BEFORE THE INDEPENDENT COMMISSIONER
OF CENTRAL OTAGO DISTRICT COUNCIL

IN THE MATTER	of the Resource Management Act 1991 ("**RMA**")
AND	
IN THE MATTER	of an application for resource consent by Helios OTA OP LP ("**Helios**") to construct, operate and maintain a photovoltaic solar farm and associated infrastructure including a substation and transmission line infrastructure for renewable electricity generation at 48 Ranfurly-Naseby Road, Naseby ("**Project**")

STATEMENT OF EVIDENCE OF NICHOLAS ALEXANDER LOGAN ON BEHALF OF HELIOS

21 JULY 2025

Russell McVeagh

D J Minhinnick / L C Espin
P +64 9 367 8000
F +64 9 367 8163
PO Box 8
DX CX10085
Auckland

1. EXECUTIVE SUMMARY

1.1 I, Nicholas Alexander Logan, Project Engineer with ITP Renewables, have been involved in the Project since May 2023. I directed and reviewed the Glint and Glare Assessment[1] and subsequent additional clarifications.[2] [3] [4] I also prepared a technical advice note on glare from moonlight ("**Moonlight Glare Assessment**") in relation to the proposed solar farm, which is attached to my evidence as **Attachment 1**.[5]

1.2 The Glint and Glare Assessment, and Moonlight Glare Assessment are based on analysis using the ForgeSolar model. The array model was developed based on the Naseby Preliminary Layout[6] and mechanical details of the tracking structures.

1.3 The model also includes a 10-degree limitation on backtracking (as committed to by Helios via a proposed condition of consent) and also considers the mitigating effect of screen planting (both existing and as part of the extensive additional planting proposed as part of the consent conditions ("**Planting Plan**")).

1.4 Our modelling concluded that all residual yellow glare to the road network is eliminated, provided the proposed Planting Plan is implemented at the heights proposed in the *Minimum Screening Analysis for Māniatoto Solar Farm* and with sufficient depth such that it is essentially opaque. The residual green glare is not hazardous and does not require further mitigation.

1.5 Based on the mitigation measures stipulated above, it is my opinion that glint and glare effects of the Project (including on visual amenity and road safety) will have a less than minor impact.

2. INTRODUCTION

2.1 My full name is Nicholas Alexander Logan. I am a Project Engineer with ITP Renewables.

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1 Naseby Solar Farm Glint and Glare Study, prepared by ITP Renewables dated September 2023.

2 Section 92 Response dated 10 May 2024 (written response to Request Request 5 'international best practise' and Request 7 'changes to the solar panel rest angle'.

3 Naseby Solar Farm Glare Study, Glare Study Addendum dated 24 June 2024

4 Minimum Screening analysis for Maniatoto Solar Farm, dated 30 April 2025.

5 Moonlight Glare Consultant Advice Notice, dated 20 May 2025.

6 Rev 0, attached as Appendix 2 to the Assessment of Environmental Effects, March 2024.

2.2 I hold a Bachelor of Science and a Bachelor of Engineering from the Australian National University.

2.3 I have been conducting glint and glare assessments for over five years, and have completed more than 30 assessments across Australia, New Zealand, and the Pacific Islands, with a cumulative installed nameplate generation capacity of more than 1 Gigawatt ("**GW**"). This includes eleven large-scale solar farms in New Zealand across multiple districts (Mackenzie, Tasman, Hurunui, Central Hawke's Bay, South Wairapara, Taranaki, Rangitikei, and Horowhenua). I recently acted as an expert witness for Far North Solar Farm Ltd in the Environment Court Hearing for the proposed Greytown Solar Farm.

Involvement in the Project

2.4 I have been involved in the Project since May 2023. I directed and reviewed the Glint and Glare Assessment.[7] I subsequently provided additional clarifications and references to the existing Glint and Glare Assessment in response to the Request for Further Information dated 10 May 2024,[8] and a consultant's advice note clarifying the definition of green glare and the impact of residual green glare on Ranfurly Back Road.[9]

2.5 I have also issued two consultant's advice notes regarding minimum screening requirements to mitigate any residual yellow glare impacts,[10] and the potential for moonlight glare.[11]

2.6 I also prepared a response to the Glint and Glare Traffic Effects peer review undertaken by Abley Limited.[12]

2.7 The results of ITP Renewables' Consultants' Advice Notice (CAN No. 001 v2) – *Minimum Screening Analysis for Māniatoto Solar Farm* supersede that of the original study (Naseby Glint and Glare study dated September 2023). There has also been one change and one correction in the Minimum Screening Analysis (dated 30 April 2025) compared to the original study (dated 26 September 2023):

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7 Naseby Solar Farm Glint and Glare Study, prepared by ITP Renewables dated September 2023.

8 Land use consent application RC240065- Helios Māniatoto Plain Solar Farm - Section 92 Response dated 10 May 2024 written response to Request 5 'international best practise' and Request 7 'changes to the solar panel rest angle'.

9 Naseby Solar Farm Glare Study, Glare Study Addendum dated 24 June 2024.

10 Minimum Screening analysis for Maniatoto solar Farm, dated 30 April 2025.

11 Moonlight Glare Consultant Advice Notice, dated 20 May 2025.

12 Response to Māniatoto Solar Farm Glint and Glare Traffic Effects Review dated 1 July 2025.

(a) The change was the removal of modelled obstructions attributed to existing vegetation that was outside of the Project site at 48 Ranfurly-Naseby Road ("**Site**") and may not be retained or maintained through the life of the Project (ie screens that are outside of the Project's control). The removed obstructions are displayed in Figure 1 below.

