FUTURE IMPACT
ENVIRONMENTAL MODELLING & CONSULTING

GLINT AND GLARE ASSESSMENT
FOR THE PROPOSED
PAARDEVLEI SOLAR PHOTOVOLTAIC (PV)
& BATTERY ENERGY STORAGE SYSTEM (BESS) PROJECT
SOMERSET WEST
WESTERN CAPE PROVINCE
SOUTH AFRICA

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PROJECT INFORMATION	
Project name	Glint and Glare Impact Assessment of the Proposed Paardevlei Solar Photovoltaic (PV) and Battery Energy Storage System (BESS) Project
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Contributors to the report	Dr Brett Williams and Mr Jason Hutten of Future Impact (www.futureimpact.co.za)

Amendment History

Version 1	Original	04/12/2023
Version 2	Results Table for Fixed Tilt configuration at 20˚, 25˚, and 30˚	12/12/2023
Version 3	Minor Editorial Changes	14/10/2024

DECLARATION

I hereby declare that I do:

(a) have knowledge of and experience in conducting assessments, including knowledge of the Act, these regulations and guidelines that have relevance to the proposed activity;

(b) perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;

(c) comply with the Act, these regulations, guidelines, and other applicable laws.

I also declare that there is, to my knowledge, no information in my possession that reasonably has or may have the potential of influencing –

(i) any decision to be taken with respect to the application in terms of the Act and the regulations; or

(ii) the objectivity of this report, plan or document prepared in terms of the Act and these regulations.

[redacted]

Dr Brett Williams

Future Impact (PTY) Ltd

EXECUTIVE SUMMARY

Future Impact (Pty) Ltd were appointed by JG Afrika, on behalf of the City of Cape Town, to conduct a desktop review pertaining to glint and glare impacts on aviation receptors as a result of light reflecting off of the Paardevlei Solar PV panels. The proposed Solar Facility and its associated infrastructure is located in Firgrove Rural, Somerset West, Western Cape.

The assessment was conducted with the objective of determining how 'glint' and 'glare' will affect aviation receptors such as pilots on final approach to the airports, as well as the Air Traffic Control Tower (ATCT) operations. Cape Town International Airport (ICAO: FACT) and Stellenbosch Airport (ICAO: FASH) were identified as facilities that may be exposed to glint and glare impacts. Four 2-mile flight paths and one ATCT were identified as receptors for the Cape Town International Airport. Two 2-mile flight paths were identified for the Stellenbosch Airport. There is no ATCT at the Stellenbosch Airport due to its small size and low aircraft traffic.

If the 'glint' and 'glare' effects are strong enough, it has the potential to cause temporary flash blindness for the receptors and hinder their abilities to conduct their operations. The glare is rated in three categories, namely as green, yellow, and red with red being the highest risk from an aviation perspective as an after image could occur.

The modelling results indicate that the receptors at the airports will be exposed to green glint and glare if Site Plan 01 (Fixed Tilt at 34˚) or Site Plan 02 is implemented. If a 20˚ Fixed Tilt angle is considered for Site Plan 01, no glint and glare exposure will occur. Additionally, Site Plan 03 will also cause no glint and glare exposure to the receptors.

It should be noted that although green glare could be experienced by the Air Traffic Controllers at the FACT Control Tower, the intensity of the glare will be mitigated by the distance from the project to the Control Tower, the short duration thereof as well as the window tinting that is already in place, and that the project is not on the extended centre line of the main runway (FACT Runway 01/19), but 19km to the South-East of the field.

It is therefore recommended that the project receive authorisation from the Civil Aviation Authority from a glint and glare perspective.

[redacted]

Dr Brett Williams

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2-Mile Flight Path Receptor: The 2-Mile Flight Path receptor ("FP") simulates an aircraft following a straight-line approach path toward a runway, by default, including a restricted field-of-view to filter unrealistic glare. In addition, it can be modified to represent a worst-case approach and take-off path. Statute miles are used in this report as it is a commonly used distance unit in aviation.

