PAGERPOWER
Urban & Renewables

Independent Review of Glint and Glare Assessment

Proposed Wagga Wagga South Solar Farm at 157 Windmill Road, Bomen, NSW 2650

September, 2020





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ADMINISTRATION PAGE

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Issue	Date	Detail of Changes
1	September, 2020	Initial issue
2	October, 2020	Second issue – following further confirmation of visibility analysis

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EXECUTIVE SUMMARY

Report Purpose

This report concerns the proposed Wagga Wagga South Solar Farm at 157 Windmill Road, Bomen, NSW 2650. The Wagga Wagga City Council has deferred determination[1] of the application due to the requirement for further information pertaining to glint and glare impacts associated with the proposal. Specifically, the council required the following be addressed by a suitably qualified expert whose appointment was to be endorsed by the council:

1. The veracity of the existing information provided by the Applicant regarding visual impact and the potential for the development to create glare impacts on the surrounding community, including commenting on the underlying assumptions.
2. Verify that the development footprint is appropriate to prevent adverse visual or glare impacts or recommend modifications to the development footprint.
3. Advise on appropriate rectification actions to mitigate potential glare generation during operations including materials, tracking options.
4. Recommend parameters to monitor the performance of the development with regard to glare impacts.

Pager Power has been selected to carry out the above.

Summary of Findings

The content of the Visual Amenity Assessment in the context of glint and glare appears professional, transparent, and technically sound. However, additional steps could have been taken to address the limitation pertaining to potential glare in the backtracking phase. This limitation was duly acknowledged within the Visual Amenity Assessment but no technical work is presented in order to quantify this potential issue.

The supplementary modelling has addressed this, and found that glare is predicted towards fifteen of the 19 assessed receptors during the backtracking phase. No glare risk has been identified for receptors R7, R8, OR (local road) and R27. In addition, receptors R1 and R2 are judged within the Visual Amenity Assessment to have no view of any reflecting panels and are consequently unaffected.

Overall, it is judged that whilst the predicted effects are not nil, they would not be significant. This is in agreement with the conclusion presented in the Visual Amenity Assessment, and it is considered that the quantification of the predicted effects makes this conclusion more robust.

A technical summary against each of the Council's requirements is presented on the following pages.

[1] Record of Deferral dated 6 August 2020.

Summary – Requirement 1 (Veracity of Results)

Modelling of parameters that approximate backtracking to some extent shows that all arrays could produce some level of glare towards a number of the assessed receptors. All predicted glare is 'green' equating to a low potential for a temporary after-image, the lowest categorisation of glare intensity. The maximum duration per day of predicted glare is in most cases less than 10 minutes and in all cases less than 20 minutes. These results represent a glare risk assuming full visibility and bright conditions, such that real-world factors would reduce this value.

All reflecting panel areas are likely to be more than 500 metres from the respective reflecting areas. In many cases the separation distance will be greater than this. It is unlikely that all reflecting areas will be fully visible from all receptor points based on the separation distance, terrain and intervening vegetation (existing and proposed). Glare times are predominantly around sunset, such that direct sunlight is likely to coincide with reflections from the panels. Direct sunlight is likely to be the dominant source of glare in such a scenario.

It is judged that the effects would not be significant.

Summary – Requirement 2 (Whether Footprint is Appropriate)

All proposed arrays have the potential to cause some degree of glare towards some of the receptors (see Table 4 in Section 2.6 for a breakdown). In this regard, the development footprint itself does not prevent adverse visual or glare impacts in itself. The level of effect based on the modelling results that approximate the backtracking scenario the most accurately indicate that effects will be restricted and not significant. On this basis, no modifications to the development footprint are recommended.

Summary – Requirement 3 (Rectification Actions)

Rectification measures beyond the planting/landscaping that is already proposed are not judged to be a requirement because significant impacts are not predicted.

There are steps that could be taken to reduce impacts further, which include restricting the backtracking in the evening to a vertical angle of no less than 5 degrees is likely to significantly reduce, and possibly eliminate, glare during the backtracking phase[2].

No rectification measures beyond the landscaping that is already proposed have been identified. Further analysis and implementation of the solution would only be warranted if the monitoring phase identified an unforeseen impact.

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[2] In the unlikely event that this solution was to be required, further analysis could refine the range of acceptable angles within the 0-5 degree range more precisely.

Summary – Requirement 4 (Monitoring)

Monitoring is recommended via a two-pronged approach, set out in detail within Section 5. The key elements are a survey and report at areas where glare is predicted post-construction and a process for investigation of any reported glare at receptor locations within 1 kilometre of the panel boundary. This is not foreseen based on the restricted predicted visibility at relevant receptor locations.

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ABOUT PAGER POWER

The Company

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 48 countries within Australasia, Europe, Africa, America and Asia.

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

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

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

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

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

Report Authors and Reviewers

The report author is Kai Frolic. Kai is a director at Pager Power, having joined the company as a graduate technical analyst in 2008. Kai has undertaken glint and glare analysis for solar photovoltaic developments at a scoping/screening level, as part of pre-applications and at appeal. Kai holds a Masters in Physics (MPhys) from the University of Surrey in the UK and is a member of the Institute of Physics (MInstP).

The report reviewers are Mike Watson and Danny Scrivener. Mike founded Pager Power in 1997. He has a background in electrical engineering, he is a qualified Microsoft Certified Application Developer, a Member of the Institute of Engineering and Technology (MIET) and Chartered Engineer.

Danny is a director at Pager Power having joined the company as a graduate technical analyst in 2012. Danny has undertaken over 150 glint and glare assessments at all levels and is the lead author of Pager Power's own guidance document on the assessment of Glint and Glare. The guidance is based on industry experience, peer review and stakeholder review and is now in its second edition.

1 INTRODUCTION

1.1 Reviewed Documents

The key document that has been reviewed is the Visual Amenity Assessment prepared by Iris Visual Planning + Design dated January 2020. Where appropriate, supplementary original analysis has been undertaken to validate the analysis within the original assessment.

Other documents pertaining to the proposed development, council meetings and other actions have also been considered.

Guidance documents pertaining to the issue of glint and glare in general are discussed in the appendices and referenced explicitly where relevant in the body of this report.

1.2 Report Structure

The technical elements of this report are set out in phases to address the requirements set out by the council in sequential order to the extent possible – there is a level of overlap between the considerations listed above. For ease of reference the points are reproduced below.