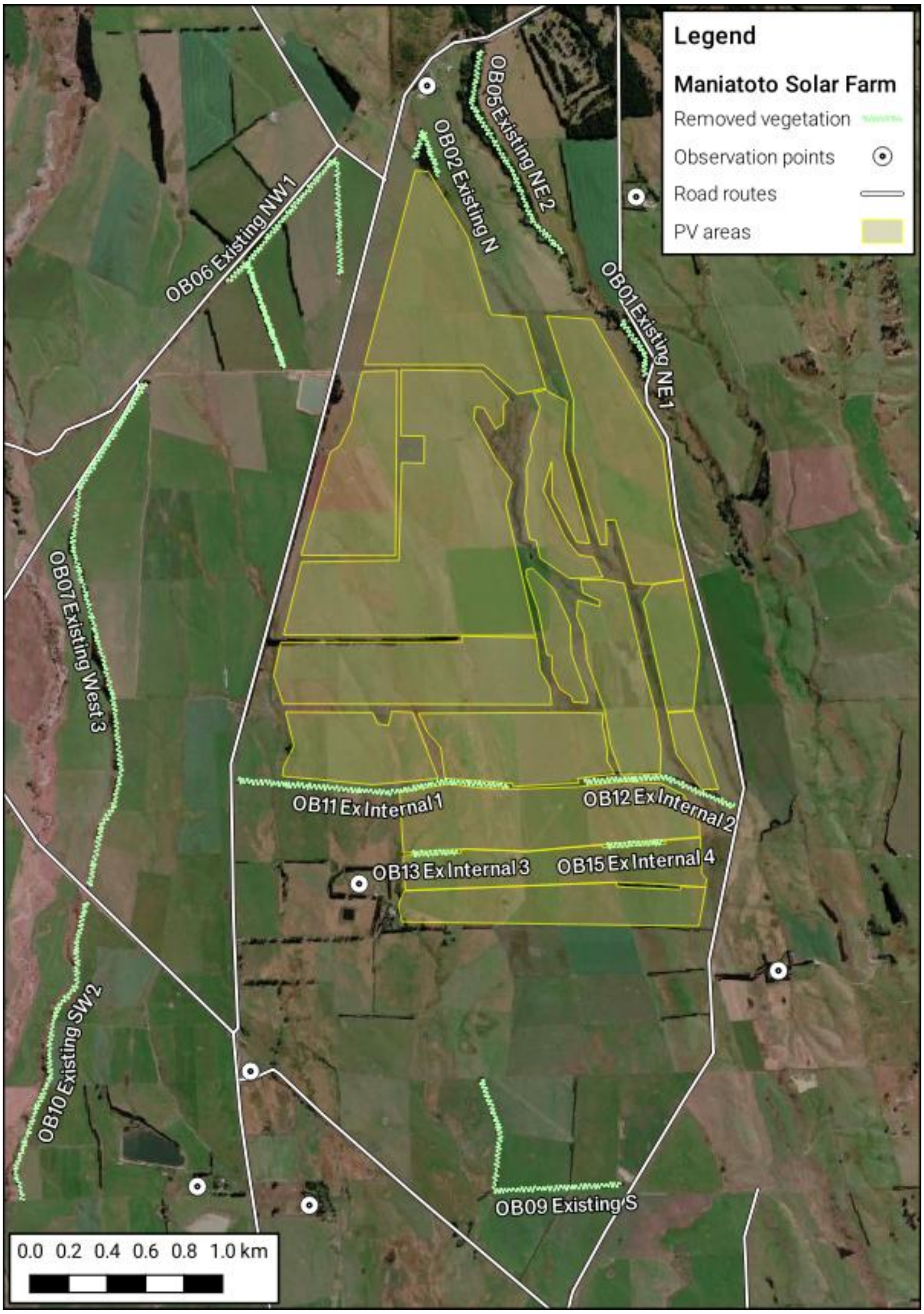

Figure 1: Vegetation removed from the glint and glare model

(b) The correction was to amend the footprint of the southernmost array of panels from its original modelling as one large object (PV06 South) rather than three smaller objects (PV06 South, PV14 South 2 and PV15 South 3) as shown in Figure 8 of the Naseby Solar Farm Glint and Glare Study Revision 2, dated September 2023. This correction follows the topography more closely and hence is more accurate.

2.8 I have not visited the Site as the Glint and Glare Assessment is a software-based assessment that adopts very conservative assumptions. This is industry standard practice.

Code of conduct

2.9 I confirm that I have read the Expert Witness Code of Conduct set out in the Environment Court's Practice Note 2023. I have complied with the Code of Conduct in preparing this evidence and will continue to comply with it while giving oral evidence before the Hearing Commissioners. Except where I state that I am relying on the evidence of another person, this written evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in this evidence.

3. SCOPE

3.1 This evidence is given in respect of the resource consent application by Helios for the proposed new solar farm at the Site. In my evidence I will:

(a) Describe the existing environment and briefly give an overview of the application.

(b) Provide a summary of the Glint and Glare analysis carried out for the Project.

(c) Respond to submissions in relation to glint and glare matters.

(d) Respond to the Section 42A Report.

(e) Provide a conclusion as to glint and glare effects and recommendations / proposed conditions relating to these findings.

4. EXISTING ENVIRONMENT AND PROJECT OVERVIEW

4.1 The Project Site is approximately 660 ha of land located approximately 3.3 km southwest of Naseby and 4.3 km north of Ranfurly in Central Otago.

4.2 The Project will comprise approximately 551,000 solar modules installed in single-axis tracking tables running north to south. Panels are arranged in a single portrait configuration, with tracker rows ranging from 52–104 modules in length. The solar farm will include 74 medium voltage ("**MV**") inverters with a capacity of 4.2 MVA.

4.3 The Project panels and tracking system will implement a backtracking limit angle of 10 degrees to mitigate potential glare impacts.

5. GLINT AND GLARE ANALYSIS

5.1 Glint is a momentary flash of bright light; in comparison, glare is a continuous source of excessive brightness relative to ambient lighting. Glint and glare are often caused when light reflected off a surface (reflector) is viewed by a person (receptor).

