'yellow' and 'green' glare intensity are geometrically possible.~~ ~~Solar reflections occur outside of the stated operational hours for Burn Airfield (10am – 30 minutes after sunset) and are therefore predicted to be operationally accommodatable.~~ ~~A low impact is predicted and mitigation is not recommended.~~
~~33~~	~~Solar reflections are geometrically possible towards the splayed approach for runway 33~~		~~Solar reflections with a 'yellow' glare intensity are possible towards approach for runway 33.~~ ~~A moderate impact is predicted and mitigation is recommended.~~

~~Table 4 *Geometric calculation results overview – splayed approaches*~~

~~6.6~~6.5 Geometric Calculation Results – Cliffe Airfield Runway Approaches

The results of the geometric calculations for the runway approaches are presented in Table ~~5~~4 below. A discussion of the results is presented in Section 7.1.

Approach	Geometric Modelling Result	Glare Intensity	Comment
10	No solar reflections geometrically possible.	N/A	No impact predicted.
28	Solar reflections are geometrically possible towards the approach for runway 28		Solar reflections with a 'yellow' glare intensity are geometrically possible. See Section 7 for further information.

Table 4~~5~~4 *Geometric calculation results overview – runway approaches*

~~6.7~~6.6 Geometric Calculation Results – Dwelling Receptors

The results of the geometric calculations for the assessed dwellings are presented in Table 5 below. A discussion of the results is presented in Section 7.2.

Dwelling(s)	Are Solar Reflections Geometrically Possible? (GMT)		Comment
	am	pm	
1-5	No.	No.	No solar reflections geometrically possible within 1km of the receptor. A low impact from the Proposed Development is predicted.
6-8	Yes.	No.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
9-13	No.	Yes.	The model output shows potential effects that would last for less than three months per year and less than 60 minutes per day. A low impact from the Proposed Development is predicted.
14-16	No.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Proposed screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
17	Yes.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.

Dwelling(s)	Are Solar Reflections Geometrically Possible? (GMT)		Comment
	am	pm	
18	No.	No.	No solar reflections geometrically possible within 1km of the receptor. A low impact from the Proposed Development is predicted.
19-21	No.	Yes.	The model output shows potential effects that would last for less than three months per year and less than 60 minutes per day. A low impact from the Proposed Development is predicted and further consideration is not required.
22-27	No.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
28	No.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
29-31	No.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. A low impact from the Proposed Development is predicted due to mitigating factors.
32-42	No.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Existing screening is present so no impact from the Proposed Development is predicted and mitigation is not required.

Dwelling(s)	Are Solar Reflections Geometrically Possible? (GMT)		Comment
	am	pm	
43-49	No.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Proposed screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
50-54	No.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
55-56	No.	Yes.	The model output shows potential effects that would last for less than three months per year and less than 60 minutes per day. A low impact from the Proposed Development is predicted and further consideration is not required.
57-64	No.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
65-67	No.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Proposed screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.

Dwelling(s)	Are Solar Reflections Geometrically Possible? (GMT)		Comment
	am	pm	
68-77	No.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
78	Yes.	Yes.	The model output shows potential effects that would last for less than three months per year and less than 60 minutes per day. A low impact from the Proposed Development is predicted and further consideration is not required.
79	No.	Yes.	The model output shows potential effects that would last for less than three months per year and less than 60 minutes per day. A low impact from the Proposed Development is predicted and further consideration is not required.
80-110, 134-140	No.	No.	No solar reflections geometrically possible. No impacts from the Proposed Development are predicted.
141-143	No.	Yes.	The model output shows potential effects that would last for less than three months per year and less than 60 minutes per day. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
144-153	Yes.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.

Dwelling(s)	Are Solar Reflections Geometrically Possible? (GMT)		Comment
	am	pm	
154-160	No.	No.	No solar reflections geometrically possible. No impacts from the Proposed Development are predicted.
161-183	Yes.	No.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Existing screening is present so no impact from the Proposed Development is predicted and mitigation is not required.
184-186	Yes.	No.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. A low impact from the Proposed Development is predicted due to mitigating factors.
187-191	Yes.	No.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Existing screening is present so no impact from the Proposed Development is predicted and mitigation is not required.
192	Yes.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Existing screening is present so no impact from the Proposed Development is predicted and mitigation is not required.
193	No.	Yes.	No solar reflections geometrically possible within the 1km assessment area. A low impact from the Proposed Development is predicted and further consideration is not required.

Dwelling(s)	Are Solar Reflections Geometrically Possible? (GMT)		Comment
	am	pm	
194-195	No.	Yes.	The model output shows potential effects that would last for less than three months per year and less than 60 minutes per day. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
196	Yes.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
197-199	Yes.	No.	No solar reflections geometrically possible within the 1km assessment area. A low impact from the Proposed Development is predicted and further consideration is not required.

Table 5~~6~~5 *Geometric analysis results for dwelling receptors*

~~6.8~~6.7 Geometric Calculation Results – Road Receptors

The results of the geometric calculations for the assessed roads are presented in Table 6 below. A discussion of the results is presented in Section 7.3.

Road Receptor(s)	Are Solar Reflections Geometrically Possible? (GMT)		Comment
	am	pm	
7-13	Yes.	No.	No solar reflections geometrically possible within the 1km assessment area. A low impact from the Proposed Development is predicted and further consideration is not required.
14-18	Yes.	No.	Reflections would originate within a driver's primary field of view when facing the direction of travel. Proposed screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
19-22	Yes.	Yes.	Reflections would originate within a driver's primary field of view when facing the direction of travel. Proposed screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
24-25	No.	Yes.	Reflections would originate within a driver's primary field of view when facing the direction of travel. Proposed screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
26	No.	Yes.	Reflections would originate outside a driver's primary field of view when facing the direction of travel. A low impact from the Proposed Development is predicted and further consideration is not required.
27	Yes.	Yes.	Reflections would originate within a driver's primary field of view when facing the direction of travel. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.

Road Receptor(s)	Are Solar Reflections Geometrically Possible? (GMT)		Comment
	am	pm	
28-30	No.	Yes	Reflections would originate within a driver's primary field of view when facing the direction of travel. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
31-40	No.	Yes.	Reflections would originate outside a driver's primary field of view when facing the direction of travel. A low impact from the Proposed Development is predicted and further consideration is not required.
41-50	No.	Yes.	Reflections would originate within a driver's primary field of view when facing the direction of travel. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
51-81	No.	Yes.	No solar reflections geometrically possible within 1km of the receptor. A low impact from the Proposed Development is predicted~~.~~ and further consideration is not required.
82-89	No.	Yes.	Reflections would originate outside a driver's primary field of view when facing the direction of travel. A low impact from the Proposed Development is predicted and further consideration is not required.
90-93, 98-117	No.	No.	No solar reflections geometrically possible within 1km of the receptor. A low impact from the Proposed Development is predicted~~.~~ and further consideration is not required.

Road Receptor(s)	Are Solar Reflections Geometrically Possible? (GMT)		Comment
	am	pm	
121-137	No.	Yes.	Reflections would originate within a driver's primary field of view when facing the direction of travel. Existing and proposed screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
138-139	Yes.	No.	Reflections would originate outside a driver's primary field of view when facing the direction of travel. A low impact from the Proposed Development is predicted and further consideration is not required.
140-146	No.	No.	No solar reflections geometrically possible within 1km of the receptor. A low impact from the Proposed Development is predicted~~.~~ and further consideration is not required.
147-149	No.	Yes.	Reflections would originate within a driver's primary field of view when facing the direction of travel. Existing screening removes visibility of the reflecting area and no impact from the Proposed Development is predicted.
150-158	No.	No.	No solar reflections geometrically possible within 1km of the receptor. A low impact from the Proposed Development is predicted~~.~~ and further consideration is not required.

Table 6~~76~~ *Geometric analysis results for road receptors*

~~6.9~~6.8 Geometric Calculation Results – Train Driver Receptors

The results of the geometric calculations for the assessed train driver receptors are presented in Table 7 below. A discussion of the results is presented in Section 7.4.

Receptor	Reflection Possible Towards Receptor? (GMT)		Comments
	am	pm	
1-21	Yes.	No.	Reflections would originate outside a train driver's primary field of view when facing the direction of travel. A low impact from the Proposed Development is predicted and further consideration is not required.
22-23	No.	No.	No solar reflections are geometrically possible. No impacts from the Proposed Development are predicted.
24-29	No.	Yes.	Reflections would originate outside a train driver's primary field of view when facing the direction of travel. A low impact from the Proposed Development is predicted and further consideration is not required.
30-31	No.	Yes.	Reflections would originate within a train driver's primary field of view when facing the direction of travel. Existing screening is present so no impact from the Proposed Development is predicted and mitigation is not required.

Table 78~~7~~ *Geometric analysis results for the identified train driver receptors*

7 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

7.1 Aviation Receptors

~~7.1.1 Overview~~

The following analysis discussion pertains to the ~~runway approach paths~~circuits at Burn Airfield ~~(runways 01/19, 07/25, and 15/33) and~~ and Cliffe Airfield (10/28).

~~7.1.2~~7.1.1 Burn Airfield

~~7.1.2.1 Circuits~~

Solar reflections with 'potential for temporary after-image' are predicted towards ~~the circuits 07/25, 01/19~~ all circuits patterns for runways 01, 19, 25 and 33. Mitigation is therefore recommended to reduce the level of impact towards a pilot to an acceptable level. A mitigation strategy for Burn Airfield is discussed within Section 7.1.2. The results for each circuit are presented in the following subsections. The receptor icons depict the glare intensity categorisation at each point; green represents 'green' glare, yellow represents 'yellow' glare and ~~15/33. Sufficient mitigating factors have not been identified to reduce the level of impact towards a pilot and therefore mitigation is recommended.~~

~~7.1.2.2 Splayed Approaches~~

grey represents no glare.

Table 8 below presents a quantitative representation of the maximum annual duration of yellow glare at any one receptor for each modelled circuit.

Circuit	Maximum Annual Duration of Yellow Glare (minutes)	Percentage of Glare relative to Average Daylight Hours[15]
01	41,494	15.8%
19	40,468	15.4%
25	14,610	5.6%
33	41,220	15.7%

Table 8 *Glare duration for circuits 01, 19, 25, and 33*

[15] Based on 12 hours of sunlight per day (262,800 minutes a year).

7.1.1.1.1 Runway 01 Circuit Results

Solar reflections with 'potential for temporary after-image' ~~and 'low~~ are predicted for almost all locations in the modelled circuit.

Solar reflections would be possible from the north western 1 and 2 and mid 1 panel areas.

Pilots overflying the northwest 1 panel area will have limited downward visibility towards the reflecting panel areas.

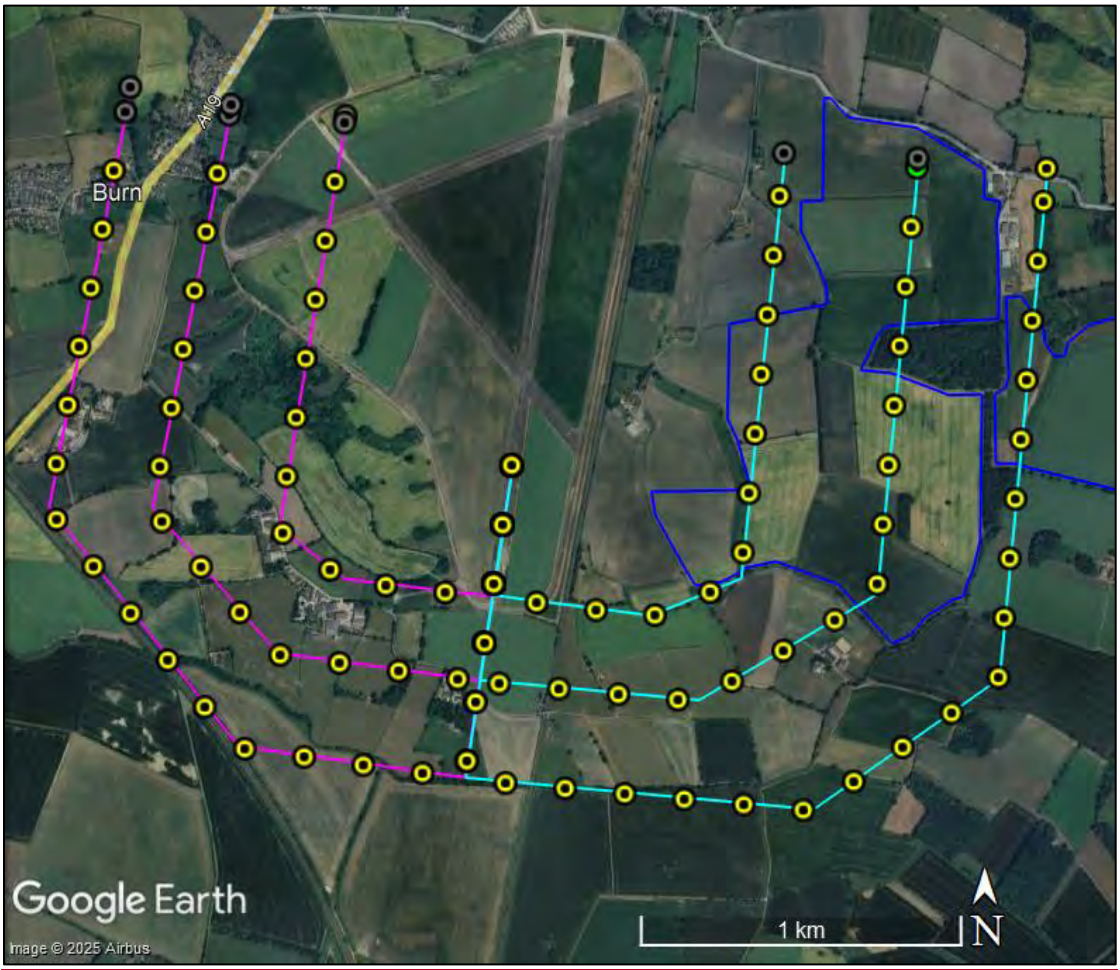

Figure 41 *Runway 01 circuit results*

7.1.1.1.2 Runway 19 Circuit Results

Solar reflections with 'potential for temporary after-image' are predicted ~~towards the approaches for runways 07/25, 01/19 and 15/33.~~on the downwind leg only.

~~For the splayed approaches for runways 07, 15 and 19, the predicted glare has been considered in an operational context to determine its acceptability. The modelling results have identified the following:~~

~~For runways 07 and 15 solar~~ Whilst glare with 'potential for temporary after-image' is predicted at the threshold, no visibility of the reflecting solar panel area would be expected.

Pilots overflying the northwest 1 panel area will have limited downward visibility towards the reflecting panel areas.

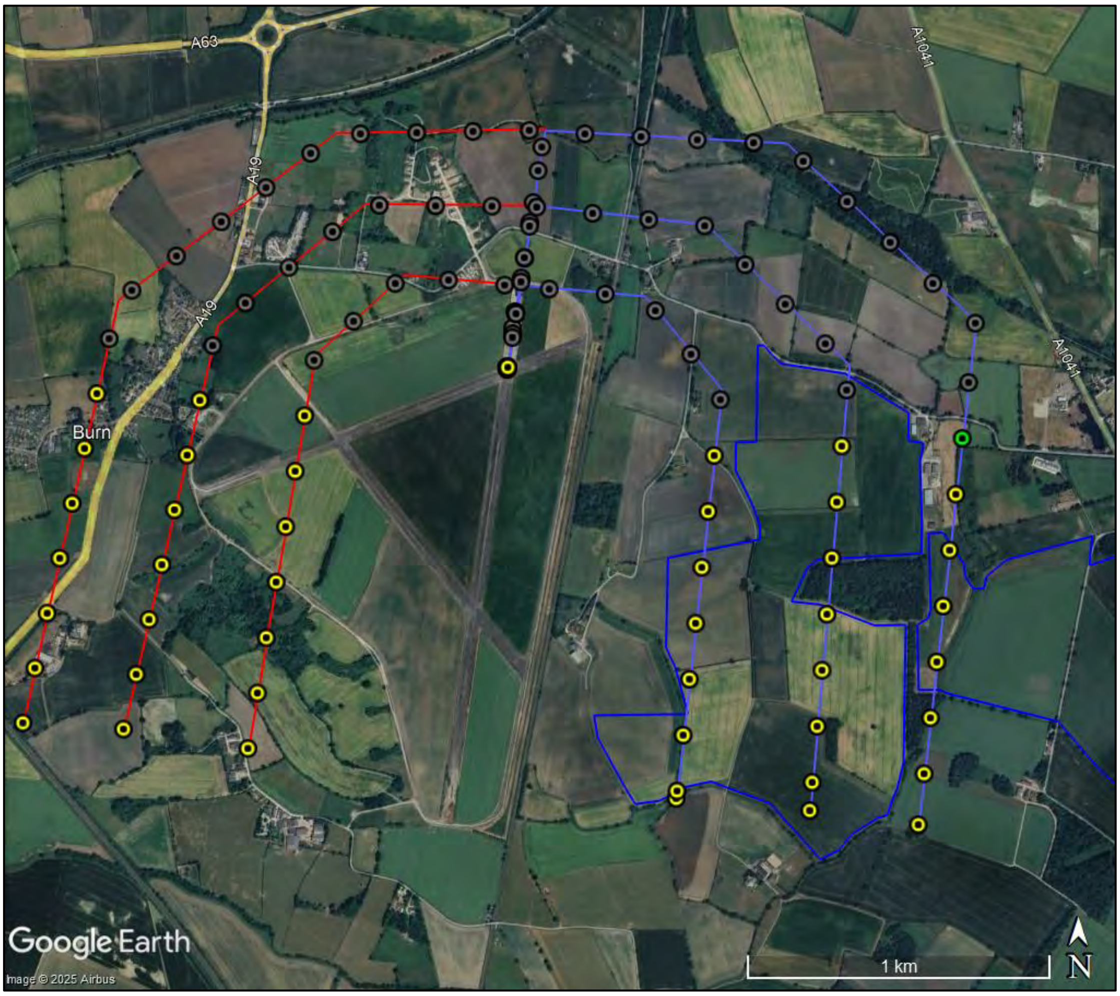

Figure 42 *Runway 19 circuit results*

7.1.1.1.3 Runway 25 Circuit Results

Solar reflections are not possible for pilots on the runway 25 right-hand circuits.