1. The veracity of the existing information provided by the Applicant regarding visual impact and the potential for the development to create glare impacts on the surrounding community, including commenting on the underlying assumptions.
2. Verify that the development footprint is appropriate to prevent adverse visual or glare impacts or recommend modifications to the development footprint.
3. Advise on appropriate rectification actions to mitigate potential glare generation during operations including materials, tracking options.
4. Recommend parameters to monitor the performance of the development with regard to glare impacts.

2 TECHNCIAL ASSESSMENT PHASE 1 – REVIEW OF VISUAL AMENITY ASSESMENT

2.1 Council Requirement 1

To address:

The veracity of the existing information provided by the Applicant regarding visual impact and the potential for the development to create glare impacts on the surrounding community, including commenting on the underlying assumptions.

2.2 Review Notes

Table 1 below presents Pager Power's notes on the external report – comments are limited to parameters pertaining to glint and glare specifically. For the avoidance of doubt, the page number refers to the PDF document itself, this does not always correlate with the number printed at the bottom of the page.

Page	Description	Pager Power Comments
1/93	Cover page.	-
2/93	Table of Contents.	-
3/93	Introduction.	Glare risk is one of three categories of visual impact set out in the introduction. The report states that additional vegetation will be provided and that the panels will be fitted with anti-reflective coating. The technical modelling, presented in the appendices of the Visual Amenity Assessment has in fact been run based on panels that do not have an anti-reflective coating. In terms of intensity, this means the assessment has been conservative because reflections are more intense in the modelled scenario than the actually proposed one. The potential glare zones are technically larger for the anti-reflective coating case because there is increased potential for scattering, the differences are generally negligible in cases such as this one. This has been explored later within Pager Power's supplementary modelling.
4/93	Planning context.	-
5/93	Planning context continued.	East Bomen Road is identified as a Major Arterial Road.

Page	Description	Pager Power Comments
6/93	Existing environment.	-
7/93	Existing environment continued.	Reference to the approved Wagga Wagga Solar farm adjoining the proposal site and is under construction.
8/93	Planning context continued.	Reference to residential receptors near the site boundary, with others at a distance of four to five kilometres.
9/93	Visual impact assessment.	Methodology refers to modelled Zone of Visual Influence (ZVI) and Visual Absorption Capacity (VAC) – understood to apply predominantly in the context of the area's character. For glint and glare effects it is generally advisable to consider visibility of the reflecting areas of the site on a per-dwelling basis as far as possible.
10/93	Visual impact assessment continued.	Methodology for assigning likely visual impact is set out here – this appears to relate to visual impact of the proposal in general rather than specifically to glint and glare[3].
11/93	Visual impact assessment continued.	-
12/93	Visual impact assessment continued.	-
13/93	Visual impact assessment continued.	Description of ZVI process – this does not appear tailored to glint and glare issues which are generally sensitive to which specific areas of the site are visible based on the reflecting panel locations.
14/93	Visual impact assessment continued.	-

[3] Pager Power recommends evaluating glare effects based on more specific parameters, discussed in Section 2.2.

Page	Description	Pager Power Comments
15/93	Viewpoint 1.	This is a view from East Bomen Road. It is classed as 'negligible visual impact', however this does not appear to be in a glint and glare specific context.
16/93	Viewpoint 2.	-
17/93	Viewpoint 2 continued.	This is a view from Dunns Road.
18/93	Viewpoint 2 continued.	The report concludes negligible visual impact. Whilst this does not appear to be a glint and glare specific context, this described as an unsurfaced road that is rural, as such Pager Power would classify this as a 'local' road whereby glint and glare impacts are not significant due to the generally low traffic volumes/speeds.
18/93	Viewpoint 3.	-
19/93	Viewpoint 3 continued.	-
20/93	Viewpoint 3 continued.	The report concludes minor adverse visual impact. Whilst this does not appear to be a glint and glare specific context, this is described as a rural road, as such Pager Power would classify this as a 'local' road whereby glint and glare impacts are not significant due to the generally low traffic volumes/speeds.
21/93	Viewpoint 4.	-
21/93	Viewpoint 4 continued.	-
22/93	Viewpoint 4 continued.	The report concludes minor adverse visual impact. Whilst this does not appear to be a glint and glare specific context, this is described as a rural road, as such Pager Power would classify this as a 'local' road whereby glint and glare impacts are not significant due to the generally low traffic volumes/speeds.
23/93	Viewpoint 5.	-

Page	Description	Pager Power Comments
24/93	Viewpoint 5 continued.	The report concludes negligible visual impact. Whilst this does not appear to be a glint and glare specific context, this is described as a track, as such Pager Power would classify this as a 'local' road whereby glint and glare impacts are not significant due to the generally low traffic volumes/speeds.
25/93	Viewpoint 6.	-
26/93	Viewpoint 6.	The report concludes negligible visual impact. Whilst this does not appear to be a glint and glare specific context, this is described as an unsurfaced rural road, as such Pager Power would classify this as a 'local' road whereby glint and glare impacts are not significant due to the generally low traffic volumes/speeds.
27/93	Viewpoint 7.	-
28/93	Viewpoint 7 continued.	The report concludes negligible visual impact. Whilst this does not appear to be a glint and glare specific context, this is described as an unsurfaced rural road, as such Pager Power would classify this as a 'local' road whereby glint and glare impacts are not significant due to the generally low traffic volumes/speeds.
29/93	Summary of visual impact.	-
30/93	Summary of visual impact continued.	-
31/93	Visual impact on private residential properties.	Methodology for assessing impact significance is set out– this appears to relate to visual impact of the proposal in general rather than specifically to glint and glare
32/93	Visual impact on private residential properties continued.	-

Page	Description	Pager Power Comments
33/93	Visual impact on private residential properties continued.	-
34/93	Visual impact on private residential properties continued.	-
35/93	Visual impact on private residential properties continued.	-
36/93	Photographs	-
37/93	Photographs	-
38/93	Photographs.	-
39/93	Glare Risk Assessment.	Key concepts and terms are accurate. Ocular impacts are accurate – there are several ways to approach this topic, but the information provided here is based on guidance produced originally by Sandia Laboratories for the Federal Aviation Administration in the USA. This is largely considered industry standard and is appropriate to reference in this context, although the intensity categorisations were designed to evaluate effects on pilots of approaching aircraft only. It is reasonable to conclude, as the report has done, that retinal burn causing permanent eye damage is not possible for a solar array such as this one. It may not be technically correct to say that it is not possible for photovoltaic modules, particularly if they were configured to concentrate sunlight, but for an array such as this one the conclusion is accurate and appropriate. GlareGauge is a commonly used modelling approach within the industry and it is an appropriate choice.