5.2 The difference between glint and glare is, therefore, a matter of duration. Glint typically occurs when either the receptor or the reflector is moving. Glare typically occurs when the reflector and receptor are completely, or nearly, stationary.[13]

5.3 The severity of the ocular hazard caused by glint or glare can be divided into three levels, which are described below.[14]

(a) green glare, which has low potential to cause temporary after image and is generally not considered a safety hazard;

(b) yellow glare, which has potential to cause temporary after image; and

(c) red glare, which can cause retinal burn. Red glare is not usually possible from solar photovoltaics ("**PV**"), as PV modules do not focus reflected sunlight.

5.4 PV cells are designed to absorb as much light as possible (generally around 98% of direct sunlight) to maximise efficiency. To enhance absorption and limit reflection, PV cells are constructed from dark, light absorbing material and are treated with an anti-reflective coating.[15]

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13 Refer to Section 1.2 of the Naseby Solar Farm, Glint and glare study, dated September 2023 for a detailed definition of glint and glare.

14 See also Figure 2: Classification of glare based on severity of ocular effects on page 8 of Naseby Solar Farm, Glint and glare study, dated September 2023.

15 Refer to Section 1.3 of the Naseby Solar Farm, Glint and glare study, dated September 2023 for an overview of glare from a solar panel.

5.5 The single axis tracking solar panel arrays proposed by Helios operate with a low angle of incidence for the majority of the day.[16] The main exception to this tracking approach occurs during very early mornings and late evenings. During these times, the low elevation of the sun causes trackers to cast shadows on each other (known as self-shading), which leads to significant loss of generation. To avoid these losses during these periods, the arrays are programmed not to face the sun directly, but to adopt lower tracking angles to eliminate self-shading. This strategy is called "backtracking". In most cases, the only time glare impact is experienced from tracking arrays is during backtracking as the combination of low sun elevation and near horizontal modules leads to a higher angle of incidence and a higher level of reflection.

5.6 For the Project, backtracking has been limited to ten degrees to mitigate the potential glare impact from certain receptors in very early mornings and late evenings.

5.7 The Glint and Glare Assessment is based on analysis using the ForgeSolar model, which uses the Solar Glare Hazard Analysis Tool ("**SGHAT**").[17]

5.8 The array model was developed based on Naseby Preliminary Layout[18] and mechanical details of the tracking structures. The proposed solar arrays at the Site will be bordered by vegetation screens, with the height and locations considered in the Glint and Glare Assessment based on the Planting Plan.[19]

5.9 My assessment considered potential visual receptors within 3 kilometres of the Site. There is no formal standard on the maximum distance for glint and glare assessments, however, the significance of a reflection decreases with distance for two main reasons:

(a) the solar farm appears smaller; and

(b) visual obstructions (ie terrain and vegetation) may block the view of the solar farm.

5.10 Glint and glare impacts beyond 3 km are highly unlikely. This choice of distance is conservative and is based on existing studies and assessment experience.

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16 Refer to section 1.3, of the Naseby Solar Farm, Glint and glare study, dated September 2023 for a further discussion of the angle of incidence.

17 Refer to Section 3.1 of the Naseby Solar Farm, Glint and glare study, dated September 2023 for an overview of the SGHAT tool.

18 Rev 0, attached as Appendix 2 to the Assessment of Environmental Effects, March 2024.

19 Figure 5A Landscape Mitigation Plan, Māniatoto Solar Farm Graphic Supplement dated 28 February 2024.

5.11 The original Glint and Glare Assessment concluded that,[20] without any additional mitigation, the seasonal amount of yellow glare which would be experienced on Ranfurly Naseby Road and Ranfurly Naseby Back Road would have been within reasonable limits, given the durations of glare are short and seasonal and the local roads are low traffic volume.

5.12 However, further Glint and Glare modelling was requested by Helios (following discussions with Central Otago District Council ("**Council**")) and undertaken in 2025 with the aim of eliminating yellow glare observed by drivers on the local road network.[21] This supersedes the previous assessment. The modelling incorporated:

(a) A backtracking limit of 10 degrees.

(b) The height of obstructions modelled as the height of vegetation and screens in the first year of the Project's operation.

(c) The changes stated in paragraph 2.7 of my evidence.

5.13 The further Glint and Glare modelling shows that, with the ten-degree backtracking limitation, the "existing vegetation screens" and "new vegetation screens" shown in Figure 2 below with a height of 3 metres are sufficient to eliminate residual yellow glare effects from the local road network.