Whilst glare with 'potential for temporary after-image' is predicted ~~to occur~~at the threshold, no visibility of the reflecting solar panel area would be expected.

Pilots overflying the northwest 1 panel area will have limited downward visibility towards the reflecting panel areas.

Solar reflections would be possible from the north western 1 and 2 panels areas.

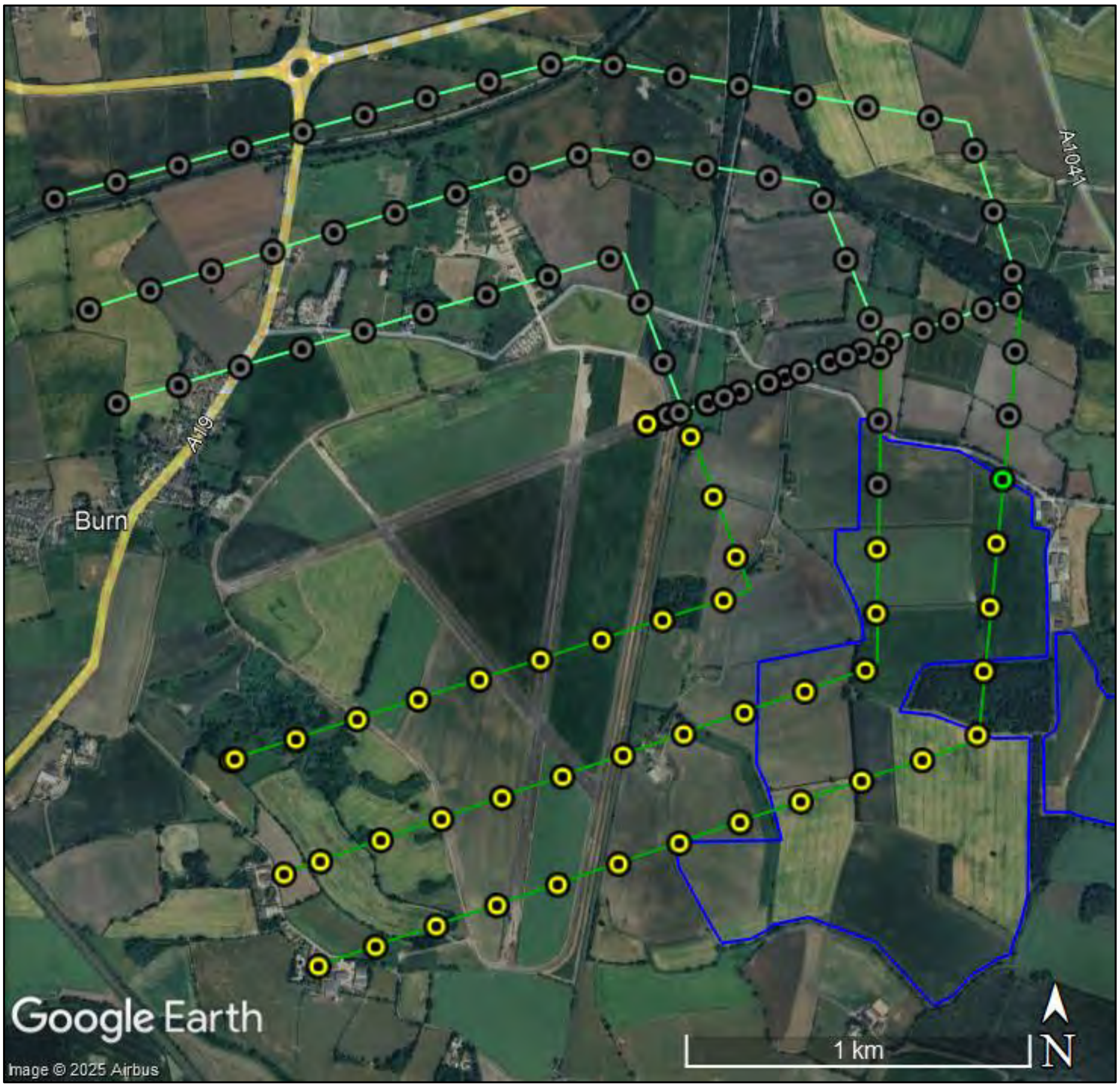

Figure 43 *Runway 25 circuit results*

7.1.1.1.1 Runway 33 Circuit Results

Solar reflections are not possible for pilots on the runway 25 right hand circuits.

Pilots overflying the northwest 1 panel area will have limited downward visibility towards the reflecting panel areas.

Solar reflections would be possible from the north western 1 and 2 and mid 1 panel areas.

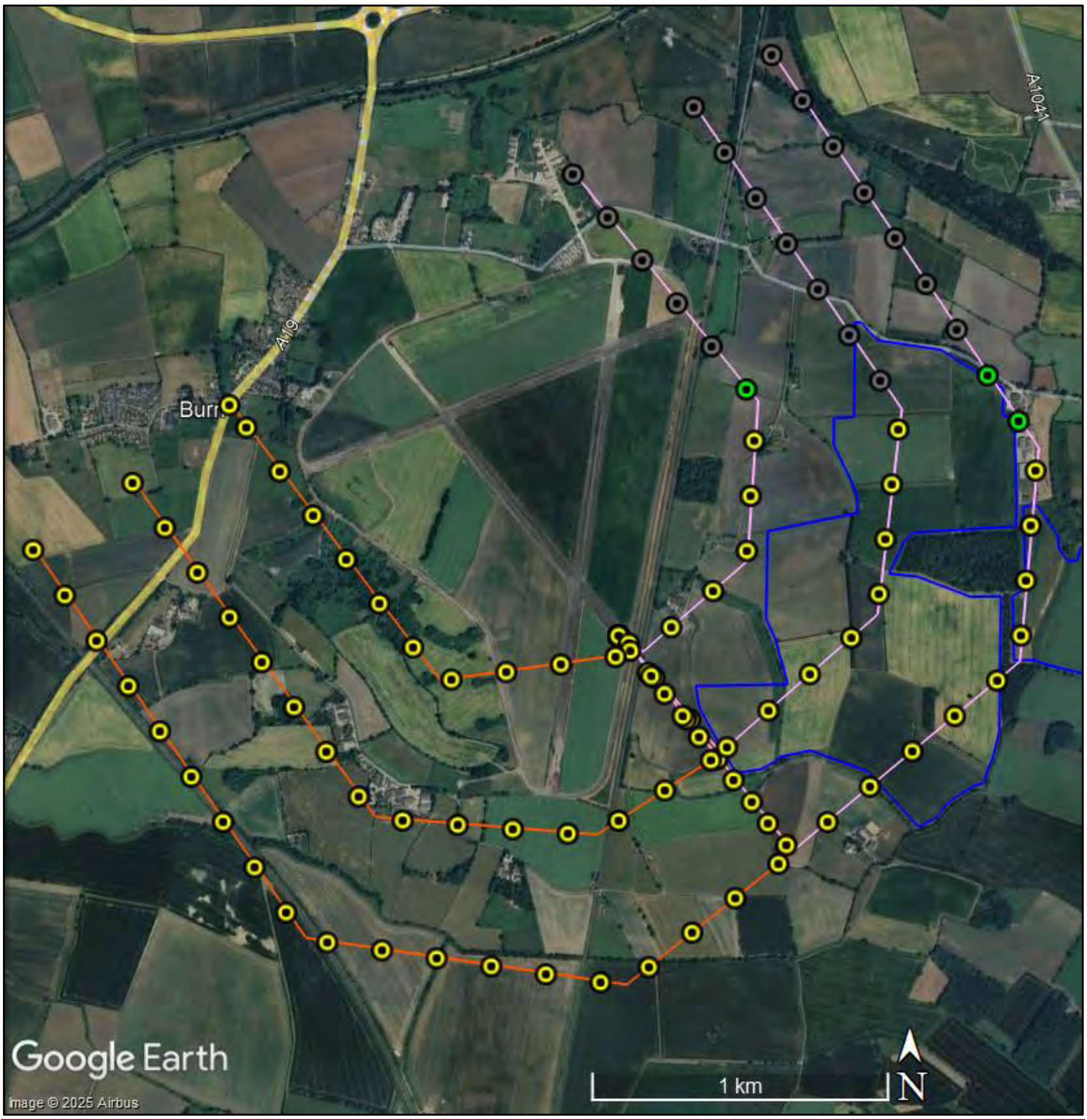

Figure 44 *Runway 33 circuit results*

7.1.2 Mitigation Strategy

Potential mitigation for the Proposed Development can include fixing the Single Access Tracker System at a resting angle that would avoid significant effects at the times at which glare is predicted towards the, the circuit paths at Burn Airfield, and the. Any glare that occurs outside

~~of~~ the ~~stated~~ operational hours for Burn Airfield ~~(10am GMT – 30 minutes after sunset)[16]. Solar reflections are predicted~~will not be mitigated.

- Once the detailed design is confirmed modelling can be undertaken to identify the appropriate mitigation solution(s) to be implemented. On the basis that the mitigation solution(s) once implemented would reduce the glare to ~~occur at times between 5am-10am GMT at points during September-early May~~an acceptable intensity or reduce the glare to times/durations that can be operationally accommodated, the predicted impact will be low at worst and therefore not significant. The identified solution will be presented within a Glint and Glare Mitigation Strategy secured by a Requirement in the draft Development Consent Order, as outlined in Appendix I.

  - ~~For runway 19, where solar reflections originate within a pilot's primary field of view (50 degrees horizontally either side of the direction of travel), these are geometrically possible outside of the stated operational hours for Burn Airfield. Where solar reflections are geometrically possible during the stated operational hours, these will occur behind a pilot following the direction of travel along the left-hand base leg join.~~
  - ~~The weather would have to be clear and sunny at the specific times when glare is possible. A pilot would also have to be on approach at these times.~~

~~Overall, it is judged that 'yellow' glare along the splayed approaches for runways 01, 15 and 19 at Burn Airfield can be operationally accommodated. Considering the points made above, there are mitigating factors that reduce the overall impact. In particular, solar reflections 'with potential for after-image' are predicted to occur outside the operational hours of the airfield.~~

~~For the runway 25 splayed approach path, the majority of solar reflections that are geometrically possible will occur outside of the operational hours of the airfield. However, solar reflections originating from the two most northern panel areas are predicted occur during the stated operational hours, without sufficient mitigating factors. Therefore, a moderate impact is predicted and mitigation is recommended to reduce the level of impact.~~

~~For the runway 01 splayed approach path, the majority of solar reflections that are geometrically possible will occur outside of the operational hours of the airfield. However, solar reflections originating from the two most southern panel areas are predicted occur during the stated operational hours, without sufficient mitigating factors. Therefore, a moderate impact is predicted and mitigation is recommended to reduce the level of impact.~~

~~For the runway 33 splayed approach path, solar reflections with 'potential for temporary after-image' are predicted and sufficient mitigating factors have not been identified. Therefore, mitigation is recommended to reduce the level of impact towards a pilot.~~

7.1.3 Cliffe Airfield

The results of the analysis have shown that no solar reflections towards pilots approaching runway 10 are geometrically possible. Therefore, no mitigation is required.

~~[16] Provided by Burn Airfield during consultation via Zoom on 14/11/24.~~

Solar reflections are geometrically possible towards pilots between 0.0-2.0 miles from the runway 28 threshold. The modelling for the Proposed Development has shown that the predicted glare intensities have a 'potential for temporary after-image' (yellow), which requires assessment ~~in an operational context~~relative to the operations at Cliffe Airfield to determine its acceptability.

The modelling results have identified the following:

- Predicted glare towards runway approach path 28 occurs between 15:30 and 17:30 during January to March and early October to December. A pilot would have to look in the direction of the sunset to experience the effects of the Proposed Development. The effects would less significant than the existing sunlight effects experienced by the pilot.
- The weather would have to be clear and sunny at the specific times when glare is possible. A pilot would also have to be on approach at these times.
- Effects would be less significant than existing sunlight effects experienced by approaching pilots for all approach paths.

Overall, it is judged that 'yellow' glare along circuits for runway 28 at Cliffe Airfield can be operationally accommodated~~.~~ by the airfield. Considering the points made above, there are mitigating factors that reduce the overall impact.

~~7.1.4 Mitigation Strategy~~

~~Potential mitigation for the Proposed Development can include fixing the Single Access Tracker System at a resting angle that would avoid significant effects at the times at which glare is predicted towards the 07/25, 01/19 and 15/33 circuits and the splayed approaches for runways 25, 01 and 33.~~

~~Further modelling is required to confirm this mitigation solution. However, on the basis that this mitigation solution would reduce the glare to acceptable intensity or reduce the glare to times/durations that can be operationally accommodated, the predicted impact will be low at worst and therefore not significant.~~

7.2 Dwelling Results

The key considerations for quantifying the impact significance for dwelling receptors are:

- Whether a significant reflection is predicted to be experienced in practice.
- The duration of the predicted effects, relative to thresholds of:
  - 3 months per year.
  - 60 minutes per day.

Where reflections are predicted to be experienced for less than 3 months per year and less than 60 minutes per day or where the separation distance to the nearest visible reflecting panel is over 1km, the impact significance is low, and mitigation is not required.

Where reflections are predicted to be experienced for more than 3 months per year or for more than 60 minutes per day, the impact significance is moderate and expert assessment of the following mitigating factors is required to determine the mitigation requirement:

- The separation distance to the panel area. Larger separation distances reduce the proportion of an observer's field of view that is affected by glare.
- The position of the Sun. Effects that coincide with direct sunlight appear less prominent than those that do not. The Sun is a far more significant source of light.
- Whether solar reflections will be experienced from all storeys. The ground floor is typically considered the main living space and therefore has a greater significance with respect to residential amenity.
- Whether the dwelling appears to have windows facing the reflecting areas. An observer may need to look at an acute angle to observe the reflecting areas.

Where reflections are predicted to be experienced for more than 3 months per year and more than 60 minutes per day, the impact significance is high, and mitigation is required.

A conservative review of the available imagery has been undertaken within the desk-based assessment, whereby it is assumed views of the panels are possible if it cannot be reliably determined that existing screening will remove effects.

Solar reflections lasting for more than 3 months per year and less than 60 minutes on any one day have been predicted for 104 of the 177 assessed dwellings. These dwellings are discussed below and on the following pages.

For dwellings 1-5, 18, 193, and 197-199, no solar reflections are geometrically possible within the 1km assessment area. Therefore, a low impact from the Proposed Development is predicted, and mitigation is not recommended.

For dwellings 6-8, 14-17, 22-28, 32-54, 57-77, 141-153, 161-183, 187-192, and 194-196, there is existing and proposed (please see Figures 7.~~8~~20-7.~~10~~22 of the Landscape Strategy ~~of the PEIR~~Plan) screening in the form of vegetation, terrain and buildings which removes the visibility of the reflecting panel areas. Therefore, no impact from the Proposed Development is predicted and no mitigation is required. Figures ~~42-51~~45-54 on the following pages show the existing screening.

~~Figure 42 *Existing screening for dwellings 6-8*~~

~~Figure 43 *Existing screening for dwelling 17*~~

~~*Figure 44 Existing screening for dwellings 22-28 and 32-35*~~

Figure 45 *Existing screening for dwellings* ~~36-42~~6-8

Figure 46 *Existing screening for ~~dwellings 50-63 and 68-77~~dwelling 17*

Figure 47 *Existing screening for dwellings ~~141-153~~22-28 and 32-35*

Figure 48 *Existing screening for dwellings ~~161-183 and 187-189~~36-42*

Figure 49 *Existing screening for dwellings ~~191-192~~50-63 and 68-77*

Figure 50 *Existing screening for dwellings ~~194-195~~141-153*

Figure 51 Existing screening for dwellings 161-183 and 187-189

Figure 52 *Existing screening for dwellings 191-192*

Figure 53 *Existing screening for dwellings 194-195*

Figure 54 *Existing screening for dwelling 196*

For dwellings 29-31 and 184-186, it cannot be conclusively determined whether the existing screening will remove views of the reflecting panel area; however there are other mitigating factors that can be considered, including the following:

- There is a large separation distance of approximately 795m for dwellings 29-31 and 411m for dwellings 184-186, between the reflecting panel area and the dwelling. This reduces the proportion of an observer's field of view that is affected by glare.
- Views from a ground floor observer are removed by existing vegetation; the ground floor is typically considered the main living space and therefore has a greater significance with respect to residential amenity;
- The effects coincide with direct sunlight, which is a more significant source of light; therefore the glint and glare effects will appear much less significant.

For dwellings 9-13, 19-21, 55-56, and 78-79, a reflection is geometrically possible; however, the predicted impact of the reflecting solar panel is of low significance due to the duration of effects. Therefore, mitigation is not recommended.

7.3 Road Results

The key considerations for quantifying impact significance for road users along major national, national, and regional roads are:

- Whether a reflection is predicted to be experienced in practice.
- The location of the reflecting panels relative to a road user's direction of travel (a reflection directly in front of a driver is more hazardous than a reflection from a location off to one side).