Page	Description	Pager Power Comments
40/93	Glare Risk Assessment continued.	The assumptions and limitations presented are reasonable and appropriate. Whilst the model referred to does account for dust etc. as highlighted within the report, the surface roughness does correlate with the panel surface type, which introduces an element of diffusivity within the assessment. Assessment of receptors within 1 km is considered appropriate. This is discussed in more detail in Section 2.3 below. Whilst the model referred to does not formally account for backtracking, this can be accommodated to an extent via the 'resting angle' feature – this appears not to have been done in this case. In addition, modelling of the 'flat panel' scenario can further inform potential impacts during backtracking. **Supplementary modelling has been undertaken by Pager Power to investigate this – see Section 2.5.**
41/93	Glare assessment.	The parameters presented here are appropriate, with the possible exception of the resting angle which can be set to zero to accommodate backtracking to an extent. Even this approach would not be 100% representative of the real case but it could provide further certainty because it approximates the backtracking process to a reasonable extent. The assessed locations have been evaluated based on the coordinates shown later in the document, see Section 2.4. The report acknowledges the limitation around backtracking and that there could be glare during the backtracking phase. It concludes that the effect would be negligible, in part because backtracking occurs for a short duration. The report does not quantify the duration of effects, nor does it specify which receptors are potentially affected or which parts of the solar farm would potentially produce glare.
42/93	Glare assessment continued.	The report concludes that the risk during construction is negligible due to the site being well screened and the fact that this phase is temporary. This conclusion seems reasonable and appropriate.

Page	Description	Pager Power Comments
43/93	Landscape plan and mitigation measures.	The report recommends stowing the panels such that they face away from receivers during construction to minimise potential glare effects. This is a reasonable suggestion.
44/93	Cumulative impacts.	-
45/93	Cumulative impacts continued.	The report concludes that there will be no cumulative glare impact due to their being no predicted glare. This is an appropriate conclusion based on the results of the modelling itself, although effects during backtracking could be explored more thoroughly (see Section 2.5).
46/93	Conclusions.	-
48/93	References.	-
49/93	Figure (topography).	-
50/93	Figure (ZVI).	-
51/93	Figure (viewpoints).	-
52/93	Figure (private residential receptors)	-
53/93	Figure (cross section view)	-
54/93	Figure (cross section view)	-
55/93	Figure (cross section view)	-
56/93	Figure (cross section view)	-

Page	Description	Pager Power Comments
57/93	Figure (cross section view)	-
58/93	Figure (cross section view)	-
59/93	Figure (cross section view)	-
60/93	Figure (cross section view)	-
61/93	Figure (cross section view)	-
62/93	Figure (cross section view)	-
63/93	Figure (cross section view)	-
64/93	Figure (viewshed).	-
65/93	Figure (glare receptor locations)	
66/93	Images and descriptions of plants and vegetation.	-
67/93	Landscape strategy and notes.	-
68/93	Landscape plan.	-
69/93	Description of existing trees with supplementary planting.	-

Page	Description	Pager Power Comments
70/93	Description of native revegetation areas.	-
71/93	Description of native screen planting.	-
72/93	Attachment A – principles of visual impact.	-
73/93	Attachment B – Viewing distances and solar farms.	-
74/93	Viewing distances and solar farms continued.	-
75/93	Viewing distances and solar farms continued.	-
76/93	Distant views.	-
77/93	Distant views.	-
78/93	Distant views.	-
79/93	Attachment C – Solar farms and glare.	The text presented here is appropriate. It does not mention the relationship between angle of incidence and glare intensity, whereby intensity increases at low angles. However, this is not crucial in this context because the intensity categorisation is not of material concern for ground-based receptors and a solar development of this type.
80/93	Solar farms and glare continued.	-

Page	Description	Pager Power Comments
81/93	Attachment D – Glare gauge results.	Title page only.
82/93	Glare gauge results continued.	This is modelling output for the first four arrays.
83/93	Glare gauge results continued.	This is modelling output for the first four arrays.
84/93	Glare gauge results continued.	This is modelling output for the first four arrays.
85/93	Glare gauge results continued.	This is modelling output for the first four arrays.
86/93	Glare gauge results continued.	This is modelling output for the first four arrays.
87/93	Assumptions from Forge model.	-
88/93	Glare gauge results continued.	This is modelling output for arrays 5 to 8.
89/93	Glare gauge results continued.	This is modelling output for arrays 5 to 8.
90/93	Glare gauge results continued.	This is modelling output for arrays 5 to 8.
91/93	Glare gauge results continued.	This is modelling output for arrays 5 to 8.
92/93	Glare gauge results continued.	This is modelling output for arrays 5 to 8.
93/93	Assumptions from Forge model.	-

Table 1 *Review notes*

2.3 Pager Power's Recommended Approach for Quantifying Impacts

There are numerous ways of quantifying and assessing impacts. There is no formal guidance in Australia that defines the process by which impact significance is to be assigned. Pager Power's approach is set out below.

For the avoidance of doubt, alternative approaches to quantifying impacts are not judged to be incorrect. A reasonable requirement for any approach is that it be specific to glint and glare impacts.

Pager Power's recommended approach is provided for context purposes. Table 2 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.

Table 2 *Impact significance definition*

This is applicable to any receptor type, the considerations for classifying impacts for road users and dwellings specifically are provided in the following sections.

2.3.1 Road Receptors

For road users, the key considerations are:

- Whether a reflection is predicted in practice.
- The type of road (and associated likely traffic levels/speeds).

The location of the reflecting panel 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).

Figure 1 below shows a flowchart for determining mitigation requirements.

The box that says 'mitigation not required but could be considered' relates to the scenario where the potential worst-case impact is 'moderate' and expert assessment of the specific case is required to determine whether mitigation is required (see Section 2.2.3). Simplistically, this is the grey area whereby it is not appropriate to assign a mitigation process based on the relatively simple process set out in the flowchart.