20 Naseby Solar Farm, Glint and Glare Study dated September 2023.

21 ITP Renewables Minimum Screening Analysis for Maniatoto Solar Farm, Dated 30 April 2025.

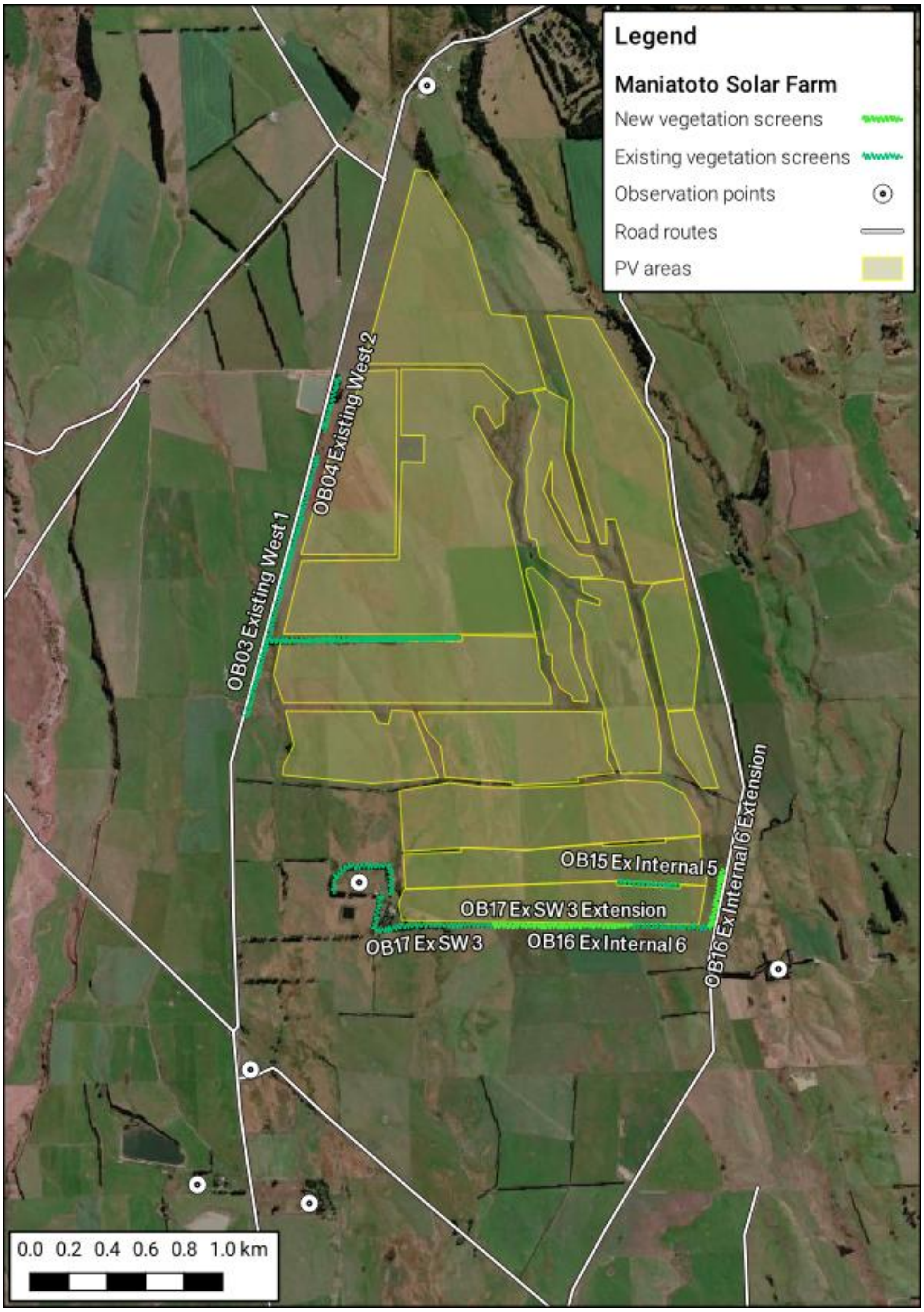

Figure 2: Existing and extended vegetation screening

5.14 The Landscape Planting and Maintenance Plan prepared by Boffa Miskell reflects these planting requirements as shown in Figure 1 and Figure 2.[22]

5.15 For completeness, the peer review of the Glint and Glare Assessment requested confirmation the glint and glare results would also apply to a driver

22 Dated 28 May 2025.

eye height of 1.15m (car driver) and 2.5m (truck driver).[23] I confirm that the glare effects at these heights do not change the conclusions of the assessment.

5.16 With the backtracking limitation, and the planting as outlined above, I am confident the glare effects from the Project will have a less than minor impact on amenity and road safety from the first year of the operation of the Project.

5.17 I recommend a condition of consent requiring the backtracking limit of ten degrees remains in place until the applicant can demonstrate the planting on all boundaries has reached sufficient height and density to screen all yellow glare effects from the Project, which will be confirmed by further glint and glare modelling based on the detailed designs and detailed planting plan, once complete.

6. MOONLIGHT GLARE ANALYSIS

6.1 I also conducted a Moonlight Glare Assessment for the Project (attached to my evidence as **Attachment 1**),[24] to address concerns raised by submitters during the public notification period regarding reflected moonlight affecting the town of Naseby's International Dark Sky Accreditation application and reflected moonlight creating a distraction for drivers.[25]

6.2 As the light from the Moon is hundreds of thousands of times dimmer than light from the Sun, there is no prospect that reflected moonlight poses an ocular hazard to drivers.

6.3 I expect any reflections will make a negligible contribution on local light pollution relative to the direct effect of the Moon itself due to the low luminance from the moon and the light absorbing properties of solar panels.

6.4 In conclusion, moonlight will have a negligible effect on local light pollution and would therefore not impact the ability of Naseby to obtain Dark Sky Accreditation.[26] Reflected moonlight will not pose an ocular hazard to drivers.

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23 Abley, Glint and Glare - Traffic Effects Review dated 13 June 2025.

24 ITP Renewables Consultants Advice Note, Moonlight glare dated 20 May 2025.

25 Submissions on moonlight glare are summarised in Section 7.

26 Noting also the Dark Sky Community Accreditation Naseby is seeking states under eligibility criteria there are **no night sky quality requirements** (https://darksky.org/what-we-do/international-dark-sky-places/apply/).

7. RESPONSE TO RELEVANT SUBMITTERS

7.1 I have read the 46 submissions which raise matters in relation to glint and glare.[27]

7.2 I have summarised the concerns raised by submissions below and responded to each thereafter:

(a) Sun strike and glare impacts for visual amenity.

(b) Sun strike and temporary blindness on roads, in particular Ranfurly-Naseby Road, Ranfurly Back Road, and State Highway 85 (Ranfurly-Wedderburn Road).

(c) The adequacy, applicability, and accuracy of the glare study.

(d) Glare for non-commercial pilots.

(e) The efficacy of vegetation screens to mitigate glare.