Where reflections are predicted to be experienced from outside of a road user's primary field of view (50 degrees either side of the direction of travel), the impact significance is low, and mitigation is not required.

Where reflections are predicted to be experienced from inside of a road user's primary field of view but there are mitigating circumstances, the impact significance is moderate and expert assessment of the following mitigating factors is required to determine the mitigation requirement:

- Whether visibility is likely for elevated drivers (applicable to dual carriageways and motorways only) – there is typically a higher density of elevated drivers (such as HGVs) along dual carriageways and motorways compared to other types of road;
- Whether the solar reflection originates from directly in front of a road user – a solar reflection that is directly in front of a road user is more hazardous than a solar reflection to one side;
- The separation distance to the panel area – larger separation distances reduce the proportion of an observer's field of view that is affected by glare;
- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not.

Where reflections predicted to be experienced originate from directly in front of a road user and there are no further mitigating circumstances, the impact significance is high, and mitigation is required.

The results of the analysis have shown that solar reflections from the Proposed Development towards the assessed surrounding roads are geometrically possible along all sections of the assessed roads.

At road locations 14-25, 27-30, 41-50, 121-137, and 147-149 reflections are found to be geometrically possible within the driver's primary field of vision; however, existing and proposed (see Figure 7.8 Landscape Strategy of the PEIR) screening has been identified that would remove views of the reflecting solar panel areas. Therefore, no impact from the Proposed Development upon road users at these locations are predicted. Figures ~~52-57~~55-60 on the following pages highlights the existing screening from selected receptors, representative of selected locations above.

Figure 55~~52~~55 *Street view image ~~from~~: location 27 showing views towards the solar panel area*

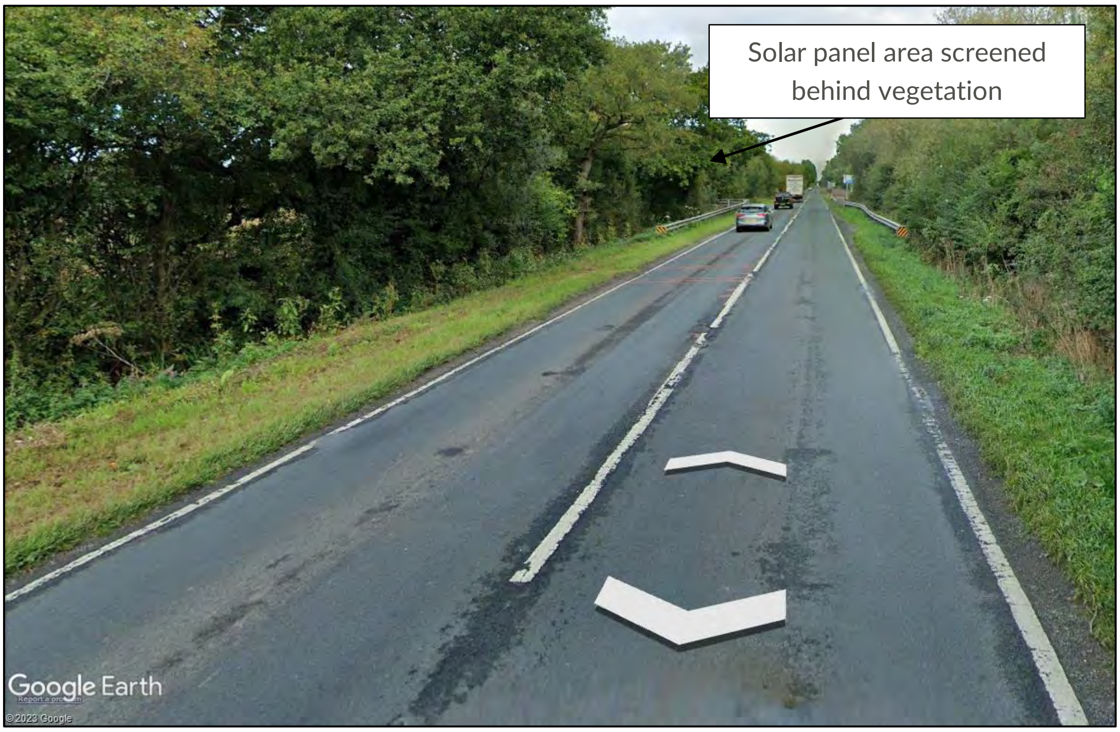

Figure 56~~53~~56 *Street view image ~~from~~: location 44 showing views towards the solar panel area*

Figure 57~~54~~57 *Street view image ~~from~~: location 122 showing views towards the solar panel area*

Figure 58~~55~~58 *Street view image ~~from~~: location 128 showing views towards the solar panel area*

Figure 59~~56~~59 *Street view image* ~~*from*~~*: location 131 showing views towards the solar panel area*

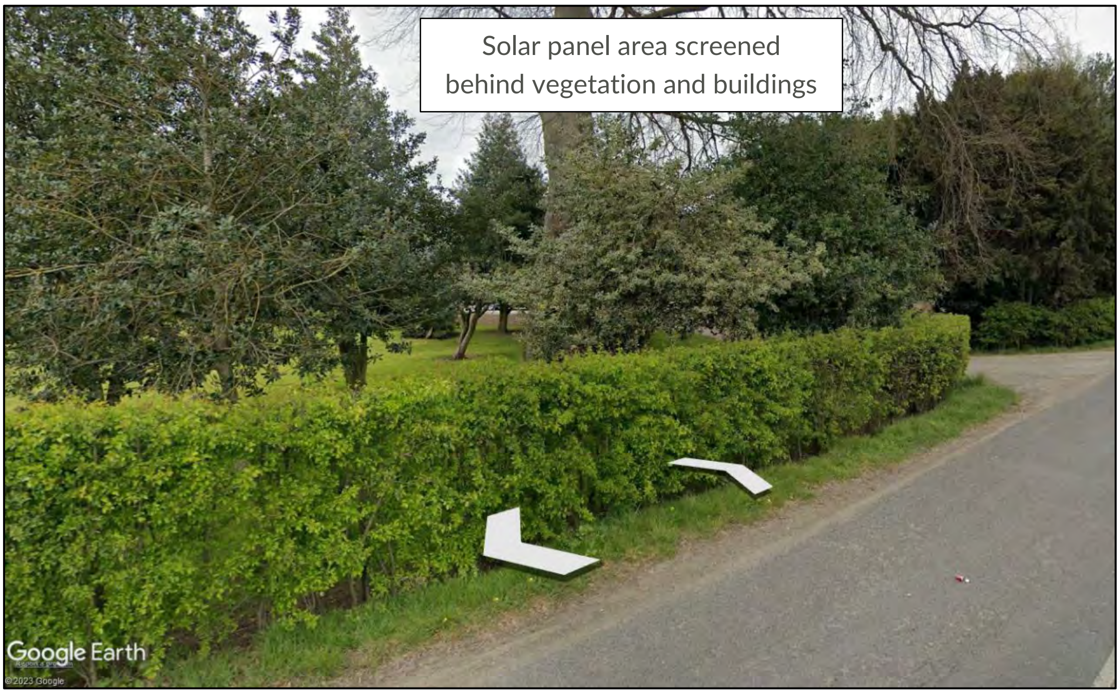

Figure 60~~57~~60 *Street view image* ~~*from*~~*: location 148 showing views towards the solar panel area*

Reflections between receptors 26, 31-40, 82-89, and 138-39 are not significant because they would occur from a bearing that is outside a driver's primary field of view. There is a low impact predicted upon road users from the Proposed Development and mitigation measures are not recommended.

Furthermore, for receptors 7-13, 51-81, 90-93, 98-117, 140-146, and 150-159, solar reflections occur outside of the 1km assessment area. Therefore, a low impact from the Proposed Development is predicted and mitigation is not recommended.

7.4 Train Driver Receptors

The results of the modelling indicate that solar reflections are geometrically possible towards a combined 2.8km section of railway track, between receptors 1-21 and 24-31.

The key considerations for quantifying impact significance for train driver receptors are:

- Whether a reflection is predicted to be experienced in practice.
- The location of the reflecting panel relative to a train driver's direction of travel.
- The workload of a train driver experiencing a solar reflection.

Where reflections originate from outside of a train driver's field of view (30 degrees either side of the direction of travel), the impact significance is low, and mitigation is not required.

Where reflections originate from inside of a train driver's field of view but there are mitigating circumstances, the impact significance is moderate and expert assessment of the mitigating factors is required to determine the mitigation requirement (if any). Of particular relevance is whether the solar reflection originates from directly in front of a train driver and the workload of the train driver along the section of railway line.

Where reflections originate from directly in front of a train driver and there are no further mitigating circumstances, the impact significance is high, and mitigation is required.

Between receptors 30-31, the predicted solar reflections originate from within the train drivers' primary field of view (30 degrees either side of the direction of travel).

For these receptors there is existing heavy vegetation that screens the reflections from the solar panel area, thus no impact from the Proposed Development is predicted; however, in the circumstances that this vegetation was removed the impact significance would remain moderate and mitigation would need to be implemented. Therefore, although mitigation is not recommended, the existing screening along the boundary of the Proposed Development should be maintained to ensure views of the reflecting solar panel area continue to be removed. Figure ~~58 below~~61 on the following page shows the existing screening outlined in orange.

Figure 61~~5861~~ *Existing screening for receptors 30-31*

Where solar reflections are predicted to be experienced outside the train drivers' primary field of view (30 degrees either side of the direction of travel), at receptors 1-21 and 24-29, a low impact from the Proposed Development is predicted and mitigation is not recommended.

8 HIGH-LEVEL AVIATION CONSIDERATIONS

8.1 Overview

Sherburn-in-Elmet is an unlicensed airfield located approximately 9.5km northwest of the Proposed Development, which is understood to not have an ATC Tower. The airfield has four runways:

- 01/19 – 585 metres (Grass);
- 06/24 – 793 metres (Grass);
- 10/28 – 830 metres (Tarmac); and
- 10/28 – 616 metres (Grass).

The location of Sherburn-in-Elmet Airfield relative to the Proposed Development is shown in Figure ~~59~~62 below.

Figure 62~~5962~~ *Sherburn-in-Elmet airfield relative to the Proposed Development*

8.2 High-Level Conclusion

Considering the size of the Proposed Development and its location relative to Sherburn-in-Elmet Airfield (approximately 9.5km away), the following is applicable:

- In Pager Power's experience and expertise, it can be safely presumed that any predicted solar reflections towards pilots approaching runway thresholds 06, 19 and both runway 10 thresholds, would have intensities no greater than 'low potential for temporary after image', which is acceptable in accordance with the associated guidance and industry best practice.
- Any solar reflections will be outside a pilot's primary field of view (50 degrees either side of the approach bearing) along the approach paths towards runway thresholds 01, 24, and both runway 28 thresholds, which is acceptable in accordance with the associated guidance and industry best practice.

Therefore, no significant impacts~~,~~ from the Proposed Development, upon aviation activity associated with Sherburn-in-Elmet are predicted, and no further detailed modelling is recommended.

9 OVERALL CONCLUSIONS

9.1 Aviation Receptors

9.1.1 Burn Airfield

Solar reflections with 'potential for temporary after-image' are predicted towards the circuits ~~07/25, 01/19 and 15/33. Sufficient mitigating factors have not been identified to reduce the level of impact towards a pilot and therefore mitigation is recommended.~~

~~Solar reflections with 'potential for temporary after-image' are predicted towards the splayed approaches for runways 07, 25, 01, 19, 15, and 33.~~

~~It is judged that 'yellow' glare along the splayed approaches for runways 01, 15 and 19 at Burn Airfield can be operationally accommodated where solar reflections are predicted to occur outside the operational hours of the airfield.~~

~~For the runway 25 splayed approach path, the majority of solar reflections that are geometrically possible will occur outside of the operational hours of the airfield. However, solar reflections originating from the two most northern panel areas are predicted occur during the stated operational hours, without sufficient mitigating factors. Therefore, a moderate impact is predicted and mitigation is recommended to reduce the level of impact.~~

~~For the runway 01 splayed approach path, the majority of solar reflections that are geometrically possible will occur outside of the operational hours of the airfield. However, solar reflections originating from the two most southern panel areas are predicted occur during the stated operational hours, without sufficient mitigating factors. Therefore, a moderate impact is predicted and mitigation is recommended to reduce the level of impact.~~

~~For the runway 33 splayed approach path, solar reflections with 'potential for temporary after-image' are predicted and sufficient mitigating factors have not been identified. Therefore, mitigation is recommended to reduce the level of impact towards a pilot.~~

for runways 01, 19, 25 and 33. Sufficient mitigating factors have not been identified to reduce the level of impact towards a pilot and therefore mitigation is recommended.

~~Further modelling is required to confirm this mitigation solution. However, on the basis that this mitigation solution would reduce the glare to acceptable intensity or reduce the glare to times/durations that can be operationally accommodated, the predicted impact will be low at worst and therefore not significant.~~ Once the detailed design is confirmed modelling can be undertaken to identify the appropriate mitigation solution(s) to be implemented. On the basis that the mitigation solution(s) once implemented would reduce the glare to an acceptable intensity or reduce the glare to times/durations that can be operationally accommodated, the predicted impact will be low at worst and therefore not significant. The identified solution will be presented within a Glint and Glare Mitigation Strategy secured by a Requirement in the draft Development Consent Order, as outlined in Appendix I.

9.1.2 Cliffe Airfield

The results of the analysis have shown that no solar reflections towards pilots approaching runway 10 are geometrically possible. Therefore, no mitigation is required.

Solar reflections with 'potential for temporary after-image' are predicted towards the splayed approaches for runway 28. Overall, it is judged that 'yellow' glare along circuits for runway 28 at Cliffe Airfield can be operationally accommodated due to the identification of mitigating factors~~.~~

9.2 Dwelling Receptors

The results of the analysis have shown that reflections from the Proposed Development are geometrically possible towards 104 out of the identified dwelling receptors for more than three months per year and less than 60 minutes per day.

For 98 dwellings, existing and proposed (please see Figures ~~-~~7.20-7.22 of the Landscape Strategy Plan~~7.8-7.10 Landscape Strategy of the Preliminary Environmental Information Report~~) screening in the form of vegetation, terrain and buildings removes the visibility of the reflecting panel areas. Therefore, no impacts from the Proposed Development are predicted and mitigation is not required.

For the remaining six dwellings, there are sufficient mitigating factors. These include:

- A large separation distance between the reflecting panel area and the dwelling. This reduces the proportion of an observer's field of view that is affected by glare.
- The effects coincide with direct sunlight, which is a more significant source of light; therefore the effects appear much less significant.
- The effects cannot be seen from an observer on the ground floor – which has the greatest impact on residential amenity.
- The effects occur outside the 1km assessment area and would therefore be a maximum of low impact, due to the separation distance and intervening terrain/vegetation.

Therefore, mitigation is not recommended for these dwellings.

9.3 Road Receptors

The results of the analysis have shown that solar reflections from the Proposed Development are geometrically possible along approximately all of the assessed sections of road along the A1041, A645, Barlow Road, Common Lane, Hirst Road and Station Road.

Where solar reflections are geometrically possible inside a road user's primary field of view, along a combined 4.1km section of road, existing and proposed vegetation and buildings will remove visibility of any solar reflections. Therefore, no impacts from the Proposed Development are predicted, and mitigation is not required for these sections of road.

9.4 Train Driver Receptors

The analysis has shown that reflections are geometrically possible towards 2.8km of railway track. Reflections are predicted to occur within the train driver's primary field of view (30 degrees either side of the direction of travel) along 200m of railway track; however, screening in the form of heavy existing vegetation is present. Therefore, no impacts from the Proposed Development are predicted and mitigation is not required.

A low impact from the Proposed Development is predicted for the remaining sections of railway track where solar reflections are geometrically possible. The reflections occur outside of the train driver's primary field of view. Therefore, no mitigation is required.

9.5 High-Level Aviation

Considering the size of the Proposed Development and its location relative to Sherburn-in-Elmet Airfield (approximately 9.5km away), the following is applicable:

- In Pager Power's experience and expertise, it can be safely presumed that any predicted solar reflections towards pilots approaching runway thresholds 06, 19 and both runway 10 thresholds, would have intensities no greater than 'low potential for temporary after image', which is acceptable in accordance with the associated guidance and industry best practice.
- Any solar reflections will be outside a pilot's primary field of view (50 degrees either side of the approach bearing) along the approach paths towards runway thresholds 01, 24, and both runway 28 thresholds, which is acceptable in accordance with the associated guidance and industry best practice.

Therefore, no significant impacts, from the Proposed Development, upon aviation activity associated with Sherburn-in-Elmet are predicted, and no further detailed modelling is recommended.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

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

- The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[17] (specifically regarding the consideration of solar farms, paragraph 013) 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.'*

[17] Renewable and low carbon energy, Ministry of Housing, Communities & Local Government, date: 18 June 2015, accessed on: 01/11/2021

Draft National Policy Statement for Renewable Energy Infrastructure

The Draft National Policy Statement for Renewable Energy Infrastructure (EN-3)[18] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Sections 3.10.93-97 state:

'3.10.93 Solar panels are specifically designed to absorb, not reflect, irradiation.[19] However, solar panels may reflect the sun's rays at certain angles, causing glint and glare. Glint is defined as a momentary flash of light that may be produced as a direct reflection of the sun in the solar panel. Glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel. The effect occurs when the solar panel is stationed between or at an angle of the sun and the receptor.

3.10.94 Applicants should map receptors to qualitatively identify potential glint and glare issues and determine if a glint and glare assessment is necessary as part of the application.

3.10.95 When a quantitative glint and glare assessment is necessary, applicants are expected to consider the geometric possibility of glint and glare affecting nearby receptors and provide an assessment of potential impact and impairment based on the angle and duration of incidence and the intensity of the reflection.