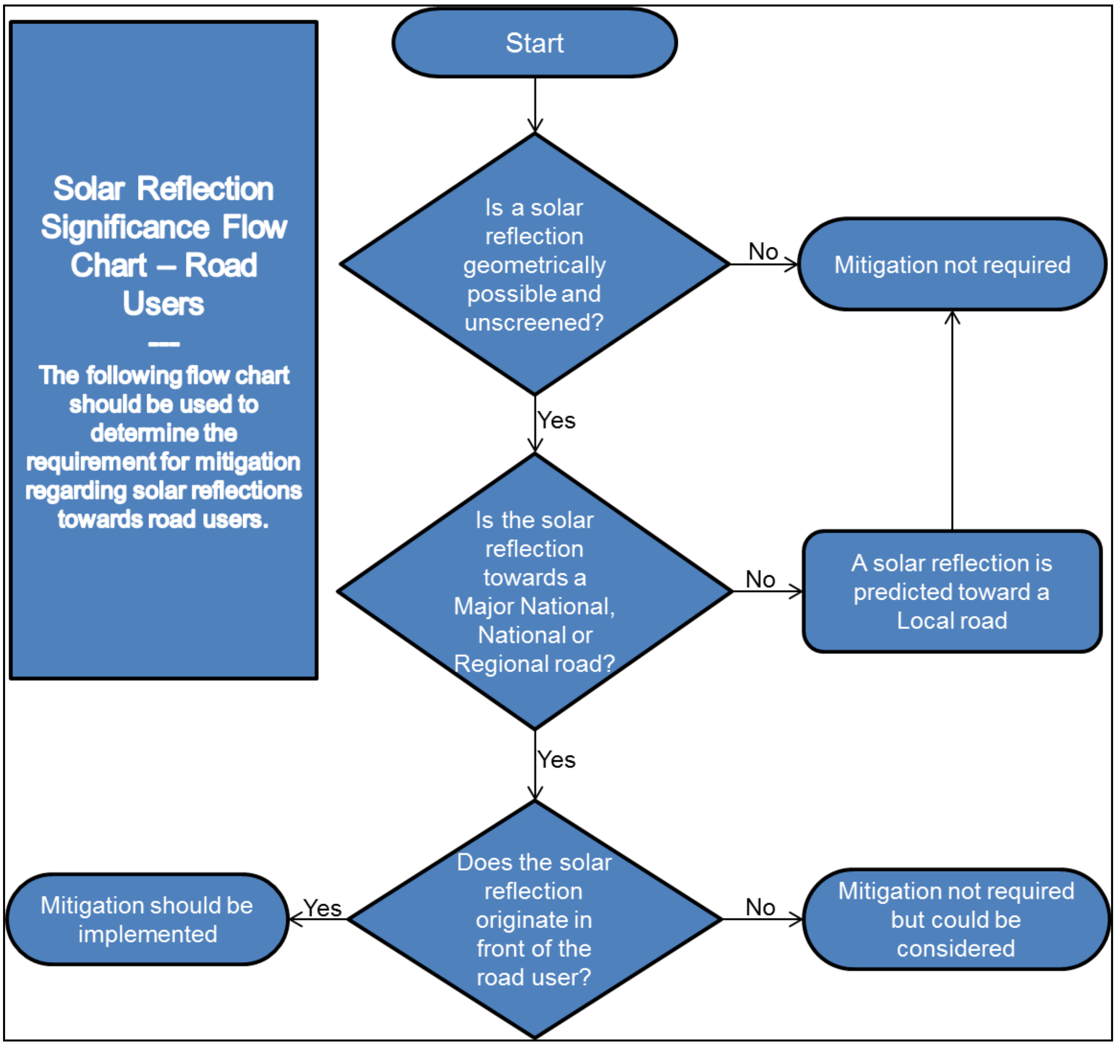

Figure 1 *Mitigation requirement flowchart for road users*

2.3.2 Dwelling Receptors

For dwelling receptors, the key considerations are:

- Whether significant visibility of the reflecting area is available in practice.
- The duration of the predicted effects, relative to thresholds of:
  - 3 months per year.
  - 60 minutes per day.

Figure 2 below shows a flowchart for determining mitigation requirements.