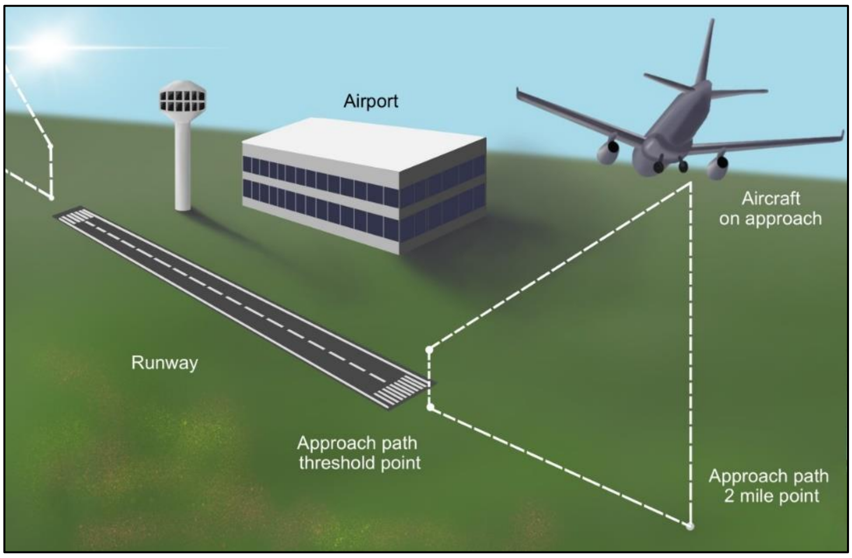

Figure 1: Flight Path

Flight Path Parameters are as follows:

- **Name:** Descriptive alphanumeric label of receptor
- **Direction (°):** Azimuthal angle of approach of aircraft which defines the straight path toward the runway. Measured clockwise from true north.
- **Glide slope (°):** Angle of descent of aircraft toward runway. Default value of 3°.
- **Threshold crossing height**: Height above ground of aircraft when it crosses the runway threshold. (Typically, 50 ft.).
- **Max downward viewing angle (°):** The vertical field-of-view of the pilot, measured positive downward from the XY plane (i.e. flat). A default value of 30° assumes glare appearing beyond that FOV is not visible to the pilot and is acceptable to FAA. A value of 90° assumes the pilot can see glare appearing directly underneath the aircraft.
- **Azimuthal viewing angle (°):** The left and right field-of-view of the pilot during approach. A view angle of 180° implies the pilot can see glare emanating from behind the plane.
- **Point coordinates:** The threshold and 2-mile point ground elevation parameters can be modified in the FP Advanced dialog. The 2-mile point height is calculated from the point elevations and threshold crossing height to ensure a smooth 2-mile descent path.

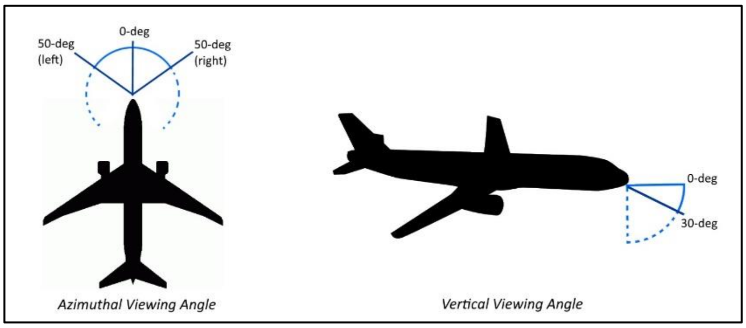

Figure 2: Viewing Angles

Glint and Glare: Glint is typically defined as a momentary flash of bright light, often caused by a reflection off a moving source. A typical example of glint is a momentary solar reflection from a moving car. Glare is defined as a continuous source of bright light. Glare is generally associated with stationary objects, which, due to the slow relative movement of the sun, reflect sunlight for a longer duration. The difference between glint and glare is duration. Industry-standard glare analysis tools evaluate the occurrence of glare on a minute-by-minute basis; accordingly, they generally refer to solar hazards as 'glare'. Based on figure 3 (below), the ocular impact of solar glare is quantified into three categories:

→Green - low potential to cause after-image (flash blindness)

→Yellow - potential to cause temporary after-image.