3.10.96 The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and design. This may need to account for 'tracking' panels if they are proposed as these may cause differential diurnal and/or seasonal impacts.

3.10.97 When a glint and glare assessment is undertaken, the potential for solar PV panels, frames and supports to have a combined reflective quality may need to be assessed, although the glint and glare of the frames and supports is likely to be significantly less than the panels.'

The EN-3 does not state which receptors should be considered as part of a quantitative glint and glare assessment. Based on Pager Power's extensive project experience, typical receptors include residential dwellings, road users, aviation infrastructure, and railway infrastructure.

Sections 3.10.125-127 state:

3.10.125 Applicants should consider using, and in some cases the Secretary of State may require, solar panels to comprise of (or be covered with) anti-glare/anti-reflective coating with a specified angle of maximum reflection attenuation for the lifetime of the permission.

3.10.126 Applicants may consider using screening between potentially affected receptors and the reflecting panels to mitigate the effects.

3.10.127 Applicants may consider adjusting the azimuth alignment of or changing the elevation tilt angle of a solar panel, within the economically viable range, to alter the angle of incidence.

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[18] Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, date: March 2023, accessed on: 05/04/2023.

[19] *Most commercially available solar panels are designed with anti-reflective glass or are produced with anti-reflective coating and have a reflective capacity that is generally equal to or less hazardous than other objects typically found in the outdoor environment, such as bodies of water or glass buildings.*

In practice this is unlikely to remove the potential impact altogether but in marginal cases may contribute to a mitigation strategy.

The mitigation strategies listed within the EN-3 are relevant strategies that are frequently utilised to eliminate or reduce glint and glare effects towards surrounding observers. The most common form of mitigation is the implementation of screening along the site boundary.

Sections 3.10.149-150 state:

3.10.149 Solar PV panels are designed to absorb, not reflect, irradiation. However, the Secretary of State should assess the potential impact of glint and glare on nearby homes, motorists, public rights of way, and aviation infrastructure (including aircraft departure and arrival flight paths).

3.10.150 Whilst there is some evidence that glint and glare from solar farms can be experienced by pilots and air traffic controllers in certain conditions, there is no evidence that glint and glare from solar farms results in significant impairment on aircraft safety. Therefore, unless a significant impairment can be demonstrated, the Secretary of State is unlikely to give any more than limited weight to claims of aviation interference because of glint and glare from solar farms.

The latest version of the draft EN-3 goes some way in referencing that the issue is more complex than presented in the previous issue; though, this is still unlikely to be welcomed by aviation stakeholders, who will still request a glint and glare assessment on the basis that glare may lead to impact upon aviation safety. It is possible that the final issue of the policy will change in light of further consultation responses from aviation stakeholders.

Finally, the EN-3 relates solely to nationally significant renewable energy infrastructure and therefore does not apply to all planning applications for solar farms.

Assessment Process – Ground-Based Receptors

No process for determining and contextualising the effects of glint and glare is provided for assessing the impact of solar reflections upon surrounding roads and dwellings. 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.

The Pager Power approach has been informed by the policy presented above, current studies (presented in Appendix B) and stakeholder consultation. Further information can be found in Pager Power's Glint and Glare Guidance document[20] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

[20] Pager Power Glint and Glare Guidance, Third Edition (3.1), April 2021.

Railway Assessment Guidelines

The following section provides an overview of the relevant railway guidance with respect to the siting of signals on railway lines. Network Rail is the stakeholder of the UK's railway infrastructure. Whilst the guidance is not strictly applicable in Ireland, the general principles within the guidance is expected to apply.

A railway operator's concerns would likely to relate to the following:

1. The development producing solar glare that affects train drivers; and
2. The development producing solar reflections that affect railway signals and create a risk of a phantom aspect signal.

Railway guidelines are presented below. These relate specifically to the sighting distance for railway signals.

Reflections and Glare

The extract below is taken from Section A5 – Reflections and glare (pages 64-65) of the 'Signal Sighting Assessment Requirements'[21] which details the requirement for assessing glare towards railway signals.

Reflections and glare

Rationale

Reflections can alter the appearance of a display so that it appears to be something else.

Guidance

A5 is present if direct glare or reflected light is directed into the eyes or into the lineside signalling asset that could make the asset appear to show a different aspect or indication to the one presented.

A5 is relevant to any lineside signalling asset that is capable of presenting a lit signal aspect or indication.

The extent to which excessive illumination could make an asset appear to show a different signal aspect or indication to the one being presented can be influenced by the product being used. Requirements for assessing the phantom display performance of signalling products are set out in GKRT0057 section 4.1.

Problems arising from reflection and glare occur when there is a very large range of luminance, that is, where there are some objects that are far brighter than others. The following types of glare are relevant:

a) Disability glare, caused by scattering of light in the eye, can make it difficult to read a lit display.

b) Discomfort glare, which is often associated with disability glare. While being unpleasant, it does not affect the signal reading time directly, but may lead to distraction and fatigue.

[21] Source: Signal Sighting Assessment Requirements, June 2016. Railway Group Guidance Note. Last accessed 18.10.2016.

Examples of the adverse effect of disability glare include:

a) *When a colour light signal presenting a lit yellow aspect is viewed at night but the driver is unable to determine whether the aspect is a single yellow or a double yellow.*
b) *Where a colour light signal is positioned beneath a platform roof painted white and the light reflecting off the roof can make the signal difficult to read.*

Options for militating against A5 include:

a) *Using a product that is specified to achieve high light source: phantom ratio values.*
b) *Alteration to the features causing the glare or reflection.*
c) *Provision of screening.*

Glare is possible and should be assessed when the luminance is much brighter than other light sources. Glare may be unpleasant and therefore cause distraction and fatigue, or may make the signal difficult to read and increase the reading time.

Determining the Field of Focus

The extract below is taken from Appendix F - Guidance on Field of Vision (pages 98-101) of the 'Signal Sighting Assessment Requirements'22 which details the visibility of signals, train drivers' field of vision and the implications with regard to signal positioning.

Asset visibility

The effectiveness of an observer's visual system in detecting the existence of a target asset will depend upon its:

a) *Position in the observer's visual field.*
b) *Contrast with its background.*
c) *Luminance properties.*
d) *The observer's adaptation to the illumination level of the environment.*

It is also influenced by the processes relating to colour vision, visual accommodation, and visual acuity. Each of these issues is described in the following sections.

[22] Source: Signal Sighting Assessment Requirements, June 2016. Railway Group Guidance Note. Last accessed 28.08.2020.

Field of vision

The field of vision, or visual field, is the area of the visual environment that is registered by the eyes when both eyes and head are held still. The normal extent of the visual field is approximately 135o in the vertical plane and 200o in the horizontal plane.

The visual field is usually described in terms of central and peripheral regions: the central field being the area that provides detailed information. This extends from the central point (0°) to approximately 30° at each eye. The peripheral field extends from 30o out to the edge of the visual field.

F.6.3 Objects positioned towards the centre of the observer's field of vision are seen more quickly and identified more accurately because this is where our sensitivity to contrast is the highest. Peripheral vision is particularly sensitive to movement and light.

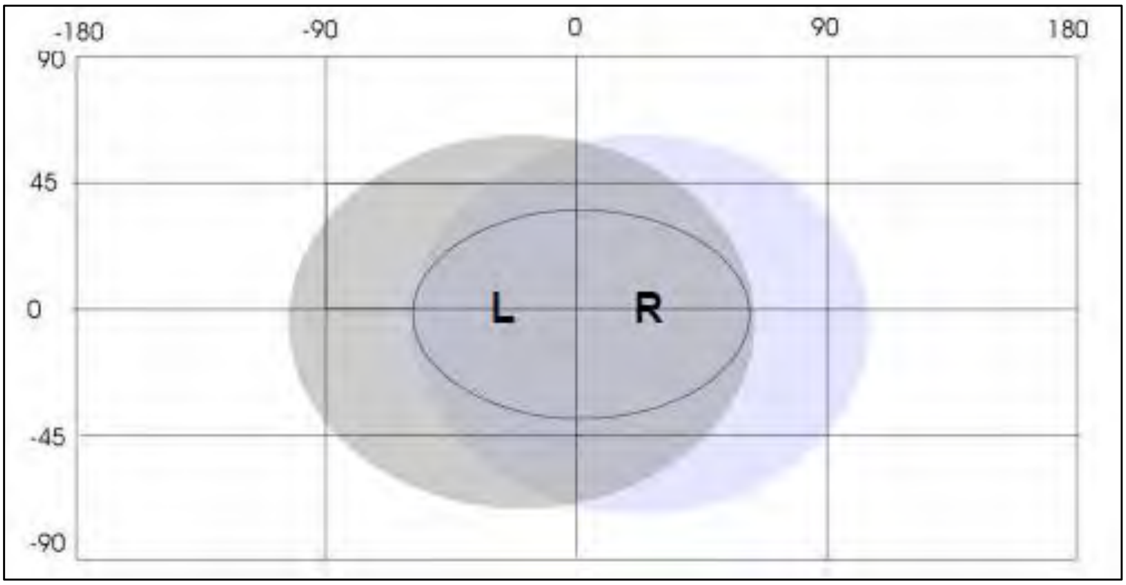


Figure G 21 - Field of view

In Figure G 21, the two shaded regions represent the view from the left eye (L) and the right eye (R) respectively. The darker shaded region represents the region of binocular overlap. The oval in the centre represents the central field of vision.

Research has shown that drivers search for signs or signals towards the centre of the field of vision. Signals, indicators and signs should be positioned at a height and distance from the running line that permits them to be viewed towards the centre of the field of vision. This is because:

a) *As train speed increases, drivers become increasingly dependent on central vision for asset detection. At high speeds, drivers demonstrate a tunnel vision effect and focus only on objects in a field of + 8° from the direction of travel.*
b) *Sensitivity to movement in the peripheral field, even minor distractions can reduce the visibility of the asset if it is viewed towards the peripheral field of vision. The presence of clutter to the sides of the running line can be highly distracting (for example, fence posts, lamp-posts, traffic, or non-signal lights, such as house, compatibility factors or security lights).*

Figure G 22 and Table G 5 identify the radius of an 8o cone at a range of close-up viewing distances from the driver's eye. This shows that, depending on the lateral position of a stop signal, the optimal (normal) train stopping point could be as far as 25 m back from the signal to ensure that it is sufficiently prominent.

The dimensions quoted in Table G 5 assume that the driver is looking straight ahead. Where driver-only operation (DOO) applies, the drivers' line of sight at the time of starting the train is influenced by the location of DOO monitors and mirrors. In this case it may be appropriate to provide supplementary information alongside the monitors or mirrors using one of the following:

a) A co-acting signal.

b) A miniature banner repeater indicator.

c) A right away indicator.

d) A sign to remind the driver to check the signal aspect.

In order to prevent misreading by trains on adjacent lines, the co-acting signal or miniature banner repeater may be configured so that the aspect or indication is presented only when a train is at the platform to which it applies.

'Car stop' signs should be positioned so that the relevant platform starting signals and / or indicators can be seen in the driver's central field of vision.

If possible, clutter and non-signal lights in a driver's field of view should be screened off or removed so that they do not cause distraction.

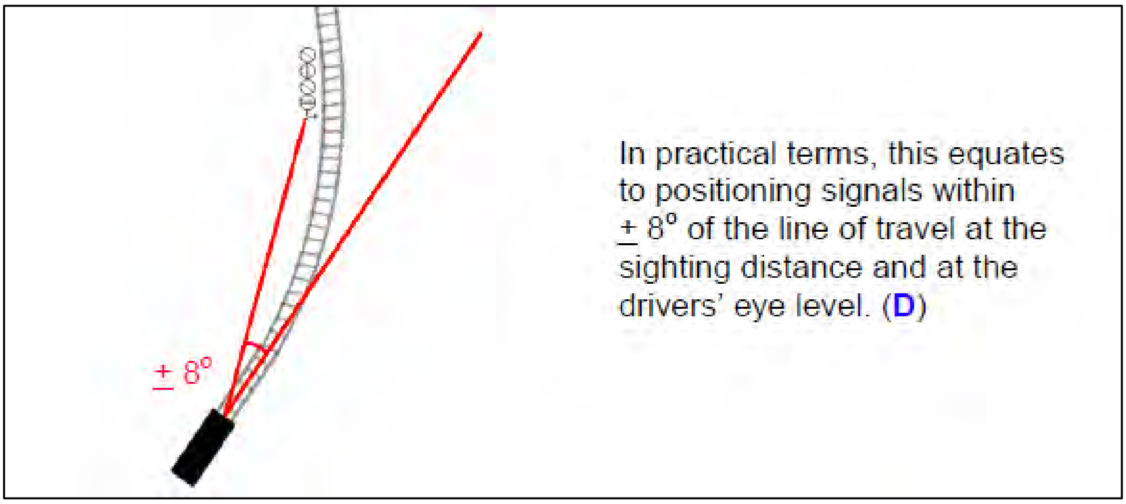


Figure G 22 - Signal positioning

'A' (m)	'B' (m)	Typical display positions
5	*0.70*	-
6	*0.84*	-
7	*0.98*	-
8	*1.12*	-
9	*1.26*	-
10	*1.41*	-
11	*1.55*	-
12	*1.69*	-
13	*1.83*	-
14	*1.97*	-
15	*2.11*	*A stop aspect positioned 3.3 m above rail level and 2.1 m from the left hand rail is within the 8° cone at 15.44 m in front of the driver*
16	*2.25*	-
17	*2.39*	-
18	*2.53*	*A stop aspect positioned 5.1 m above rail level and 0.9 m from the left hand rail is within the 8° cone at 17.93 m in front of the driver*
19	*2.67*	-
20	*2.81*	-
21	*2.95*	-
22	*3.09*	-
23	*3.23*	-
24	*3.37*	-
25	*3.51*	*A stop aspect positioned 3.3 m above rail level and 2.1 m from the right hand rail is within the 8° cone at 25.46 m in front of the driver*

Table G 5 – 8° cone angle co-ordinates for close-up viewing

The distance at which the 8° cone along the track is initiated is dependent on the minimum reading time and distance which is associated to the speed of trains along the track. This is discussed below.

Determining the Assessed Minimum Reading Time

The extract below is taken from section B5 (pages 8-9) of the 'Guidance on Signal Positioning and Visibility' which details the required minimum reading time for a train driver when approaching a signal.

'B5.2.2 Determining the assessed minimum reading time

GE/RT8037

The assessed minimum reading time shall be no less than eight seconds travelling time before the signal.

The assessed minimum reading time shall be greater than eight seconds where there is an increased likelihood of misread or failure to observe. Circumstances where this applies include, but are not necessarily limited to, the following:

- *a) the time taken to identify the signal is longer (for example, because the signal being viewed is one of a number of signals on a gantry, or because the signal is viewed against a complex background)*
- *b) the time taken to interpret the information presented by the signal is longer (for example, because the signal is capable of presenting route information for a complex layout ahead)*
- *c) there is a risk that the need to perform other duties could cause distraction from viewing the signal correctly (for example, the observance of lineside signs, a station stop between the caution and stop signals, or DOO (P) duties)*
- *d) the control of the train speed is influenced by other factors (for example, anticipation of the signal aspect changing).*

The assessed minimum reading time shall be determined using a structured format approved by the infrastructure controller.'

The distance at which a signal should be clearly viewable is determined by the maximum speed of the trains along the track. If there are multiple signals present at a location then an additional 0.2 seconds reading time is added to the overall viewing time.

Signal Design and Lighting System

Many railway signals are now LED lights and not filament (incandescent) bulbs. The benefits of an LED signal over a filament bulb signal with respect to possible phantom aspect illuminations are as follows:

- An LED railway signal produces a more intense light making them more visible to approaching trains when compared to the traditional filament bulb technology[23];

[23] Source: Wayside LED Signals – Why it's Harder than it Looks, Bill Petit.

- No reflective mirror is present within the LED signal itself unlike a filament bulb. The presence of the reflective surfaces greatly increases the likelihood of incoming light being reflecting out making the signal appear illuminated.

Many LED signal manufacturers[24,25,26] claim that LED signal lights significantly reduce or completely remove the likelihood of a phantom aspect illumination occurring.

[24] Source: http://www.unipartdorman.co.uk/assets/unipart_dorman_rail_brochure.pdf. (Last accessed 21.02.18).
[25] Source: http://www.vmstech.co.uk/downloads/Rail.pdf. (Last accessed 21.02.18).
[26] Source: Siemens, Sigmaguard LED Tri-Colour L Signal – LED Signal Technology at Incandescent Prices. Datasheet 1A-23. (Last accessed 22.02.18).