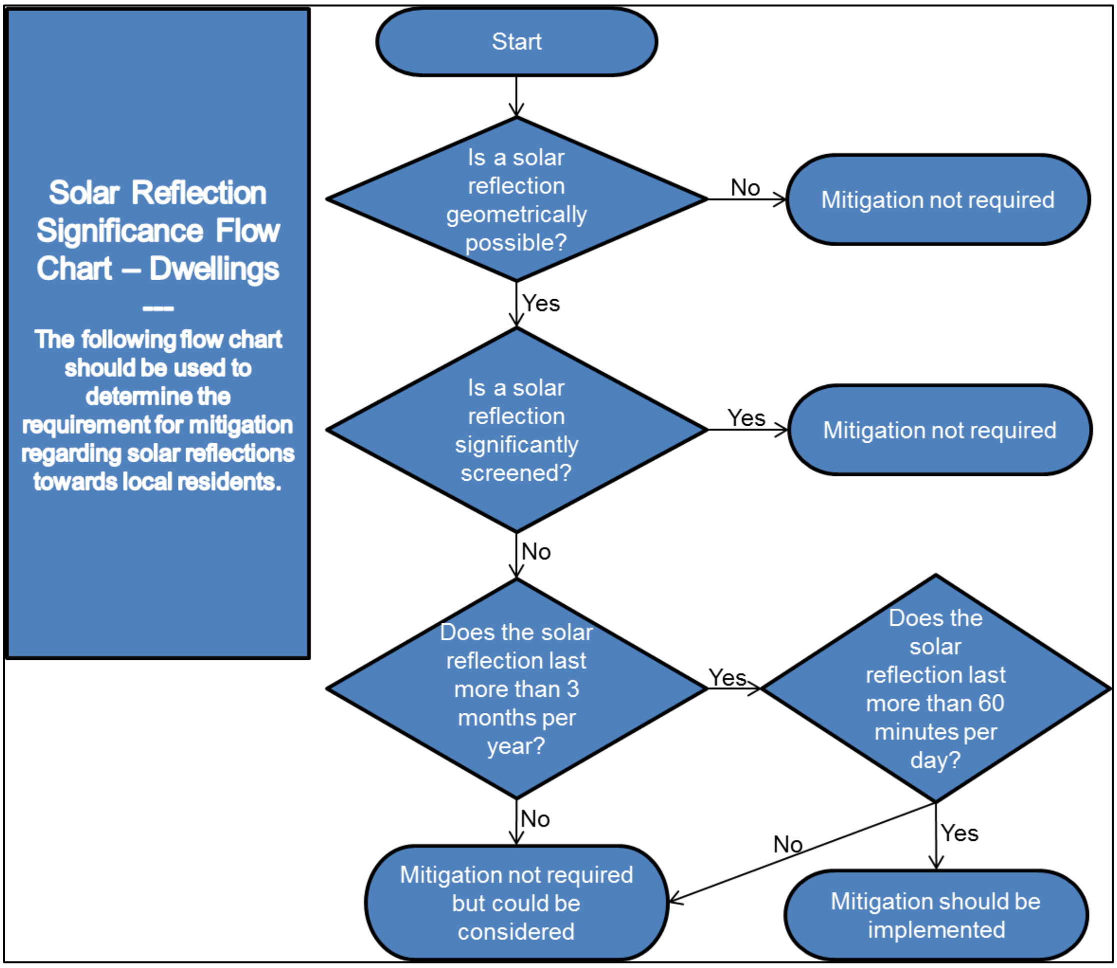

Figure 2 *Mitigation requirement flowchart for dwelling receptors*

The box that says 'mitigation not required but could be considered' relates to the scenario where the potential worst-case impact is 'moderate' and expert assessment of the specific case is required to determine whether mitigation is required. Simplistically, this is the grey area whereby it is not appropriate to assign a mitigation process based on the relatively simple process set out in the flowchart.

2.3.3 Further Considerations

Other factors that can be relevant when determining mitigation requirements can include:

- Range – The apparent intensity, and subsequently the level of potential discomfort, decreases with distance. In addition, the proportion of an observer's field of view that is taken up by reflecting panels decreases with distance. Impacts at close range are therefore potentially more serious than impacts at longer distances.
- Level of visibility – Partial obstruction of a reflecting area is better than no obstruction of a reflecting area, even if views cannot be entirely blocked.
- Position of the Sun at the time of the reflection – If the Sun is low in the sky beyond the reflecting panel, it means that an observer experiencing a reflection will also be experiencing direct sunlight. Direct sunlight is sufficiently more intense than a reflection from a solar panel, not least because solar panels are designed to absorb light as much as possible.
- Mean levels of cloud cover / low visibility – This is unlikely to be a material consideration in Australia.

The points above are considered in cases where the initial impact assessment returns a 'moderate' result and further expert assessment is required.

2.4 Evaluation of Assessed Receptor Points

The Visual Impact Assessment emphasises the importance of glare risk for receptors within 1 km of the panel area[4] in particular. Pager Power agrees with this approach.

There is no formal guidance with regard to the maximum distance at which glint and glare should be assessed. From a technical perspective, there is no maximum distance for potential reflections. The significance of a reflection however decreases with distance because the proportion of an observer's field of vision that is taken up by the reflecting area diminishes as the separation distance increases. This is illustrated in Figure 3 below.

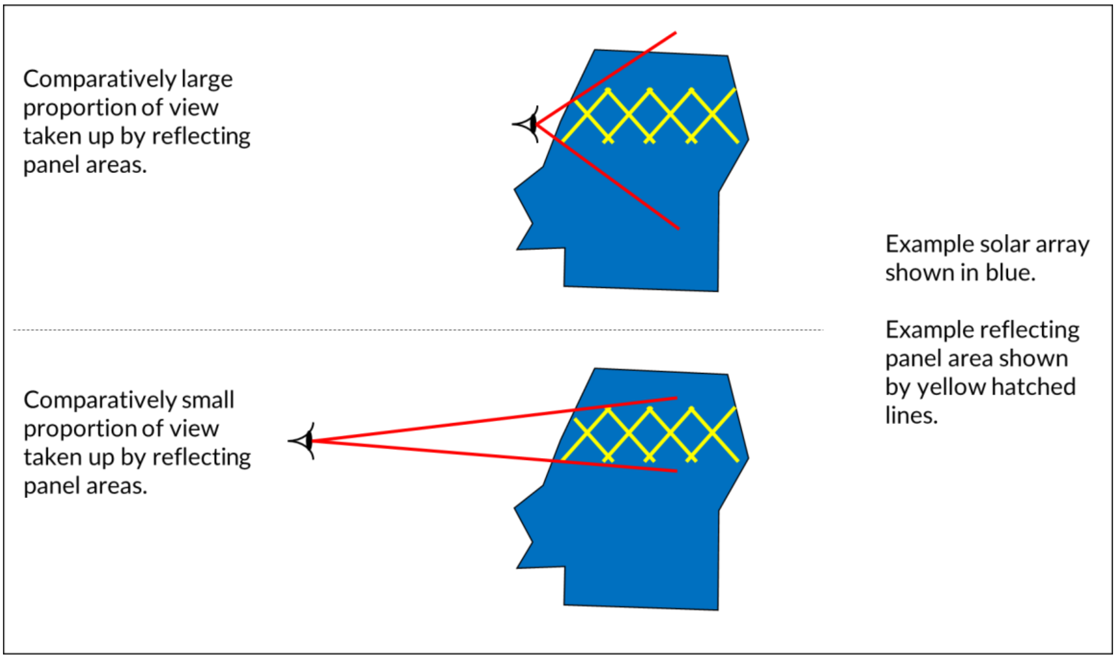

Figure 3 *Effect of range on field of view*

Terrain and shielding by vegetation are also more likely to obstruct an observer's view at longer distances.

A 1 km buffer is therefore considered appropriate for glint and glare effects on ground-based receptors.

Figure 4 on the following page[5] shows the array footprints (blue areas) and modelled receptor points (pink icons) taken from the Visual Amenity Assessment. A 1km boundary based on the array boundary points is shown in Orange for reference.

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[4] Set out in Section 7.1.2 of the Visual Amenity Assessment (page 40).

[5] Copyright ©2020 Google, Maxar Technologies, CNES/Airbus.

Figure 4 *Assessed receptors taken from Visual Amenity Assessment*

The receptor points are understood to have been selected based on range and ZVI. There are potential receptor points to southwest that appear to have been excluded due to not having predicted visibility of the panel areas. Examples of the excluded locations are shown in Figure 5 on the following page[6] (blue icons).

[6] Copyright ©2020 Google, Maxar Technologies, CNES/Airbus.

Figure 5 *Excluded receptors*

One of the excluded properties close to the southern boundary appears to be denoted as a landholder property within the Visual Amenity Assessment. In addition, some of these are very close to assessed receptor points which provide representative results for receptors in the general area.