(f) Glare at night.

Sun strike and glare impacts for visual amenity

7.3 Submitters raised concerns regarding glint and glare from the solar PV panels in general,[28] with some identifying sun strike or impacts to the visual amenity of the landscape as key issues.

7.4 The proposed Project includes vegetation screening and a backtracking angle of 10 degrees to eliminate yellow glare impacts, as detailed in the Minimum Screening analysis for Maniatoto Solar Farm, dated 30 April 2025.

7.5 Residual glare impacts for surrounding receptors are limited to green glare, which is of much lower intensity than staring at the sun and is generally not considered hazardous, as displayed in Figure 3 below.

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27 Submissions 7, 18, 21, 24, 26, 27, 34, 38, 41, 43, 45, 49, 52, 57, 58, 61, 74, 81, 82, 84, 87, 89, 92-96, 98, 106, 111, 113, 120, 124, 127, 128,135, 136, 142, 148, 149, 155, 162, 169, and 170.

28 Submissions 7, 21, 34, 41, 52, 57, 84, 87, 92, 95, 98, 106, 111, 113, 120, 124, 128, 135, 136, 137, 169, 170.

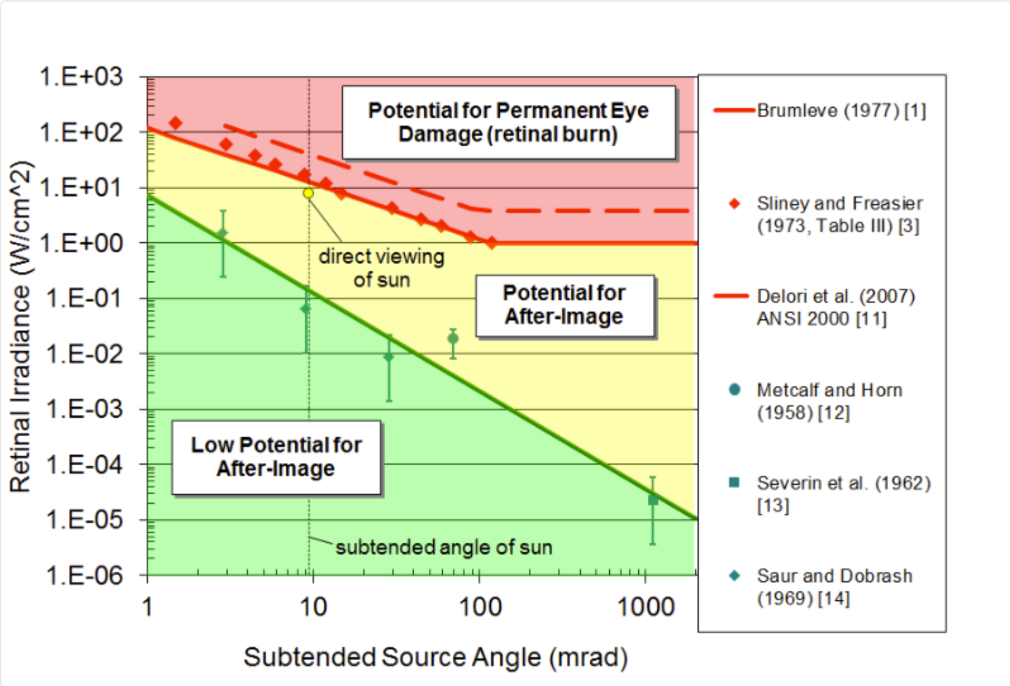

Figure 3: Glare hazard plot[29]

Glare impacts for drivers, in particular Ranfurly-Naseby Road, Ranfurly Back Road, and State Highway 85 (Ranfurly-Wedderburn Road)

7.6 Submitters raised concerns regarding the impact of glare on road safety,[30] many of which raised particular concerns regarding sun strike and temporary blindness. Several submissions identified issues with glare on Ranfurly-Naseby Road, Ranfurly Back Road, and State Highway 85.

7.7 With the proposed mitigation measures described above, glare impacts on the local road network are limited to green glare only, including for Ranfurly-Naseby Road, Ranfurly Back Road, and State Highway 85. As detailed above, green glare is generally not considered hazardous.

Adequacy, applicability, and accuracy of the glare study

7.8 Submitters raised questions concerning the adequacy, applicability, and accuracy of the glare study.[31]

7.9 Submitter 82 raised concerns regarding changes to the topography impacting study results and asked about steps to address issues following construction. In response:

29 Ho, C. K., Ghanbari, C. M., and Diver, R. B., 2011, "Methodology to Assess Potential Glint and Glare Hazards From Concentrating Solar Power Plants: Analytical Models and Experimental Validation", ASME J. Sol. Energy Eng., 133.

30 Submissions 18, 24, 26, 27, 38, 41, 43, 45, 49, 52, 58, 61, 74, 89, 93, 94, 95, 120, 127, 128, 135, 136, 137, 142, 128, 129, 152, 162.

31 Submissions 82, 96, 12, 135, 136, 149.

(a) No earthworks are proposed for the Project.

(b) The model uses site-specific elevation data from Google Earth for the PV array, receptors, roads, and obstructions to conduct the analysis.

(c) Conditions to address issues following construction are outlined in Section 9 below.

7.10 Submitter 96 questioned the adequacy of the study in general. The assessments undertaken are based on industry standard modelling and uses industry standard software carried out by a subject matter expert.

7.11 Submitters questioned the panel layout, elevations, and backing.[32] As stated above, the model uses site-specific ground elevation data and states assumptions regarding the height of PV panels above the ground. In terms of the Project layout, the PV array was divided into 13 separate areas based on the Naseby Preliminary Layout. The PV panels are then modelled as evenly distributed throughout the defined areas, based on the orientation and tracking regime of the proposed solar farm. The tracking regime includes any backtracking limits.