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

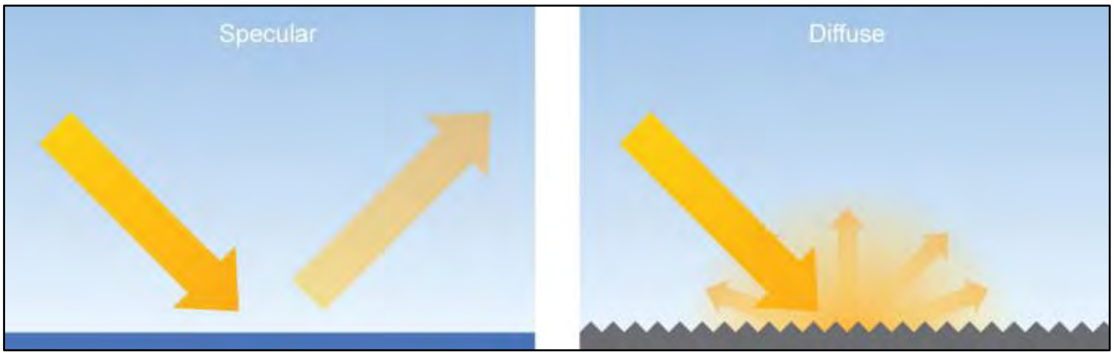
Overview

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

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, taken from the FAA guidance[27], 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

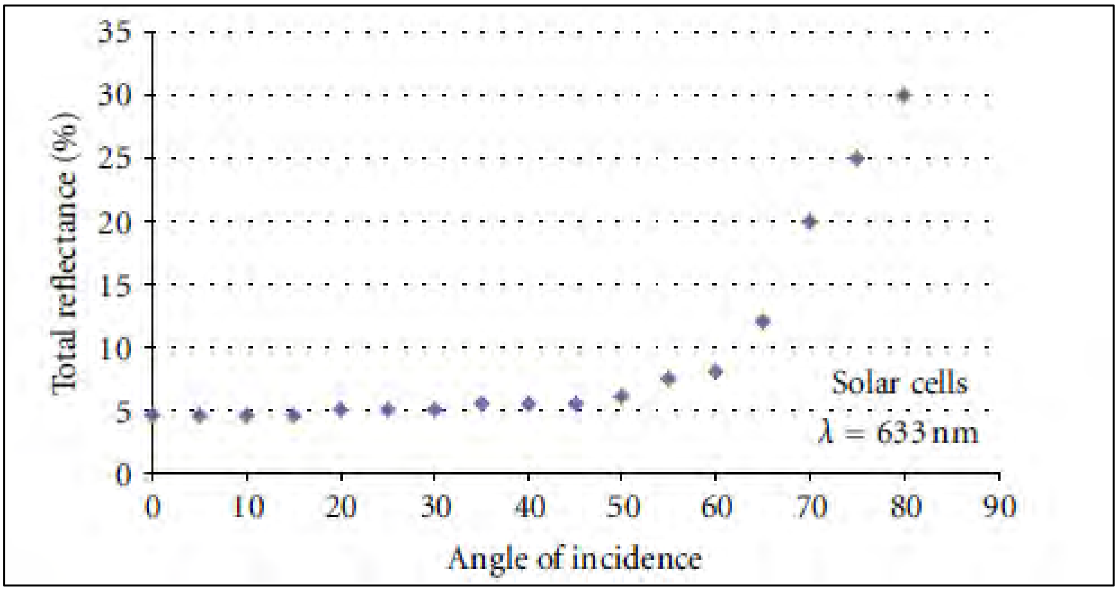
[27]Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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*[28]". 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 below.



Total reflectance % when compared to angle of incidence

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.

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[28] 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

FAA Guidance – "Technical Guidance for Evaluating Selected Solar Technologies on Airports"[29]

The 2010 FAA Guidance 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 below.

Surface	Approximate Percentage of Light Reflected[30]
Snow	80
White Concrete	77
Bare Aluminium	74
Vegetation	50
Bare Soil	30
Wood Shingle	17
Water	5
Solar Panels	5
Black Asphalt	2

Relative reflectivity of various surfaces

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

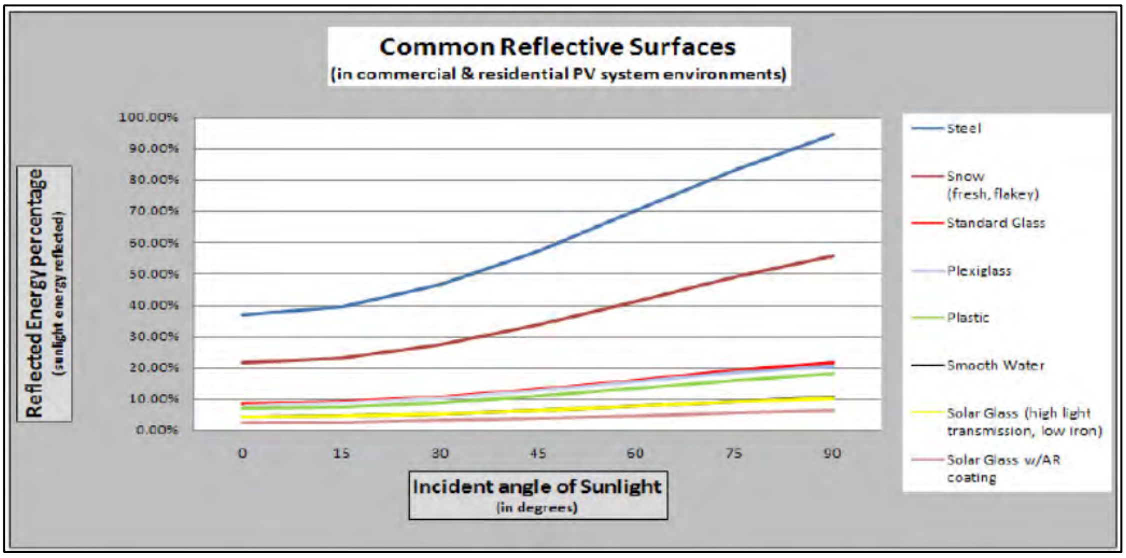
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

[29] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.
[30] Extrapolated data, baseline of 1,000 W/m^2 for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification[31] to '*increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment*'.

The figure presented below shows the relative reflectivity of solar panels compared to other natural and manmade materials including smooth water, standard glass and steel.



Common reflective surfaces

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 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.

[31] Source: 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 following is true at the location of the solar development:

- The Sun is at its highest around midday and is to the south at this time.
- The Sun rises highest on 21 June (longest day).
- On 21 December, the maximum elevation reached by the Sun is at its lowest (shortest day).

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector.

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

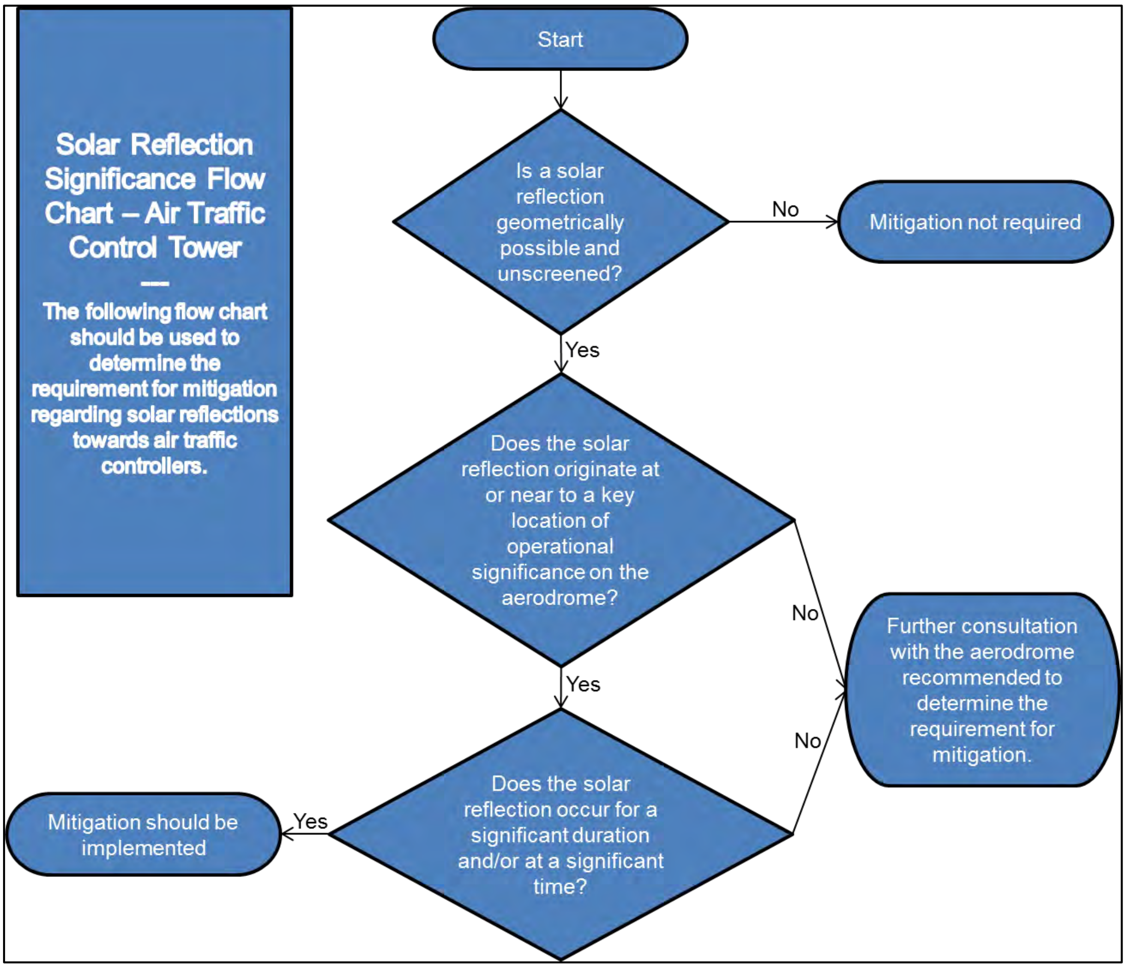
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	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.	No mitigation required.
Moderate	A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case.	Whilst the impact may be acceptable, consultation and/or further analysis should be undertaken to determine the requirement for mitigation.
Major	A solar reflection is geometrically possible and visible under conditions that will produce a significant impact. Mitigation and consultation is recommended.	Mitigation will be required if the proposed solar development is to proceed.

Impact significance definition

Impact Significance Determination for ATC Tower

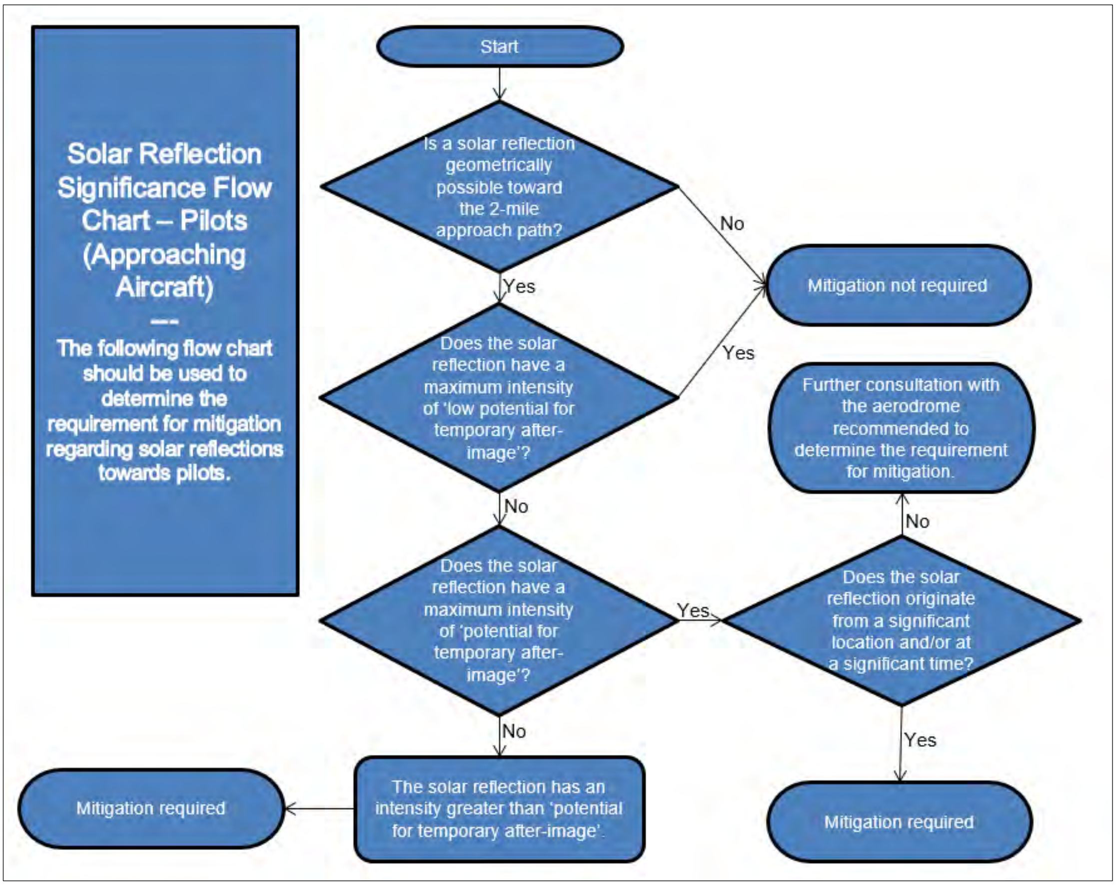
The charts relate to the determining the potential impact upon the ATC Tower.



ATC Tower mitigation requirement flow chart

Impact Significance Determination for Approaching Aircraft

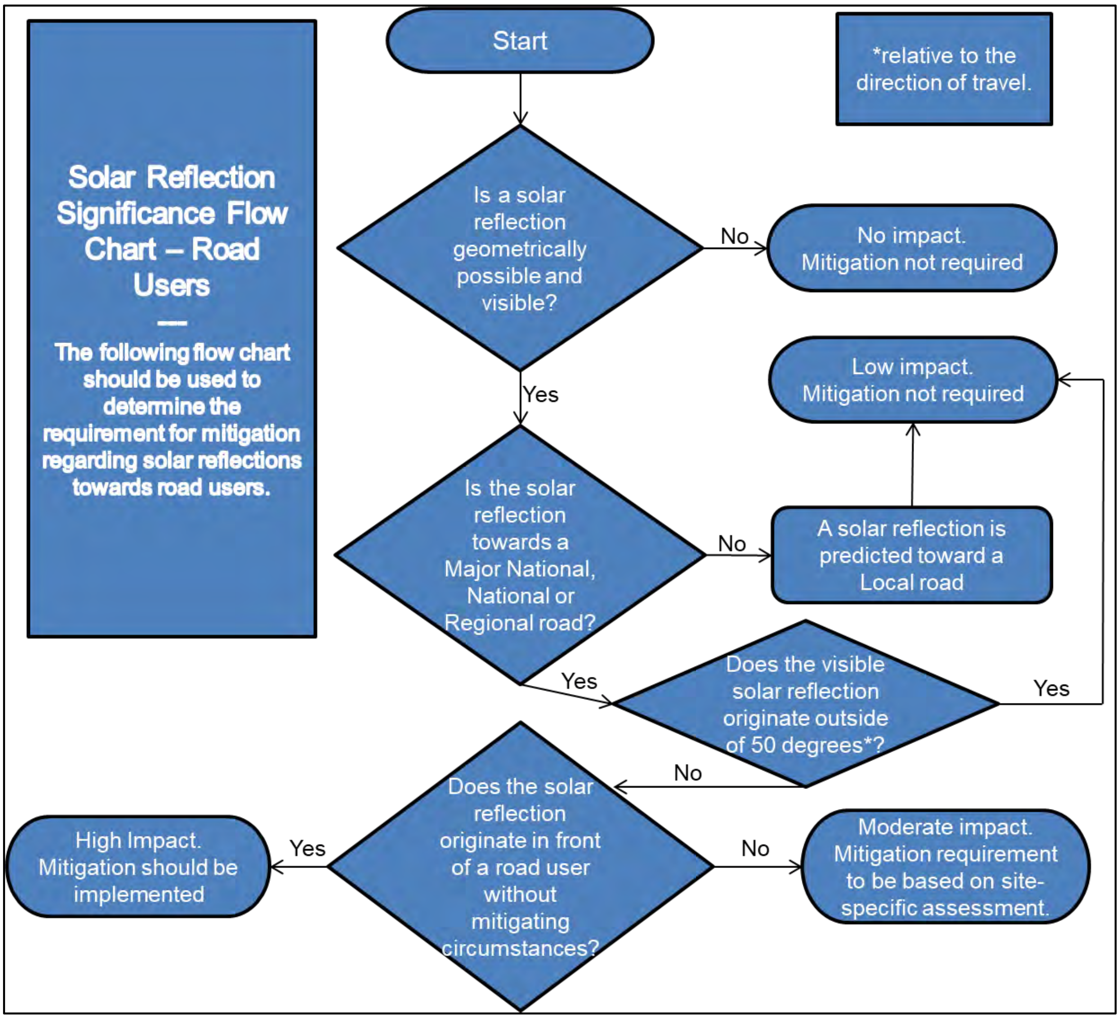
The charts relate to the determining the potential impact upon approaching aircraft.