Pager Power has not undertaken an independent ZVI, however the approach taken appears reasonable.

Inspection of the modelled receptor points shows that some of these are close to dwelling locations visible in aerial imagery, but do not exactly overlap (separation of approximately 100 metres in some cases). This may be due to coordinate data having been sourced from different maps or other sources, or because receptor points have been chosen based on locations with the maximum visibility of the site.

Regarding the selected road receptors, Pager Power's recommended approach is to space points at no less than 200 metres along assessed roads within 1 km. The approach taken within the Visual Amenity Assessment relies more on sample locations on particular roads.

In this case, the selected points are judged to be sufficient because:

- The majority of roads within 1 km would be classified as 'local' whereby modelling would not be recommended.
- The direction of traffic is such that any glare from the panels would likely be from outside a driver's main field of focus because the panel area is off to one side relative to the alignment of the roads.

Overall, the receptor point locations appear reasonable and appropriate.

2.5 Supplementary Modelling

The most important limitation with regard to the analysis that has been undertaken is that the modelling approach does not account for backtracking.

This limitation is accurately acknowledged within the Visual Amenity Assessment, which concludes that there is a subsequent possibility of glare effects. Whilst these are judged to be negligible, no steps have been taken to quantify these potential effects.

The modelling software that has been used for the assessment, which is an industry standard and credible, does not allow for detailed modelling of backtracking effects.

There are features of the modelling software that can be used to evaluate the effects of backtracking in more detail. These are set out on the following page.

2.5.1 Modelling a zero degree 'resting angle'

Selecting this option means the model assumes the panels revert instantly to a flat position whenever the Sun is outside the panels' rotation range. The purpose of this feature is to model backtracking because the panels flatten out at times when the Sun is low in the sky.

This approach does not accurately capture the real-world case. This is because the actual level of backtracking that will occur is dependent on the panel length, spacing between rows and relative heights of adjacent rows, since these factors will influence the point at which shading occurs. However, this approach does provide an indication of the level of glare that may be encountered due to backtracking. There are limitations to this approach because the actual backtracking angles will be a function of panel length/spacing and the position of the Sun, such that the modelled approach overestimates the amount of time that the panels are entirely flat.

2.5.2 Modelling fixed panel angles at zero degrees or low angles

Modelling based on fixed angles with low elevation is not at all representative of the real-world case. However, it is useful for two reasons:

1. It quantifies the times of day at which low angles would create glare. This can then be compared against the times of day at which such angles are likely. For example, consider a case whereby flat panels would cause glare between 11:00 AM and 13:00 PM but not at any other time. It can reasonably be concluded that during these times, the panels will not be backtracking since the Sun is relatively high in the sky, suggesting there would be no impacts. By contrast, if flat panels cause glare around sunrise and sunset, it is reasonable to assume that backtracking may cause noticeable glare (subject to visibility).
2. It potentially quantifies the range of low angles that would cause glare. For example, if fixed panels that are flat cause glare, but panels at 5 degrees or above do not, it is reasonable to conclude that backtracking would only cause glare if the panels are between 0 and 5 degrees.

The steps above are considered valid for quantifying the level of effect due to backtracking, at least at an indicative level.

Supplementary modelling has been undertaken for the proposed arrays and observers based on identical[7] input parameters and subsequent modifications to explore the potential effects in more detail.

[7] One exception here is that all eight arrays have been considered together rather than in two groups of four. A cosmetic difference is that the 'tracking axis orientation' in the Pager Power analysis for cases 1 and 2 is set to 180 rather than zero, this is the default setting and the two scenarios are the same, the axis runs between 0 and 180 such that the panels rotate east-west.

2.5.3 Supplementary Modelling Results

Table 3 below summarises the results of the supplementary modelling. The output from the GlareGauge (Forge Solar) software has been provided separately to this document[8].

No.	Case	Results	Comments
1	Identical parameters to the case presented in the Visual Amenity Assessment.	No glare towards any receptors i.e. the same result presented in the Visual Amenity Assessment.	This was essentially a control run to ensure the input parameters are consistent.
2	As per #1, but with a surface type of 'smooth glass with ARC'.	No glare towards any receptors i.e. no difference between this and the 'smooth glass without ARC' case.	This is judged to be a slightly more appropriate set of parameters because the proposals are for panels with an anti-glare coating[9].

[8] The modelling output for the various scenarios covers hundreds of pages.

[9] Differences between the results with and without ARC for smooth glass panels are generally minimal in cases such as this one, which is corroborated by the results presented here.

No.	Case	Results	Comments
3	As per #2 but with a 'resting angle' of zero degrees.	Glare is predicted for all arrays towards some observers. All predicted glare is 'green' signifying a low potential for a temporary after-image. Whilst Pager Power does not consider the glare intensity designation as a factor in impact significance for ground-based receptors, it is noteworthy that this is the lowest categorisation produced by the GlareGauge model. The array that produces the most glare in terms of combined duration across all receptors without consideration of visibility is Array 1, with a total of 5,196 minutes per year. This 86.6 hours per year, an average of less than 15 minutes per day. The array that produces the least glare in terms of combined duration across all receptors without consideration of visibility is Array 5, with a total of 520 minutes per year. This 8.67 hours per year, an average of less than 2 minutes per day. The maximum duration for any one array at any one receptor on any day of the year is less than 20 minutes, in most cases this value is less than 10 minutes.	This is an approximation of a backtracking system. As such, these results are considered the closest to the real world outcome. The actual figure for glare per year will be lower because many arrays are partially or entirely obscured from view. All times are indicative. The average duration per day is not very meaningful because effects are not spread evenly throughout the year, these values are presented for context because it is difficult to interpret thousands of minutes per year. Further analysis presented in Section 2.6.

No.	Case	Results	Comments
4	Fixed panels with ARC titled at 0 degrees.	Glare is predicted for all arrays, total durations are similar to Case 3. All predicted glare is ‘green’ signifying a low potential for a temporary after-image. Whilst Pager Power does not consider the glare intensity designation as a factor in impact significance for ground-based receptors, it is noteworthy that this is the lowest categorisation produced by the GlareGauge model.	The similarity between cases 3 and 4 is not surprising since effects from flat panels are most likely when the Sun is low in the sky. In the backtracking approximation, the panels are modelled as flat when the Sun is low in the sky and track throughout the day, such that the potential glare scenarios are similar.
5	Fixed panels with ARC tilted at 15 degrees with an azimuth of 270 degrees.	No glare predicted.	This indicates, but does definitively prove, that glare could be eliminated if backtracking in the evening was restricted to angles greater than 15 degrees.
6	Fixed panels with ARC tilted at 5 degrees with an azimuth of 270 degrees.	No glare predicted.	This indicates, but does definitively prove, that glare could be eliminated if backtracking in the evening was restricted to angles greater than 5 degrees.