7.12 Submitter 128 raised questions regarding the distance of the study boundary. As detailed in paragraphs 5.9 and 5.10, the glare hazard is reduced at increased distances due to the smaller subtended angle of the solar farm, meaning it takes up much less of the viewer's field of vision.

7.13 Submitter 128 raised concerns regarding increased proportion of reflected light at low angles. In response:

(a) I agree that a higher angle of incidence increases the proportion of light reflected from a surface, although I note that the proportion of reflected light remains below 10% except for very high angles of incidence (>70 degrees). This fact is included in our assessment and is incorporated into the glare model accordingly.

(b) I note that periods during which the angle of incidence is high will coincide with periods of lower light such as sunrise and sunset. Further, the source of glare and the sun will appear to come from similar locations according to the viewer (due to high angles of incidence resulting in lower redirection of reflected light). As such,

32 Submissions 128, 135, 136, 149.

the timing of glare in these instances will coincide with a pre-existing risk of glare from the sun.

(c) As stated above, until planting screens are of sufficient height and density to block glare from the road network, the Project will have a backtracking limit of 10 degrees, which will increase the angle of incidence to reduce reflected light.

7.14 Submitter 128 raised concerns regarding the number of points along road routes measured. Receptors for road routes are modelled as a continuous line along the route, rather than a single, stationary receptor at one point on the route. Road routes included in the ForgeSolar model are displayed in Figure 7 of ITP's glint and glare report and in the accompanying ForgeSolar analysis reports.

7.15 Submitter 128 raised concerns regarding the glare prior to the energisation of the Project. Prior to energisation, panels will be stowed at a high tilt angle of 50–60 degrees. This will significantly reduce, if not eliminate, glare impacts for several reasons:

(a) During sunrise and sunset – the periods with the highest risk of glare – the low angle of incidence resulting from a high tilt angle will minimise the proportion of reflected light.

(b) During the middle of the day – when the sun is high in the sky – the high tilt angle of the solar panels will result in a high angle of incidence, with reflected light directed towards the ground.

(c) Only following commissioning and the first operation of the solar farm (where there is export to the National Grid) will the panels track and follow the sun.

Glare for non-commercial pilots

7.16 Submitter 155 raised concerns regarding glare for agricultural pilots, aerial firefighting pilots, rescue pilots, and helicopter pilots for the helipad at the Ranfurly Hospital.

7.17 ITP Renewables conducted analysis using ForgeSolar flight paths associated with the helipad located at Ranfurly Hospital, which indicated pilots would not be subject to yellow glare during take-off and approach.[33] This is an acceptable outcome according to the Federal Aviation Administration policy.[34]

7.18 Further to the above, ITP Renewables also modelled the north flight path for the helipad over 3 km, to provide a conservative assessment of glare effects. This revealed no instances of yellow glare for helicopter pilots approaching / leaving the helipad in the north.

The efficacy of vegetation screens to mitigate "strobe" effect glare

7.19 Submitter 81 raised concerns regarding possible "strobe" effects for passing traffic due to glare passing through the trees.

7.20 The backtracking limit will mitigate much of the yellow glare. Given ForgeSolar models obstructions as opaque objects, the vegetation screening will need to be planted with sufficient depth to appear essentially opaque in order to be effective.

Glare at night

7.21 As the light from the Moon is hundreds of thousands of times dimmer than light from the Sun, there is no prospect that reflected moonlight poses an ocular hazard to drivers at night. Refer to the Moonlight Glare Assessment in **Attachment 1** for further detail.

8. RESPONSE TO SECTION 42A REPORT

8.1 I have reviewed the Section 42A Report dated 7 July 2025 ("**Section 42A Report**") and generally agree with the comments relating to potential glare effects of the Project.

8.2 In particular, I agree with the paragraph 84 of the Section 42A Report, that states the levels of glare on the local road network are acceptable. Further I agree that the Project should implement a 10° backtracking limit until the surrounding vegetation screens are sufficiently established to mitigate yellow glare effects in the absence of a backtracking limit angle.

8.3 Paragraph 85 of the Section 42A Report acknowledges that strobing effects may occur at points where glare occurs and is not blocked by vegetation. While

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33 The study was conducted assuming a flight path distance of 1 km from the helipad with a slope of 5°, azimuthal view of 100° (50° either side of centre), and downward view of 90°.

34 Federal Aviation Administration, *Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports*, 2013.

the Section 42A Report also notes that this could be potentially more disruptive than a constant glare, it concludes that, should the development proceed in a way that avoids instances of yellow or red glare, the effects of glare would be sufficiently low that strobing would not substantially change the potential effects.

8.4 With respect to the strobing effects, my opinion is that the vegetation screens should be established with sufficient depth and density to essentially appear as an opaque barrier.

9. RECOMMENDED CONDITIONS

9.1 The following conditions of consent were proposed in Abley's *Maniatoto Solar Farm Glint and Glare – Traffic Effects Review* dated 13 June 2025 and Condition 29 of the Proposed Conditions in the Section 42A Report. In my opinion, these conditions are reasonable with a minor amendment to (c) as shown in strikeout below.

> Condition 29: The Consent Holder must prepare and implement a Glint and Glare Adaptive Management Plan (GGAMP) to address any substantiated adverse glint and glare impacts on affected parties and/or the surrounding road network. The GGAMP must include the following:
>
> …
>
> (c) Reporting Procedures: The plan must include procedures for reporting glint and glare issues by affected parties, including Road Controlling Authorities for any road network affected by "Yellow glare" or "Green glare". This includes:
>
> (i) The process for lodging a complaint.
>
> (ii) The timeline within which the Consent Holder must acknowledge receipt of the complaint.
>
> (iii) A detailed timeline for the investigation and response process, ensuring that any substantiated glare issues reported are addressed promptly and effectively within a specified timeframe.
>
> (iv) Adaptive Management Strategies: The GGAMP should detail a range of possible mitigation solutions to address reported glint and glare issues. These solutions may include but are not limited to, ~~physical alterations to the solar farm~~

~~setup,~~ installation of screening or landscaping to block or diffuse glare, and adjustments to the operational procedures of the solar farm (such as tracking management).