Approaching aircraft receptor mitigation requirement flow chart

Impact Significance Determination for Road Receptors

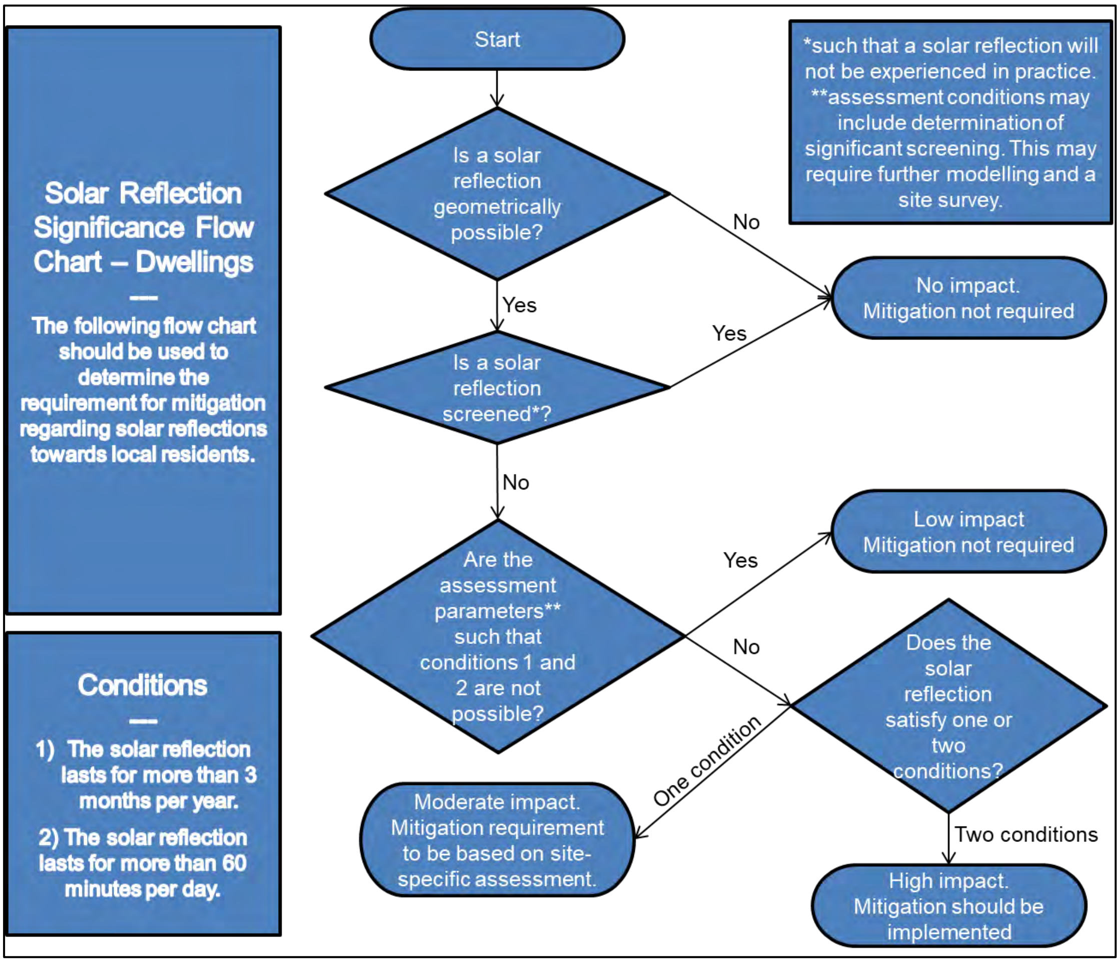
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road user impact significance flow chart

Impact Significance Determination for Dwelling Receptors

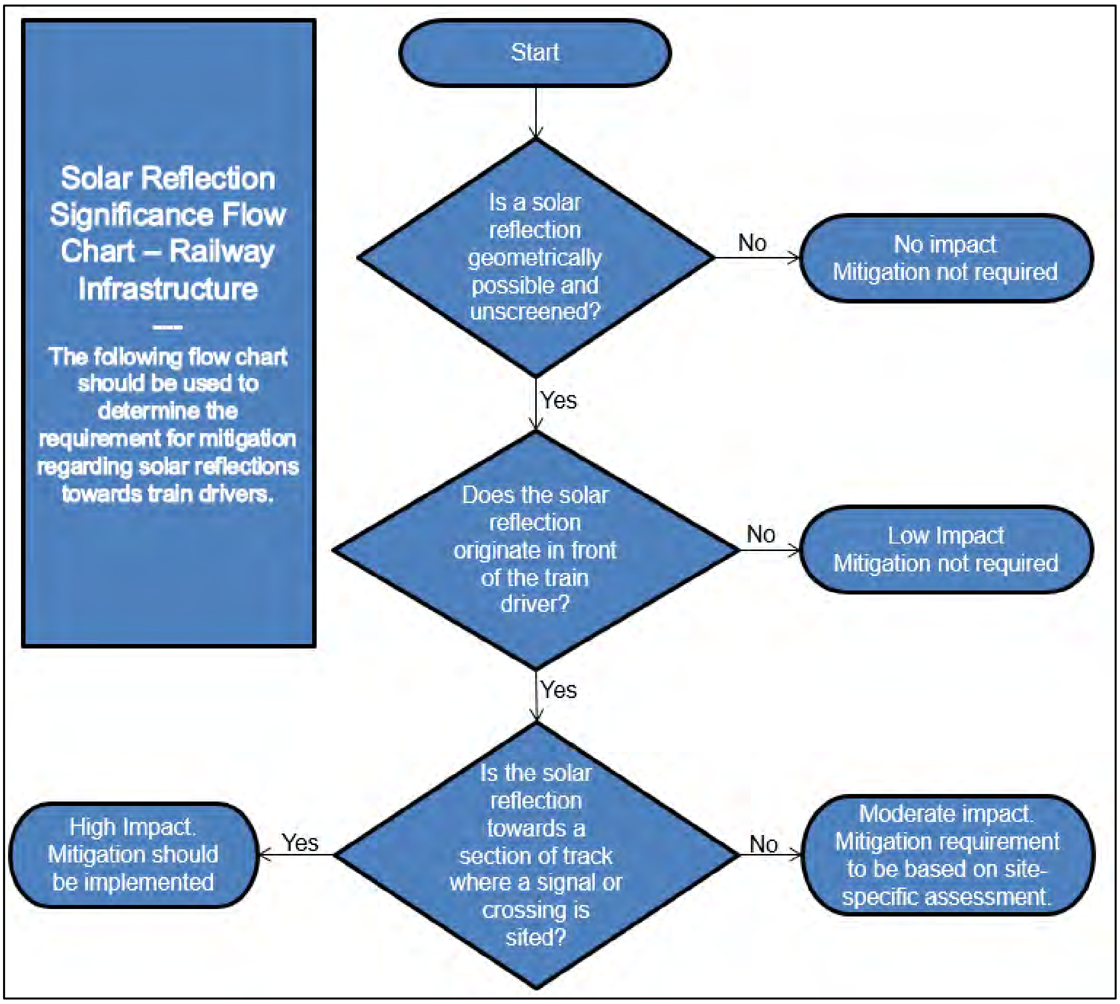
The flow chart presented below has been followed when determining the mitigation requirement for dwelling receptors.



Dwelling impact significance flow chart

Impact Significance Determination for Railway Receptors

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



Train driver impact significance flow chart

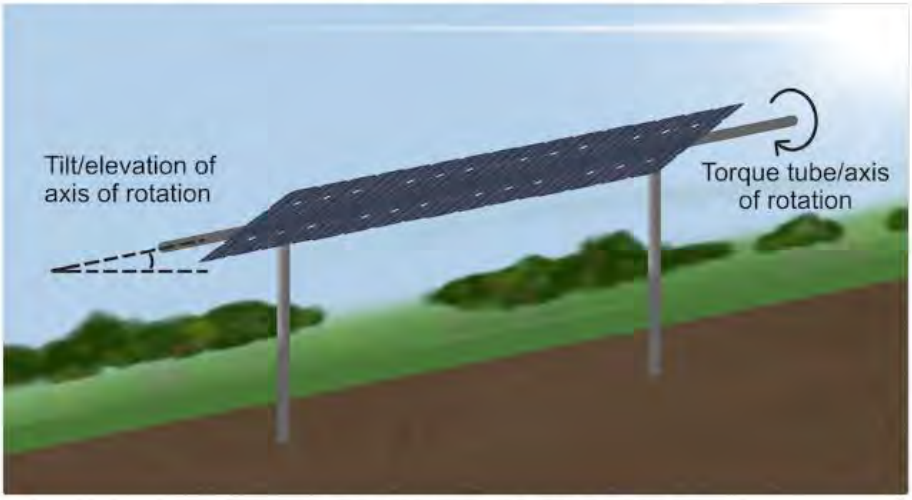
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

Forge Reflection Calculations Methodology

Extracts taken from the Forge Solar Model.

Tracking System Parameters

Single-axis module tracking systems are described by a unique set of parameters. These angular inputs model the tracking axis, rotation range and backtracking behavior. Dual-axis module tracking systems are assumed to track the sun at all times.



Single-axis tracking system with torque tube tilted due to geography

Tilt of tracking axis (°)
Tilt above flat ground of axis over which panels rotate (e.g. torque tube). System on flat, level ground would have axis tilt of 0°.

Orientation of tracking axis (°)
Azimuthal angle of axis over which panels rotate. Angle represents the facing of the axis and system. For example, typical tracking system in northern hemisphere has tracking axis oriented north-south with an orientation of 180°, allowing panels to rotate east-west with potential south-facing tilt. Typical tracking system in southern hemisphere runs south-north with axis orientation of 0°, yielding east-west rotation with potential north-facing tilt.

Offset angle of module (°)
Additional tilt angle of PV module elevated above tracking axis/torque tube. Offset angle is measured from the torque tube.

Maximum tracking angle (°)
Maximum angle of rotation of tracking system in one direction. For example, a typical system with a 120° range of rotation has a *max tracking angle* of 60° (east/west).

Resting angle (°)
Angle of rotation of panels when sun is outside tracking range. Used to model backtracking. Panels will revert to the position described by this rotation angle at all times when the sun is outside the rotation range. Setting this equal to the *maximum tracking angle* implies the panels do not backtrack.

ForgeSolar utilizes a simplified model of backtracking which assumes panels instantaneously revert to the *resting angle* whenever the sun is outside the rotation range. For example, panels with *max tracking angle* of 60° and *resting angle* of 0° would lie flat from sunrise until the sun enters the rotation range, and immediately after the sun leaves the rotation range until sunset daily.

Tracking System Parameters

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Forge's Sandia National Laboratories' (SGHAT) Model[32]

Summary of assumptions and abstractions required by the SGHAT/ForgeSolar analysis methodology

1. Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
2. Result data files and plots are now retained for two years after analysis completion. Files should be downloaded and saved if additional persistence is required.
3. The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.
4. Several calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare. This primarily affects analyses of path receptors.
5. Random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including ATCTs. Note that the SGHAT/ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.
6. The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
7. The algorithm assumes that the PV array is aligned with a plane defined by the total heights of the coordinates outlined in the Google map. For more accuracy, the user should perform runs using minimum and maximum values for the vertex heights to bound the height of the plane containing the solar array. Doing so will expand the range of observed solar glare when compared to results using a single height value.
8. The algorithm does not consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.
9. The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.
10. The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.
11. The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
12. Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
13. Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
14. Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
15. PV array tracking assumes the modules move instantly when tracking the sun, and when reverting to the rest position.

[32] https://www.forgesolar.com/help/#assumptions

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Dwelling Receptor Data

The dwelling receptor data is presented in the table below.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-1.07808	53.75427	101	-1.02404	53.71281
2	-1.07765	53.75420	102	-1.02369	53.71244
3	-1.07747	53.75418	103	-1.02345	53.71221
4	-1.07729	53.75397	104	-1.02380	53.71189
5	-1.07642	53.75427	105	-1.02412	53.71181
6	-1.07550	53.75329	106	-1.02464	53.71191
7	-1.07489	53.75384	107	-1.02532	53.71187
8	-1.07387	53.75414	108	-1.02578	53.71164
9	-1.07419	53.74856	109	-1.02577	53.71127
10	-1.07382	53.74809	110	-1.02544	53.71094
11	-1.07294	53.74988	111	-1.02529	53.71073
12	-1.05824	53.75537	112	-1.02519	53.71029
13	-1.05810	53.75498	113	-1.02510	53.70992
14	-1.06133	53.74900	114	-1.02519	53.70952
15	-1.06088	53.74907	115	-1.02434	53.70925
16	-1.05483	53.75150	116	-1.02545	53.70892
17	-1.05462	53.74716	117	-1.02554	53.70864
18	-1.04447	53.74113	118	-1.02429	53.70819
19	-1.02829	53.73867	119	-1.02404	53.70790
20	-1.02891	53.73852	120	-1.02441	53.70767
21	-1.02892	53.73828	121	-1.02436	53.70750
22	-1.03840	53.73511	122	-1.02438	53.70724

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
23	-1.03771	53.73447	123	-1.02440	53.70702
24	-1.03656	53.73276	124	-1.02388	53.70692
25	-1.03575	53.72990	125	-1.02382	53.70671
26	-1.03565	53.72976	126	-1.02948	53.70530
27	-1.03543	53.72969	127	-1.03418	53.70566
28	-1.03512	53.72967	128	-1.03485	53.70548
29	-1.03569	53.72880	129	-1.03581	53.70510
30	-1.03502	53.72886	130	-1.03989	53.70434
31	-1.03439	53.72908	131	-1.04085	53.70471
32	-1.03438	53.73014	132	-1.04142	53.70314
33	-1.03448	53.73006	133	-1.04193	53.70295
34	-1.03434	53.72988	134	-1.04177	53.70576
35	-1.03415	53.72963	135	-1.02661	53.71561
36	-1.03271	53.72874	136	-1.03766	53.71202
37	-1.03212	53.72851	137	-1.05176	53.70799
38	-1.03177	53.72840	138	-1.04931	53.71133
39	-1.03149	53.72824	139	-1.05002	53.71154
40	-1.03082	53.72795	140	-1.05214	53.71186
41	-1.03007	53.72769	141	-1.05261	53.71348
42	-1.02874	53.72740	142	-1.05368	53.71463
43	-1.02749	53.72775	143	-1.05353	53.71498
44	-1.02697	53.72756	144	-1.05140	53.71544
45	-1.02631	53.72740	145	-1.05101	53.71567
46	-1.02577	53.72708	146	-1.05064	53.71591
47	-1.02518	53.72685	147	-1.05100	53.71609

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
48	-1.02441	53.72676	148	-1.05436	53.71660
49	-1.02463	53.72626	149	-1.05625	53.71655
50	-1.02409	53.72613	150	-1.05758	53.71634
51	-1.02370	53.72656	151	-1.05760	53.71477
52	-1.02326	53.72652	152	-1.05774	53.71316
53	-1.02280	53.72653	153	-1.05352	53.71108
54	-1.02236	53.72650	154	-1.05516	53.70860
55	-1.01829	53.73164	155	-1.05696	53.70885
56	-1.01756	53.73118	156	-1.05833	53.70930
57	-1.02149	53.72645	157	-1.05937	53.70969
58	-1.02143	53.72615	158	-1.06041	53.71001
59	-1.02174	53.72579	159	-1.06214	53.71020
60	-1.02166	53.72551	160	-1.06151	53.71055
61	-1.02111	53.72517	161	-1.06967	53.71212
62	-1.02277	53.72469	162	-1.07027	53.71222
63	-1.02189	53.72423	163	-1.07158	53.71244
64	-1.02175	53.72438	164	-1.07202	53.71298
65	-1.02127	53.72417	165	-1.07188	53.71351
66	-1.02074	53.72393	166	-1.07237	53.71299
67	-1.02029	53.72367	167	-1.07282	53.71271
68	-1.02001	53.72380	168	-1.07332	53.71288
69	-1.01934	53.72398	169	-1.07372	53.71301
70	-1.01898	53.72433	170	-1.07415	53.71315
71	-1.01766	53.72548	171	-1.07457	53.71341

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
72	-1.01719	53.72544	172	-1.07501	53.71348
73	-1.01675	53.72443	173	-1.07544	53.71363
74	-1.01664	53.72426	174	-1.07642	53.71386
75	-1.01618	53.72427	175	-1.07675	53.71395
76	-1.01617	53.72395	176	-1.07708	53.71412
77	-1.01628	53.72383	177	-1.07743	53.71426
78	-1.02257	53.71772	178	-1.07807	53.71444
79	-1.01482	53.71581	179	-1.07858	53.71460
80	-1.01733	53.71521	180	-1.07901	53.71475
81	-1.01511	53.71380	181	-1.07959	53.71481
82	-1.01552	53.71380	182	-1.08038	53.71488
83	-1.01605	53.71380	183	-1.07896	53.71599
84	-1.01652	53.71378	184	-1.08263	53.71626
85	-1.01685	53.71379	185	-1.08209	53.71703
86	-1.01732	53.71368	186	-1.08327	53.71796
87	-1.01916	53.71354	187	-1.08354	53.71858
88	-1.01998	53.71245	188	-1.08226	53.71888
89	-1.02041	53.71242	189	-1.08179	53.71964
90	-1.02069	53.71244	190	-1.05536	53.72527
91	-1.02088	53.71202	191	-1.05479	53.72593
92	-1.02118	53.71201	192	-1.04598	53.72454
93	-1.02135	53.71312	193	-1.04700	53.73188
94	-1.02180	53.71312	194	-1.05632	53.73836
95	-1.02208	53.71312	195	-1.05529	53.73968

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
96	-1.02241	53.71312	196	-1.07031	53.73579
97	-1.02269	53.71312	197	-1.07860	53.74326
98	-1.02295	53.71257	198	-1.07856	53.74303
99	-1.02348	53.71311	199	-1.07699	53.74497
100	-1.02410	53.71321			

Dwelling receptor data

Road Receptor Data

The road receptor data is presented in the table below.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-1.09173	53.75396	85	-1.01880	53.71844
2	-1.09020	53.75390	86	-1.01892	53.71755
3	-1.08867	53.75380	87	-1.01903	53.71665
4	-1.08721	53.75354	88	-1.01914	53.71575
5	-1.08573	53.75335	89	-1.01928	53.71485
6	-1.08462	53.75397	90	-1.01938	53.71395
7	-1.08352	53.75459	91	-1.01950	53.71305
8	-1.08232	53.75515	92	-1.01960	53.71216
9	-1.08081	53.75500	93	-1.01972	53.71126
10	-1.07937	53.75472	94	-1.01992	53.71037
11	-1.07793	53.75441	95	-1.02034	53.70951
12	-1.07648	53.75414	96	-1.02064	53.70862
13	-1.07513	53.75372	97	-1.02072	53.70779
14	-1.07411	53.75304	98	-1.00898	53.72637
15	-1.07269	53.75272	99	-1.01028	53.72590
16	-1.07124	53.75245	100	-1.01158	53.72543
17	-1.06985	53.75208	101	-1.01287	53.72494