Table 3 *Supplementary modelling results*

2.6 Investigation of Potential Effects – Backtracking

The case that is most relevant for understanding the likely level of effect is Case 3. The GlareGauge modelling output does not give a cumulative quantification of effects from all arrays, rather results are presented individually for each one.

Table 4 below summarises the collated data for the receptor points taken from the GlareGauge output (array numbering is shown in Appendix A).

Receptor	VAA Ref	Contributing array(s)	Visibility Assessment Results (provided by the VAA team)
1 and 2	Dwelling R7	None.	N/A since no glare is predicted.
3	Dwelling R9	1 and 2.	Less than 50% of arrays 1 and 2 are predicted to be visible from this receptor location, which reduces the potential risk. The receptor is more than 1.5 km from the panels which reduces the potential significance.
4	Dwelling R16	1, 2, 3, 4, 7 and 8.	Less than 50% of arrays 4, 7 and 8 are predicted to be visible which reduces the potential risk. The receptor is more than 2.5 km from the panels which reduces the potential significance.
5	Dwelling R17	1, 2, 3, 4, 5, 6[10] and 8.	No visibility of arrays 4, 5 and 6 is predicted from this receptor location. Less than 50% of array 8 is predicted to be visible from this location. This reduces the potential risk. The receptor is more than 2 km from the panels which reduces the potential significance.
6	Dwelling R13	1, 2, 3, 4, 5, 6 and 8.	No visibility of arrays 4, 5, 6 or 8 is predicted from this receptor location. Less than 50% of arrays 1, 2 and 3 is predicted to be visible from this location. This reduces the potential risk.
7	Local Road OR	None.	N/A since no glare is predicted.

[10] Array 6 is predicted to produce 1 minute of glare per year. Array 5 is predicted to produce 7 minutes per year.

Receptor	VAA Ref	Contributing array(s)	Visibility Assessment Results (provided by the VAA team)
8	Local Road OR	1, 2, 3, 4, 7 and 8.	No visibility of arrays 4, 6 or 8 is predicted from this receptor location. Less than 50% of arrays 1, 2, 3 and 7 is predicted to be visible from this location. This reduces the potential risk.
9	Local Road PR	1, 2, 3, 4, 6, 7 and 8.	No visibility of arrays 3, 4 or 6 is predicted from this receptor location. Less than 50% of arrays 1, 7 and 8 is predicted to be visible from this location. This reduces the potential risk.
10	Local Road PR	1, 2, 3, 4, 6[11], 7 and 8.	No visibility of arrays 4 or 6 is predicted from this receptor location. Less than 50% of arrays 7 and 8 is predicted to be visible from this location. This reduces the potential risk.
11	Local Road DR	All.	No visibility of arrays 4, 5, 6 or 7 is predicted from this receptor location. Less than 50% of arrays 1, 3 and 8 is predicted to be visible from this location. This reduces the potential risk.
12	Local Road DR	1, 3, 4, 5 and 6.	No visibility of arrays 2, 3, 4, 5, 6, 7 or 8 is predicted from this receptor location. Less than 50% of array 1 is predicted to be visible from this location. This reduces the potential risk.
13	Main Road EBR	5.	No visibility of any array is predicted from this receptor location, such that impacts would not occur.
14	Dwelling R1	All.	No visibility of any array is predicted from this receptor location, such that impacts would not occur.
15	Dwelling R2	2, 3, 4, 7 and 8.	No visibility of any array is predicted from this receptor location, such that impacts would not occur.

[11] Array 6 is predicted to produce 2 minutes of glare per year.

Receptor	VAA Ref	Contributing array(s)	Visibility Assessment Results (provided by the VAA team)
16	Dwelling R27	None.	No visibility of any array is predicted from this receptor location, such that impacts would not occur.
17	Dwelling R26	All[12].	No visibility of arrays 4, 5 and 6 is predicted from this receptor location. Less than 50% of arrays 2, 3, 7 and 8 is predicted to be visible from this receptor location. This reduces the potential risk. This receptor is more than 5 km from the panels which reduces the potential significance.
18	Local Road WR	1 and 2.	No visibility of array 1 is predicted from this receptor location. Less than 50% of array 2 is predicted to be visible from this location. This reduces the potential risk.
19	Local Road WR	1, 2, 3, 4, 7 and 8.	No visibility of arrays 1, 3 or 4 is predicted from this receptor location. Less than 50% of arrays 1, 7 and 8 is predicted from this receptor location. This reduces the potential risk.

Table 4 *Investigation of backtracking effects*

It is important to consider that the results in Table 4 do not account for overlap of effects i.e. the extent to which effects from different arrays are staggered throughout the day.

In order to investigate the level of overlap, the individual charts from each array for a given receptor were manually overlaid.

This process has confirmed that the overlap in time of day is very strong between the various arrays. The time of year varies for the different arrays. What this means is that the duration per day that glare occurs is likely to be no more than 10 minutes (the maximum duration per day predicted for any one array) – because of the strong overlap in times. If the green lines were vertically spaced for the various arrays, an observer could experience 10 minutes from the first array, then some time later another ten minutes from the next array and so on. The model does not indicate that impacts would be sequential in this way, thereby limiting the duration significantly.

[12] Array 7 is predicted to produce 1 minute of glare per year.

2.7 Summary of Phase 1

Pager Power has endeavoured to investigate the veracity of the Visual Amenity Assessment for the proposal based on a detailed reading of the study and technical crosschecks pertaining to glint and glare. This has not included crosschecks of other technical elements such as the ZTV assessment.

The content of the Visual Amenity Assessment in the context of glint and glare appears professional, transparent, and technically sound. However, additional steps could have been taken to address the limitation pertaining to potential glare in the backtracking phase. This limitation was duly acknowledged within the Visual Amenity Assessment but no technical work is presented in order to quantify this potential issue.

The supplementary modelling has addressed this and found that glare is predicted towards fifteen of the 19 assessed receptors during the backtracking phase.