…

9.2 Physical alteration of the solar farm set up is not required as a possible solution because, in my opinion, the other solutions listed above provide sufficient options for removing residual yellow glare from the road network.

10. CONCLUSION

10.1 Given the results of ITP Renewables' glare study for the Project, and the evidence provided above, it is my opinion that the glare effects of the Project are less than minor.

Nicholas Logan

21 July 2025

Attachment 1 – Moonlight Glare Assessment

(separate attachment)

ITP Renewables

Consultants Advice Notice

To	Sarah Brooks, Senior Environmental Planner, Helios Energy Limited		
From	Nicholas Logan, Project Engineer, ITP Renewables		
Subject	Moonlight glare		
Project No.	25038	**CAN No.**	002
Date	20/05/2025	**Pages**	4

Background

ITP Renewables conducted the glint and glare study for Helios Energy Limited's (Helios) proposed Maniatoto Solar Farm at 48 Ranfurly-Naseby Road in Central Otago. The town of Naseby (to the north of the proposed solar farm) is working towards Internation Dark Sky accreditation. Some residents have raised concerns about reflected moonlight affecting the bid for dark sky status and creating a distraction for drivers. This advice notice details our assessment of these concerns.

We assume that readers are familiar with our original 2023 study[1] and our June 2024 addendum,[2] although some diagrams to contextualise solar glare are repeated in this notice.

Glare from Solar PV

Solar photovoltaic (PV) cells are designed to absorb as much light as possible to maximise efficiency (generally around 98% of the light received). To limit reflection, solar cells are constructed from dark, light-absorbing material and are treated with an anti-reflective coating. PV modules generate less glare than many other surfaces, as shown in Figure 1.

The small percentage of light reflected from PV modules varies depending on the angle of incidence. Figure 2 shows an example of this with a solar module. A larger angle of incidence will result in a higher percentage of reflected light.

[1] ITP Renewables (2023), *23048 – Naseby Solar Farm – Glint and Glare Study Final*
[2] ITP Renewables (2024), *23048-CAN001 – Glare Study Addendum*

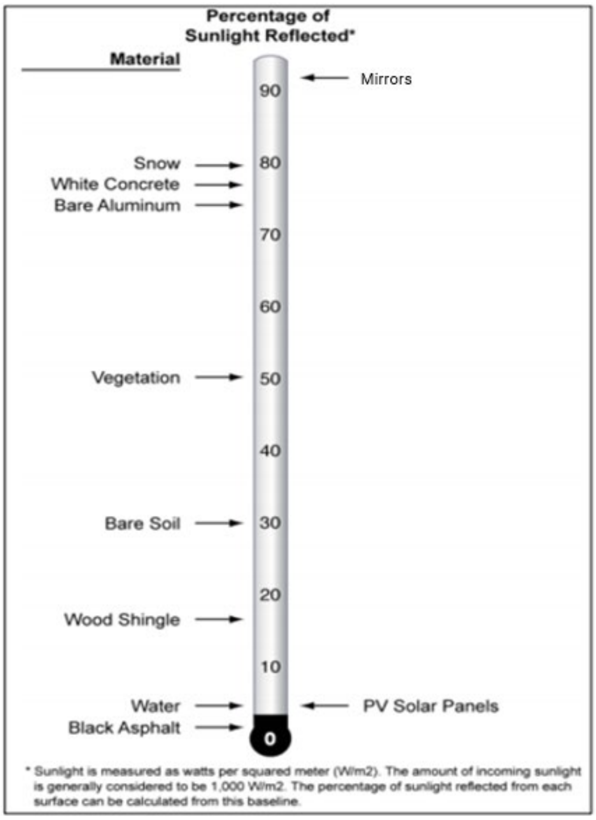

Figure 1: Typical percentage of sunlight reflected from different surfaces.[3]

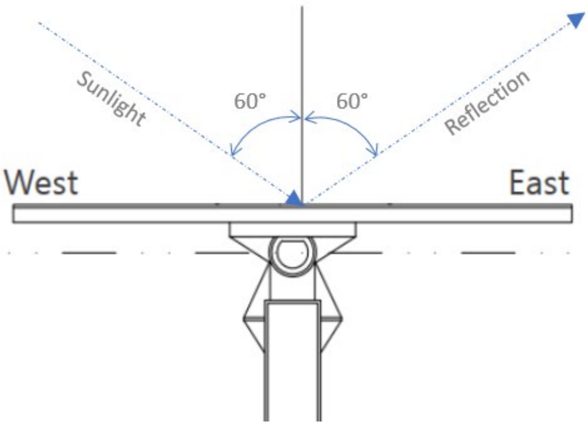

Figure 2: Typical sunlight reflection off the surface of a PV module with an angle of incidence of 60°

The two most common PV mounting structures are fixed tilt and single axis tracking. Fixed tilt arrays are stationary, while single axis tracking arrays rotate the receiving surface of the modules from east to west throughout the day as the Sun moves across the sky. At night, the modules are stowed at a fixed angle before rotating to face east at sunrise.

In a fixed tilt PV array, since the Sun is moving but the modules are stationary, the angle of incidence varies as the Sun moves across the sky. It is smallest around noon when the Sun is overhead and largest

[3] Journal of Airport Management, 2014

in the early morning and late afternoon when the Sun is near the horizon. There is therefore a higher potential for glare at these times. The potential for glare from the Moon follows the same pattern.