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
18	-1.06885	53.75140	102	-1.01416	53.72446
19	-1.06740	53.75112	103	-1.01544	53.72398
20	-1.06589	53.75099	104	-1.01670	53.72347
21	-1.06443	53.75073	105	-1.01798	53.72298
22	-1.06313	53.75025	106	-1.03283	53.74582
23	-1.06183	53.74978	107	-1.03376	53.74510
24	-1.06033	53.74960	108	-1.03452	53.74432
25	-1.05882	53.74945	109	-1.03528	53.74354
26	-1.05775	53.74881	110	-1.03603	53.74276
27	-1.05627	53.74862	111	-1.03679	53.74197
28	-1.05474	53.74856	112	-1.03752	53.74118
29	-1.05322	53.74850	113	-1.03827	53.74040
30	-1.05188	53.74846	114	-1.03905	53.73963
31	-1.06028	53.75797	115	-1.03972	53.73882
32	-1.05957	53.75718	116	-1.04034	53.73801
33	-1.05885	53.75638	117	-1.04097	53.73718
34	-1.05815	53.75559	118	-1.09193	53.71860
35	-1.05743	53.75479	119	-1.09044	53.71844
36	-1.05671	53.75399	120	-1.08895	53.71826
37	-1.05599	53.75319	121	-1.08747	53.71806
38	-1.05529	53.75239	122	-1.08596	53.71794
39	-1.05457	53.75160	123	-1.08445	53.71791
40	-1.05384	53.75080	124	-1.08300	53.71763
41	-1.05313	53.75001	125	-1.08251	53.71678
42	-1.05241	53.74922	126	-1.08312	53.71596
43	-1.05168	53.74843	127	-1.08264	53.71511

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
44	-1.05098	53.74763	128	-1.08129	53.71471
45	-1.05026	53.74684	129	-1.07977	53.71463
46	-1.04955	53.74605	130	-1.07833	53.71436
47	-1.04882	53.74525	131	-1.07703	53.71388
48	-1.04811	53.74446	132	-1.07570	53.71345
49	-1.04740	53.74366	133	-1.07431	53.71309
50	-1.04667	53.74287	134	-1.07301	53.71262
51	-1.04595	53.74208	135	-1.07159	53.71230
52	-1.04520	53.74130	136	-1.07014	53.71205
53	-1.04450	53.74051	137	-1.06866	53.71181
54	-1.04379	53.73971	138	-1.06718	53.71156
55	-1.04308	53.73892	139	-1.06573	53.71130
56	-1.04237	53.73813	140	-1.06427	53.71107
57	-1.04167	53.73733	141	-1.06282	53.71078
58	-1.04095	53.73653	142	-1.06157	53.71028
59	-1.04024	53.73574	143	-1.06035	53.70974
60	-1.03951	53.73495	144	-1.05900	53.70934
61	-1.03880	53.73417	145	-1.05771	53.70886
62	-1.03807	53.73337	146	-1.05640	53.70843
63	-1.03734	53.73258	148	-1.05505	53.70799
64	-1.03663	53.73179	149	-1.05354	53.70787
65	-1.03589	53.73100	150	-1.05202	53.70780
66	-1.03515	53.73022	151	-1.05055	53.70755
67	-1.03423	53.72950	152	-1.04908	53.70730
68	-1.03295	53.72901	153	-1.04762	53.70706
69	-1.03170	53.72851	156	-1.04618	53.70676

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
70	-1.03043	53.72803	157	-1.04485	53.70632
71	-1.02905	53.72766	158	-1.04349	53.70591
72	-1.02760	53.72739	159	-1.04216	53.70546
73	-1.02620	53.72705	160	-1.04084	53.70503
74	-1.02494	53.72655	161	-1.03950	53.70459
75	-1.02349	53.72627	162	-1.03802	53.70439
76	-1.02218	53.72581	163	-1.03649	53.70445
77	-1.02201	53.72492	164	-1.03513	53.70486
78	-1.02145	53.72408	165	-1.03375	53.70523
79	-1.02034	53.72346	166	-1.03228	53.70547
80	-1.01920	53.72285	167	-1.03078	53.70568
81	-1.01856	53.72203	168	-1.02930	53.70550
82	-1.01851	53.72113	169	-1.02779	53.70564
83	-1.01859	53.72023	170	-1.02630	53.70579
84	-1.01870	53.71934			

Road receptor data

Train Driver Receptor Data

The train driver receptor data is presented in the table below.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-1.07701	53.75316	17	-1.08176	53.73819
2	-1.07730	53.75228	18	-1.08204	53.73731
3	-1.07759	53.75140	19	-1.08232	53.73644
4	-1.07785	53.75052	20	-1.08261	53.73556
5	-1.07814	53.74964	21	-1.02554	53.71613
6	-1.07841	53.74876	22	-1.02423	53.71659
7	-1.07869	53.74787	23	-1.02291	53.71705

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
8	-1.07898	53.74699	24	-1.02159	53.71750
9	-1.07926	53.74611	25	-1.02029	53.71796
10	-1.07954	53.74523	26	-1.01897	53.71841
11	-1.07982	53.74435	27	-1.01766	53.71886
12	-1.08010	53.74347	28	-1.01635	53.71933
13	-1.08036	53.74259	29	-1.01503	53.71978
14	-1.08065	53.74171	30	-1.01372	53.72023
15	-1.08093	53.74083	31	-1.02554	53.71613
16	-1.08121	53.73996			

Train Driver Receptor Data

APPENDIX H – DETAILLED MODELLING RESULTS

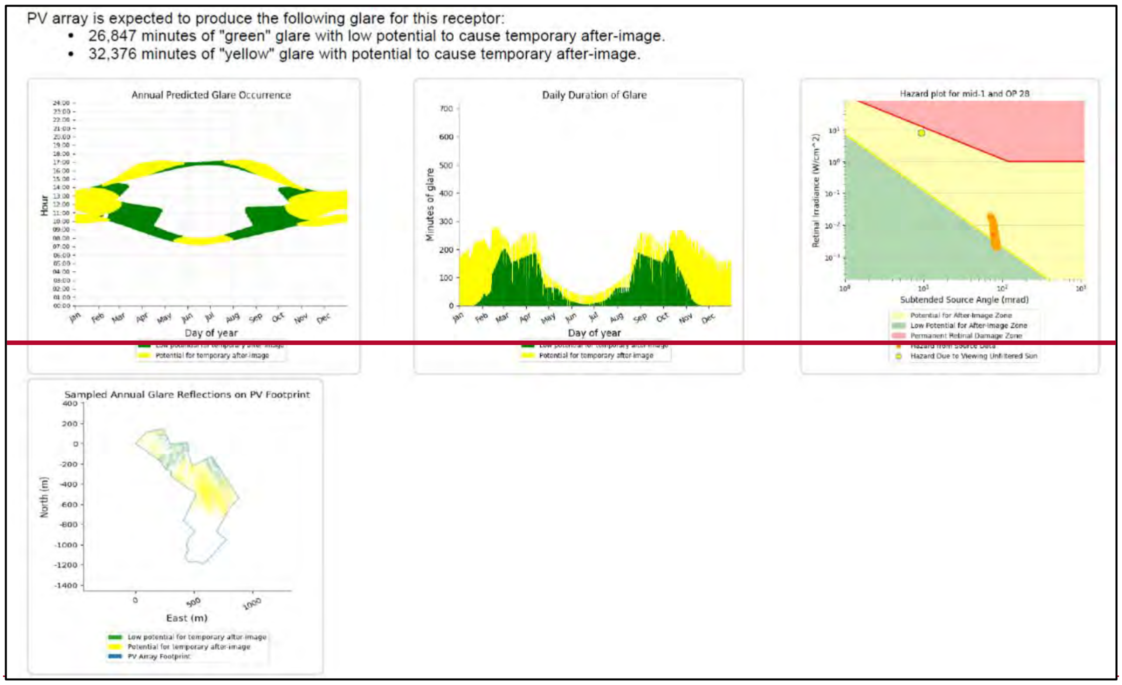
Overview

The output charts are taken from Forge and present relevant information for the receptors in which solar reflections are predicted to be experienced. Each chart shows:

- The reflection date/time graph – top left graph. This relates to reflections from the yellow areas;
- The daily duration of glare – top right image;
- Hazard plot categorising the glare – middle left image;
- The positions along the approach path where glare is received – middle right and bottom right images;
- The reflecting panels – bottom left 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.

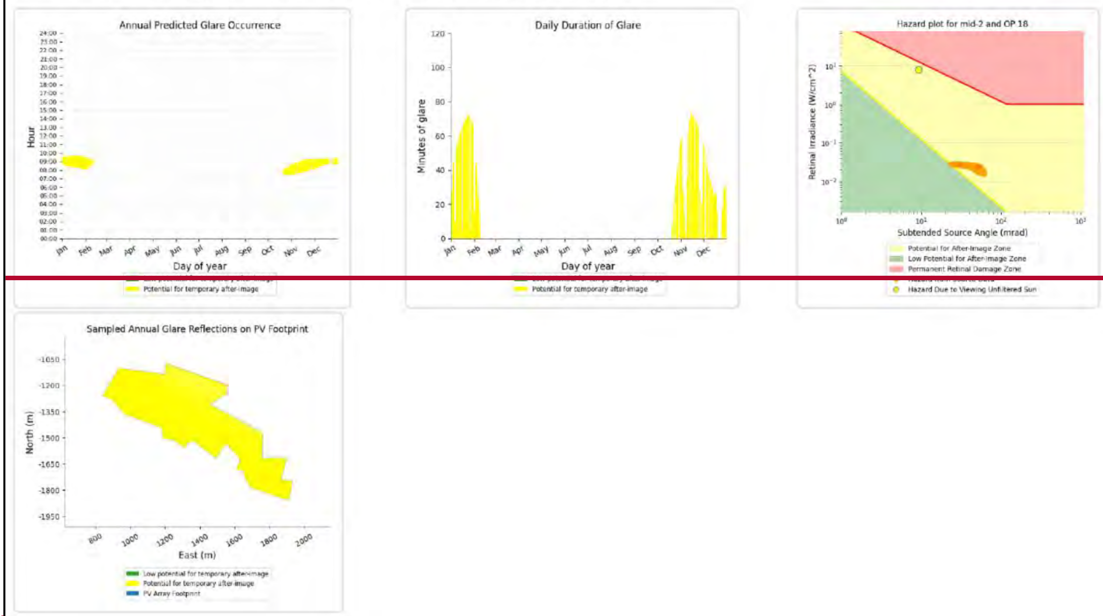
~~The charts below pertain to the splayed approach for runway 33. Modelling outputs for the remaining receptors can be provided upon request.~~

~~**Splayed Approach Path – 33**~~



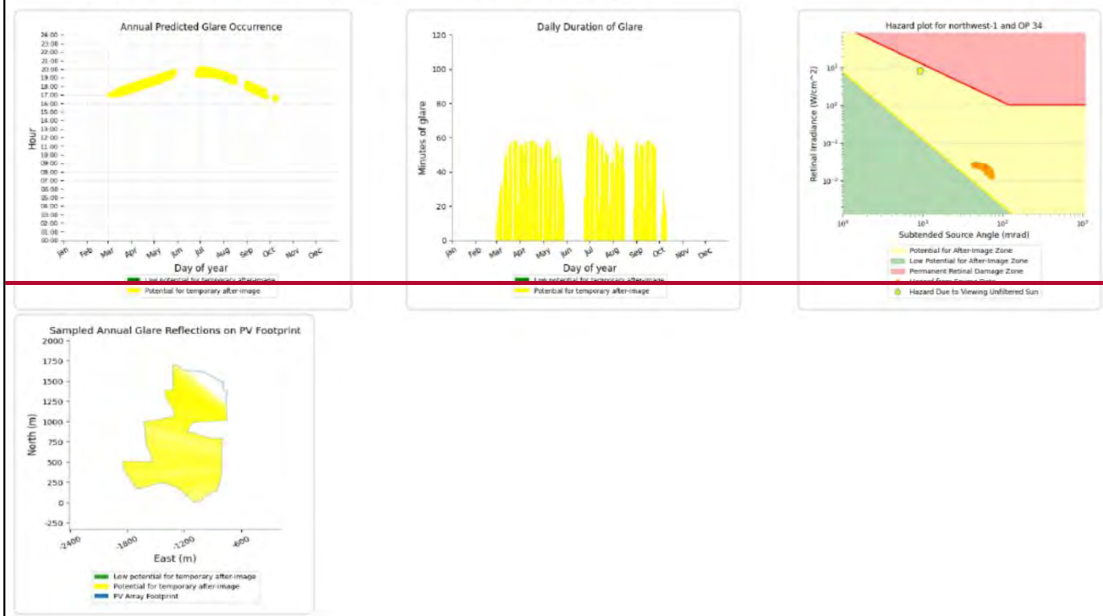
PV array is expected to produce the following glare for this receptor:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 4,067 minutes of "yellow" glare with potential to cause temporary after-image.



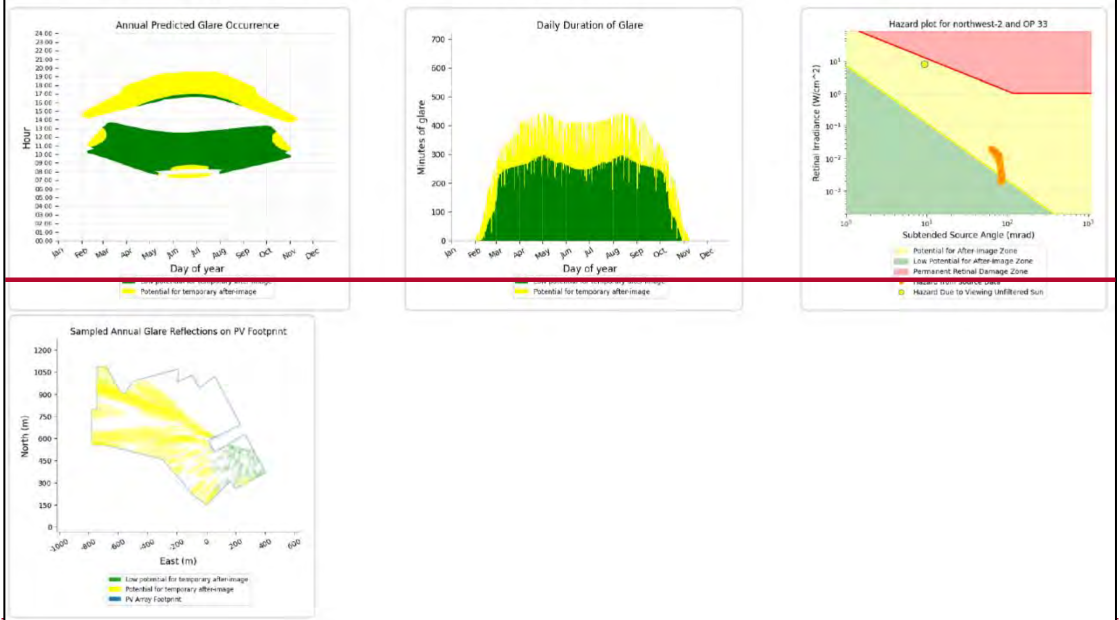
PV array is expected to produce the following glare for this receptor:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 7,608 minutes of "yellow" glare with potential to cause temporary after-image.



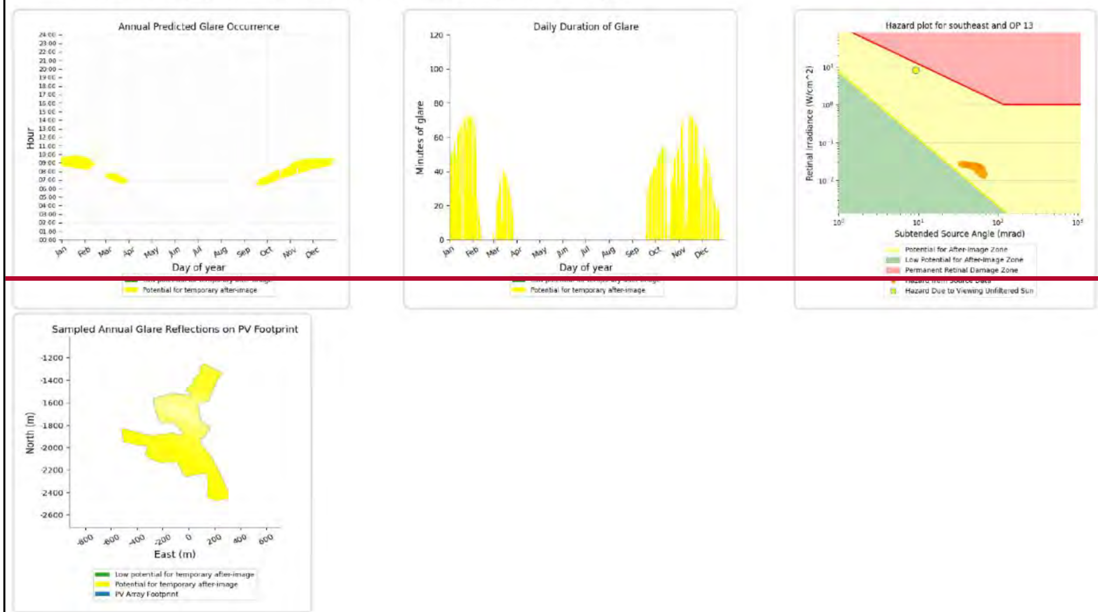
PV array is expected to produce the following glare for this receptor:

- 59,375 minutes of "green" glare with low potential to cause temporary after-image.
- 28,897 minutes of "yellow" glare with potential to cause temporary after-image.