Modelling of parameters that approximate backtracking to some extent shows that:

- All arrays could produce some level of glare towards a number of the assessed receptors – but many of these are obstructed by terrain and existing/proposed vegetation as set out in Table 4.
- All predicted glare is 'green' equating to a low potential for a temporary after-image, the lowest categorisation of glare from the GlareGauge software.
- The maximum duration per day of predicted glare is in most cases less than 10 minutes and in all cases less than 20 minutes.

All reflecting panel areas are likely to be more than 500 metres from the respective receptor. In many cases the separation distance will be greater than this.

It is unlikely that all reflecting areas will be fully visible from all receptor points based on the separation distance, terrain and intervening vegetation (existing and proposed).

Glare times are predominantly around sunset, such that direct sunlight is likely to coincide with reflections from the panels. Direct sunlight is likely to be the dominant source of glare in such a scenario.

Overall, it is judged that whilst the predicted effects are not nil, they would not be significant. This is in agreement with the conclusion presented in the Visual Amenity Assessment, and it is considered that the quantification of the predicted effects makes this conclusion more robust.

3 TECHNICAL ASSESSMENT PHASE 2 – EVALUATION OF THE DEVELOPMENT FOOTPRINT

3.1 Council Requirement 2

Verify that the development footprint is appropriate to prevent adverse visual or glare impacts or recommend modifications to the development footprint.

3.2 Findings – Development Footprint

As shown in the previous section, all proposed arrays have the potential to cause some degree of glare towards some of the receptors (see Table 4 in Section 2.6 for a breakdown).

In this regard, the development footprint itself does not prevent adverse visual or glare impacts in itself.

The level of effect based on the modelling results that approximate the backtracking scenario the most accurately indicate that effects will be restricted and not significant. On this basis, no modifications to the development footprint are recommended.

4 TECHNICAL ASSESSMENT PHASE 3 – RECTIFICATION MEASURES

4.1 Council Requirement 3

Advise on appropriate rectification actions to mitigate potential glare generation during operations including materials, tracking options.

4.2 Findings – Rectification Measures

Rectification measures beyond the planting/landscaping that is already proposed are not judged to be a requirement because significant impacts are not predicted.

There are steps that could be taken to reduce impacts further, which include restricting the backtracking in the evening to a vertical angle of no less than 5 degrees is likely to significantly reduce, and possibly eliminate, glare during the backtracking phase[13].

No rectification measures beyond the landscaping that is already proposed have been identified. Further analysis and implementation of the solution would only be warranted if the monitoring phase identified an unforeseen impact.

Changes to the panel materials are not likely to significantly mitigate the predicted glare. It is already the lowest classification of intensity and modelling of the even less reflective surfaces generally does not reduce this to zero.

[13] In the unlikely event that this solution was to be required, further analysis could refine the range of acceptable angles within the 0-5 degree range more precisely.

5 TECHNICAL ASSESSMENT PHASE 4 – RECTIFICATION MEASURES

5.1 Council Requirement 4

Recommend parameters to monitor the performance of the development with regard to glare impacts.

5.2 Monitoring Impacts

The most appropriate process for monitoring impacts is considered to be a two-pronged approach:

1. A physical site survey, at predicted glare times where applicable, of the assessed receptor locations once the development is fully operational and the proposed planting measures are in place i.e. the 'final' operational state. Provided this does not highlight any concerns, this need only be done once. An accompanying report summarising the surveyor's assessment at each receptor location should be provided to the Council. This report should set out:
    a. The date and time at each visited location.
    b. Whether glare was observed.
    c. Whether this was in keeping with predicted glare – where applicable.
    d. Photographs of any observed glare.
    e. A subjective assessment of the level of discomfort experienced.
2. Residents within 1 km of the panel area should be given the opportunity to register reported glare impacts with the Council or the developer directly. Ideally such reports should include as much of the below as possible:
    - Location(s) of observer(s) at the time the effects were noticed e.g. stood inside the kitchen on the ground floor.
    - Date(s) of reported incident(s).
    - Start and end time of reported incident (or the earliest time that the effect was noticed and the earliest time it was observed to have passed).
    - Which area within the array was observed to be reflecting.
    - Photographs of the reflecting panels.

    Reported incidents raised within 1 year should be investigated by the developer via:
    a. Evaluation of the reported incident.
    b. A site visit, ideally during the time of day at which effects have been reported.

    Should this process reveal that significant impacts are being experienced, consideration of further mitigation in the form of planting at the site boundary or any intervening location where permission to plant is readily available. For these purposes, it is recommended that 'significant' is defined in terms of duration per day.

5.3 Notes on Implementation

5.3.1 Part 1

With regard to part 1 d) above, it is recommended that the camera model, height above ground and technical settings are recorded at the time of any photograph.

With regard to part 1e) above, it is accepted that a subjective assessment of discomfort is open to significant human interpretation. Nevertheless, it is recommended that this is included because a qualitative assessment glare has some value. In particular it may be beneficial to note:

- Whether the reflecting panels stood out significantly when looking towards the development.
- Whether the surveyor felt the need to squint or avert their gaze from the direct source of glare.
- Whether direct sunlight was observable on a similar bearing to the reflecting area.
- Whether an after-image of the reflecting panel was noticed when looking away from the reflecting area.

5.3.2 Part 2

The timeframe of 12 months for reported incidents is appropriate because it allows for a cycle through every season / day of the year which can reasonably be expected to capture any significant glare effects.

It is accepted that all of the suggested information pertaining to reported glare incidents may not be readily available. However, the more data is reported the more thoroughly such a report can be investigated, so these factors should be presented as questions if reports are raised.

Finally, Pager Power recommends that the duration per day that qualifies as a 'significant' effect is 60 minutes or more i.e. a duration of at least one hour on any one day is required for an effect to be significant. Whilst a more sophisticated approach is to base this on duration per day and number of months per year, this is logistically much harder to determine. A resident cannot reasonably be expected to monitor the start and end times of observable glare for a period of successive weeks. The duration at a given location can be accurately determined based on:

- The residents' reports – ideally with evidence.
- The modelling results. For example, if the reported glare incidents coincide entirely with predicted glare times, it is reasonable to conclude that the model is accurate. If they do not, it may be beneficial to run further modelling corresponding to the exact reported case e.g. the location and viewing height that has been reported.

APPENDIX A ARRAY NUMBERING

The figure below shows the array numbering referenced within this document (provided by Iris Visual Planning + Design, cropped)

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