The angle of incidence for a single axis tracking system varies less as the reflective surface of the modules rotates on a horizontal axis to follow the Sun. Single axis tracking arrays therefore generate less glare than fixed tilt arrays. The tracking varies throughout the year to match seasonal changes in the Sun's path (see Figure 3). As trackers do not follow the motions of the Moon at night, the glare potential from the Moon is similar to the fixed tilt case.

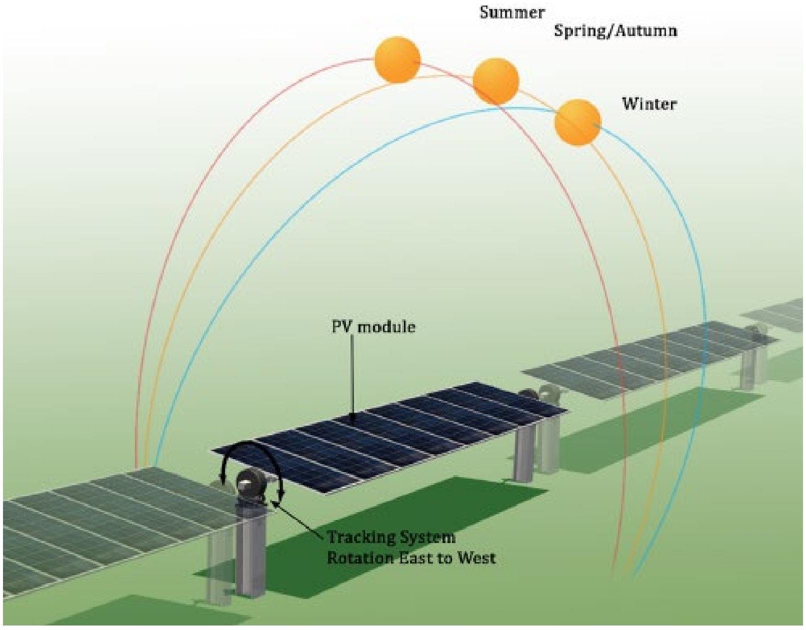

Figure 3: Sun position relative to PV modules on a horizontal single-axis tracking system

Moonlight in Context

The luminance of Moon varies dramatically depending on the phase, season, and distance from the Earth. For simplicity, we will only consider the case of a full moon, which has maximum luminance, and clear skies as this is the worst-case scenario for any reflected moonlight.

The most common comparison of the brightness of Moon to the Sun states that the Moon is about 400,000 times less bright than the Sun. This is based on astronomical observations that compare the brightness of bodies to known standards (called the "apparent magnitude"). This measure is not typically used to assess glare hazard, as it is primarily intended for measuring the luminance of stars.

The two quantities that are used to assess glare hazard are irradiance (radiant power per unit area), which is measured in Watts per square metre (W/m^2), and luminance (irradiance adjusted to account for human visual perception of light), which is measured in candelas per square metre (cd/m^2).

ForgeSolar assesses glare based on the ocular hazard posed by the light source (i.e. sunlight reflected from solar panels). Ocular hazards are determined based on the irradiance (in W/m^2) that reaches an observers' retina, and apparent size of the source as seen by that observer. Many factors affect this determination, but when comparing lunar glare to solar glare, the only significant difference is the source irradiance of the Moon and Sun. The irradiance of the Sun is typically assumed to peak at 1,000 W/m^2. A similar standard assumption for the Moon does not exist as the Moon is not typically considered to be a hazardous source of glare. A detailed study of the spectral irradiance of the Moon for the calibration of satellite instruments was undertaken in 2013.[4] Based on this spectrum we estimate that the total irradiance of reflected moonlight at the top of the atmosphere to be 0.013–0.014 mW/m^2, which is approximately 1 million times smaller than solar radiation at the top of the atmosphere. Transmission through the atmosphere, and reflection from solar panels (which are designed to absorb light) will further reduce this.

Glare assessments can also be based on the source luminance (in cd/m^2). Some typical luminance values are listed in Table 1 below. The luminance of the full Moon is approximately 640,000 times smaller than the luminance of the Sun at noon. The luminance of both the Sun and the Moon is significantly lower at the horizon when the glare potential from solar panels on single-axis trackers is typically highest.

Table 1: Typical luminance values

Source	Typical luminance (cd/m^2)
Sun disk at noon	1,600,000,000
Sun disk at horizon	600,000
Cool white fluorescent lamp	11,000
Average clear sky	8,000
Moon surface (full moon)	2,500
Average cloudy sky	2,000

As illustrated above, light from the Moon is hundreds of thousands of times dimmer than light from the Sun. Hence, there is no prospect that reflected moonlight poses an ocular hazard to drivers. Furthermore, many other sources of light are far more luminous than the Moon, including streetlights, headlights of other vehicles, and reflected light from a vehicle's own headlights.

Dark Sky Accreditation

As stated above, the luminance of the Moon varies significantly based on phase, season, and distance from the Earth. The maximum potential for reflected moonlight from the solar farm coincides with peak luminance from the Moon. The luminance from the Moon itself can significantly affect dark sky conditions and the visibility of other stellar objects. Hence, we are only concerned about the incremental effect of the solar farm.

As described above, solar PV modules are designed to absorb light to increase efficiency (generally around 98% of received light). Hence, during periods of peak luminance from the Moon (i.e. the Moon is at the full and high in the sky) the solar farm will absorb the vast majority of received moonlight. Any reflections will make a negligible contribution on light pollution relative to the direct effect of the Moon.

Conclusions

Based on our analysis, reflected moonlight does not pose an ocular hazard to drivers, and reflected moonlight will have a negligible effect on light pollution.

[4] C. E. Cramer, K. R. Lykke, J. T. Woodward, and A. W. Smith (2013), *Precise Measurement of Lunar Spectral Irradiance at Visible Wavelengths*, http://dx.doi.org/10.6028/jres.118.020