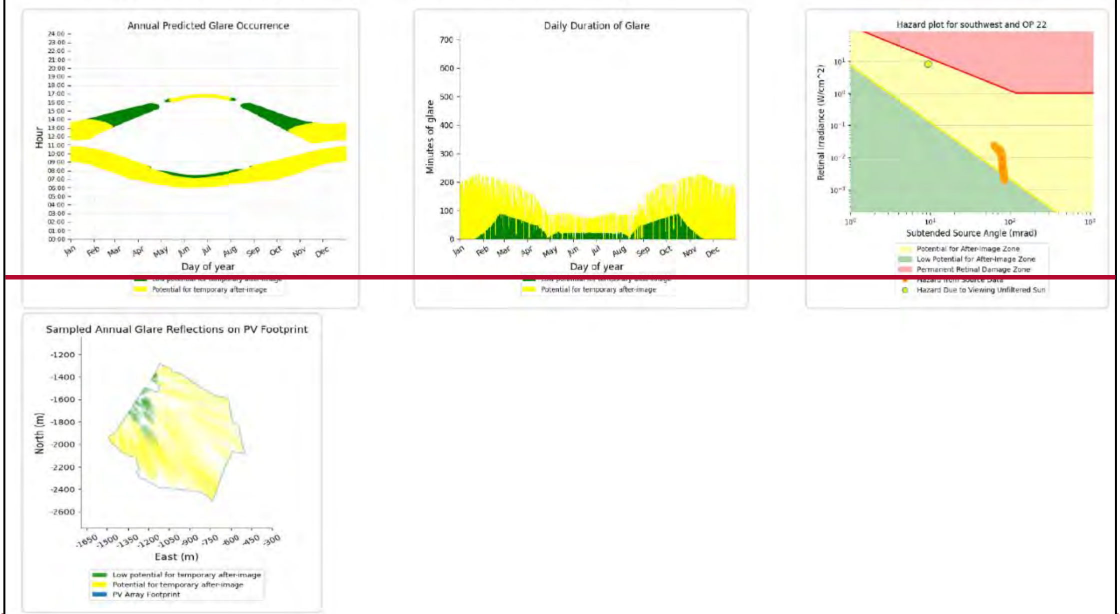
PV array is expected to produce the following glare for this receptor:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 6,009 minutes of "yellow" glare with potential to cause temporary after-image.

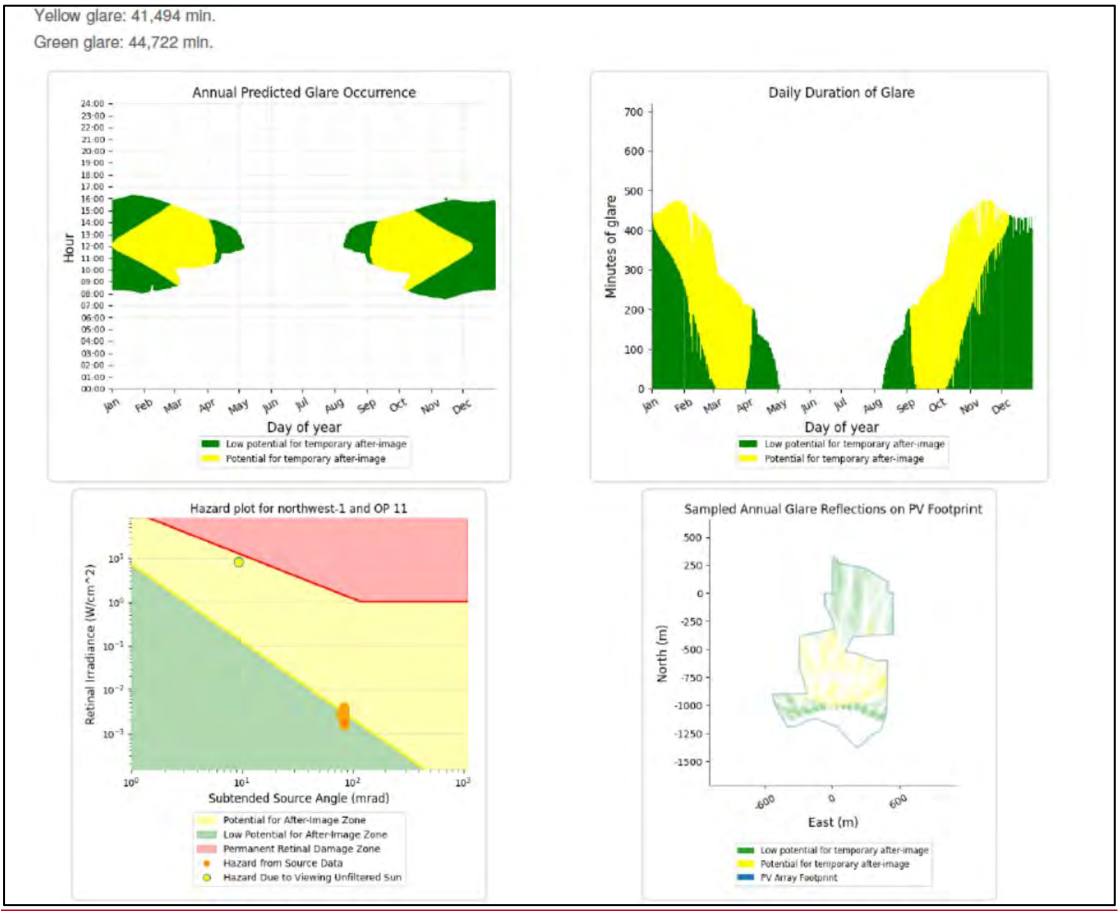


PV array is expected to produce the following glare for this receptor:

- 10,461 minutes of "green" glare with low potential to cause temporary after-image.
- 39,414 minutes of "yellow" glare with potential to cause temporary after-image.



01


Yellow glare: 41,494 min.
Green glare: 44,722 min.
Annual Predicted Glare Occurrence
Hour
Day of year
Low potential for temporary after-image
Potential for temporary after-image
Daily Duration of Glare
Minutes of glare
Day of year
Low potential for temporary after-image
Potential for temporary after-image
Hazard plot for northwest-1 and OP 11
Retinal Irradiance (W/cm^2)
Subtended Source Angle (mrad)
Potential for After-Image Zone
Low Potential for After-Image Zone
Permanent Retinal Damage Zone
Hazard from Source Data
Hazard Due to Viewing Unfiltered Sun
Sampled Annual Glare Reflections on PV Footprint
North (m)
East (m)
Low potential for temporary after-image
Potential for temporary after-image
PV Array Footprint

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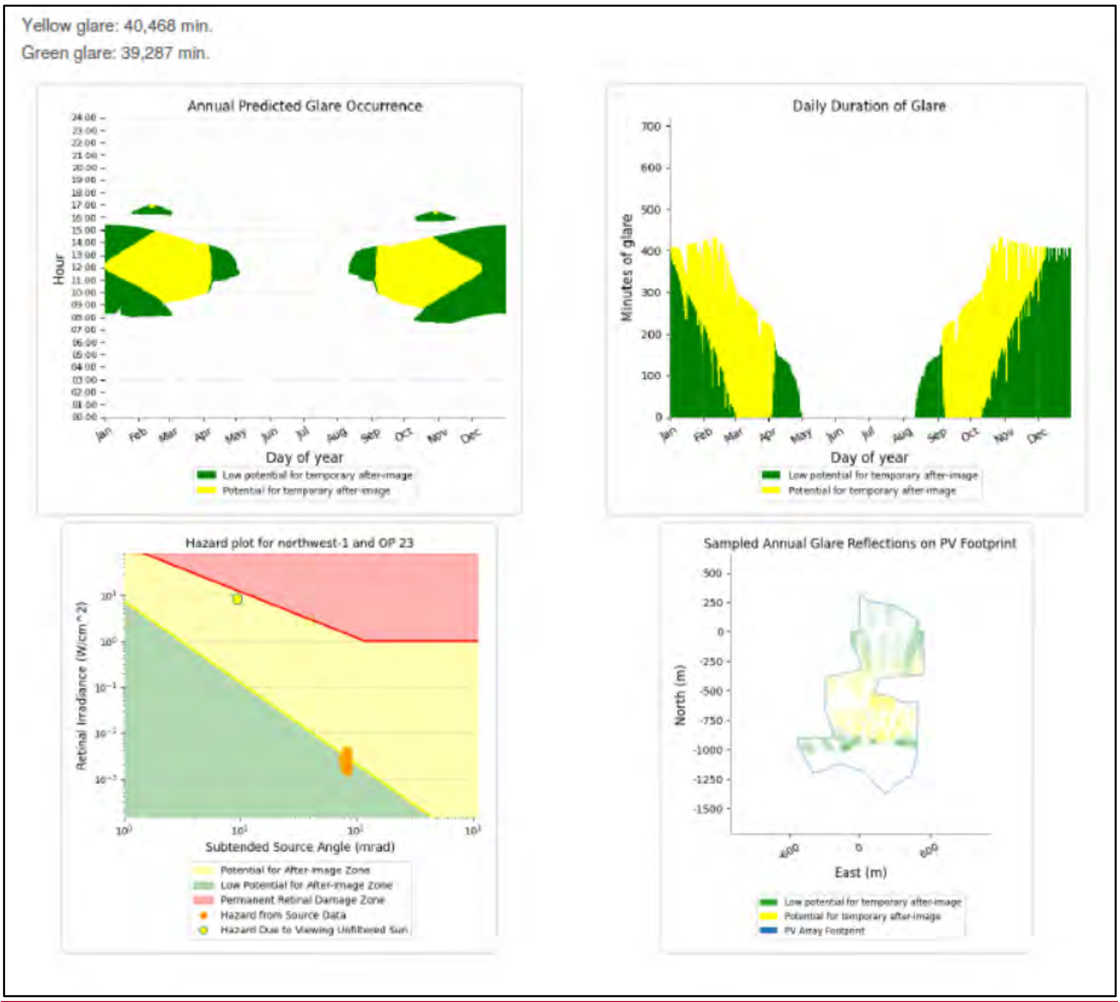
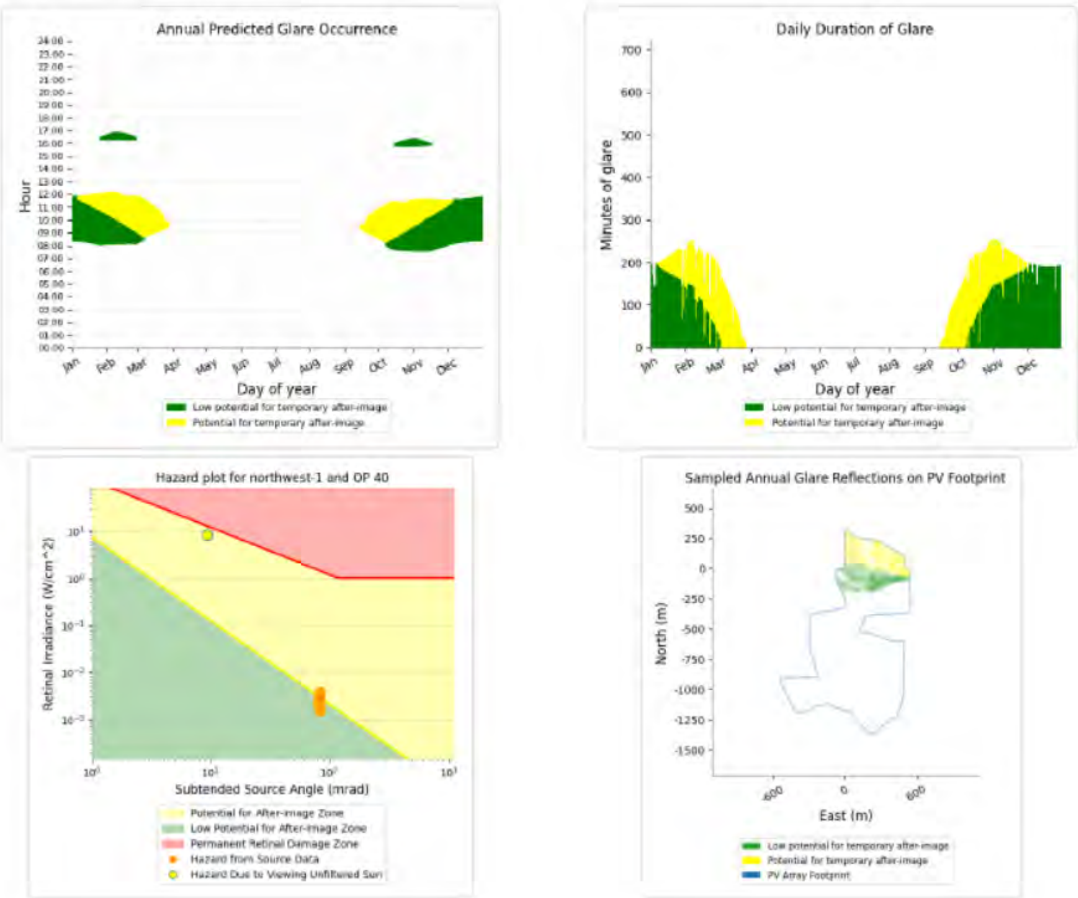

Yellow glare: 40,468 min.
Green glare: 39,287 min.
Annual Predicted Glare Occurrence
Hour
Day of year
Low potential for temporary after-image
Potential for temporary after-image
Daily Duration of Glare
Minutes of glare
Day of year
Low potential for temporary after-image
Potential for temporary after-image
Hazard plot for northwest-1 and OP 23
Retinal Irradiance (W/cm^2)
Subtended Source Angle (mrad)
Potential for After-image Zone
Low Potential for After-image Zone
Permanent Retinal Damage Zone
Hazard from Source Data
Hazard Due to Viewing Unfiltered Sun
Sampled Annual Glare Reflections on PV Footprint
North (m)
East (m)
Low potential for temporary after-image
Potential for temporary after-image
PV Array Footprint

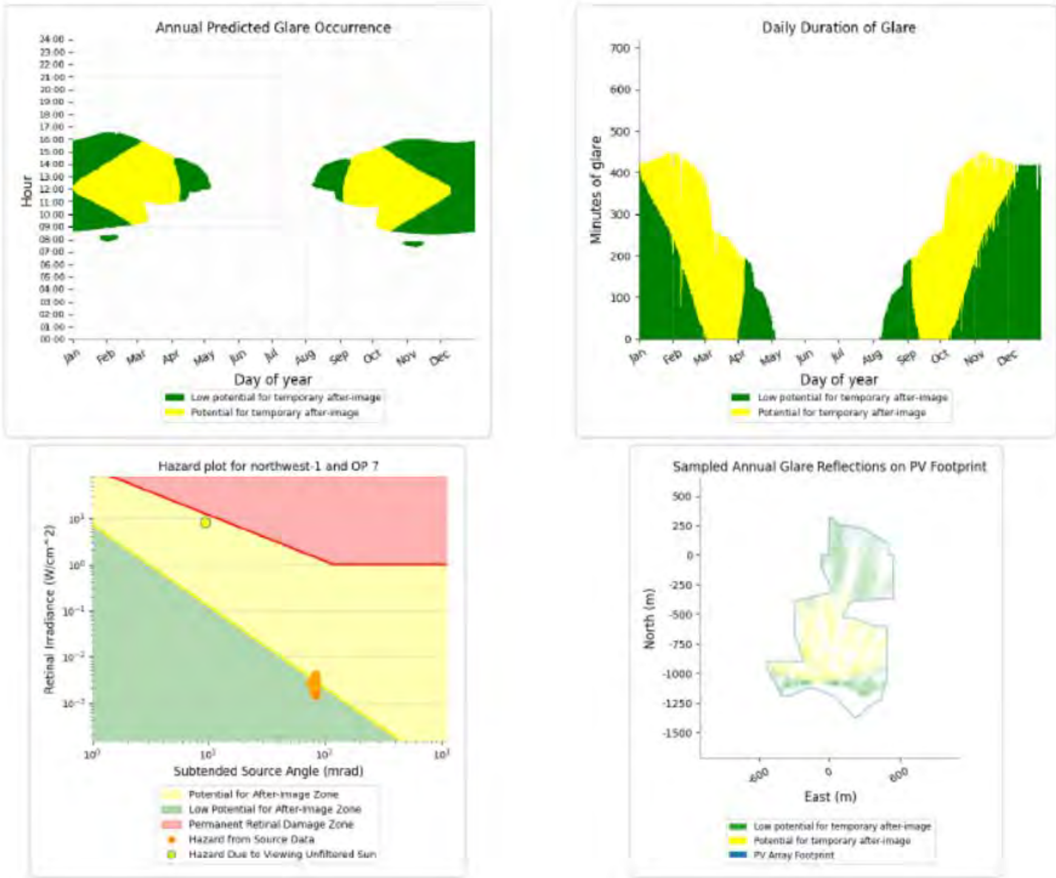
25

Yellow glare: 14,610 min.
Green glare: 20,633 min.



33

Yellow glare: 41,220 min.
Green glare: 43,103 min.



APPENDIX I – GLINT AND GLARE MITIGATION STRATEGY

Overview

Mitigation is recommended for operations at Burn Airfield to reduce the glare to acceptable intensity or reduce the glare to times/durations that can be operationally accommodated. A Glint and Glare Mitigation Strategy will be produced and this will outline a solution that is technically viable to mitigate the predicted significant impacts.

Outline

The Glint and Glare Mitigation Strategy will include:

- Proposed development plan;
- Burn Airfield operational details;
- Explanation mitigation strategy requirement;
- Overview of further modelling results;
- Presentation of viable mitigation solution;
- Glare times;
- Overall conclusions.

Urban & Renewables

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