→Red - potential to cause retinal burn (permanent eye damage)

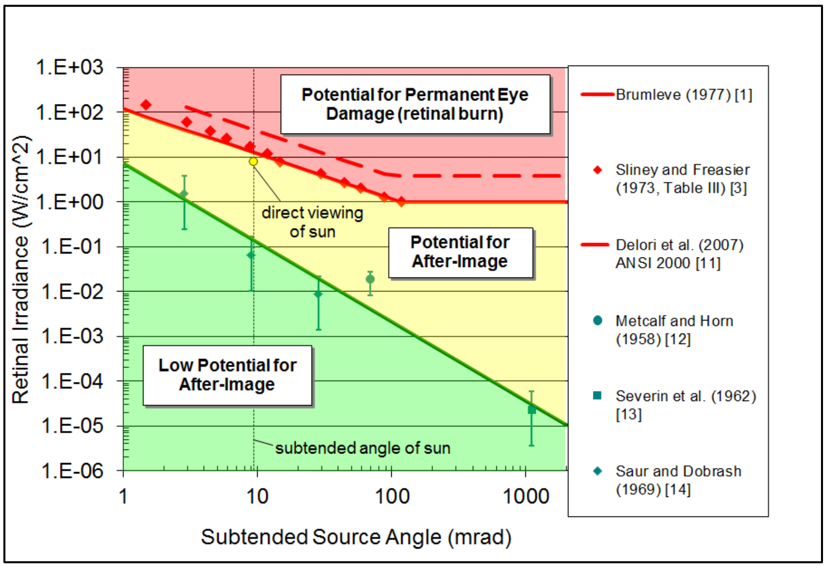

Figure 3: Glare Categories.

mrad: Milliradian, equal to one-thousandth of a radian. A radian is a unit of angular measure equal to the angle subtended at the centre of a circle by an arc equal in length to the radius of the circle, approximately 57°17'44.6".

Peak DNI (W/m2 or Wh/m2): The maximum Direct Normal Irradiance at the given location at solar noon. DNI is the amount of solar radiation received in a collimated beam on a surface normal to the sun during a 60-minute period. On a clear sunny day at solar noon, a typical peak DNI is ~1,000 W/m2.

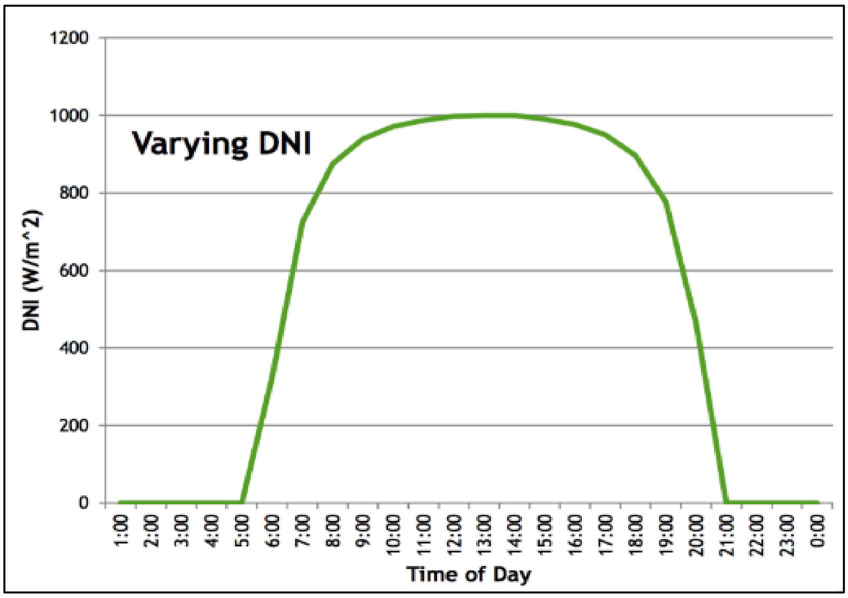

Figure 4: Peak Daily DNI

Slope error (mrad): Specifies the amount of scatter that occurs from the PV module. Mirror-like surfaces that produce specular reflections will have a slope error closer to zero, while rough surfaces that produce more scattered (diffuse) reflections have higher slope errors. Based on observed glare from different PV modules, an RMS slope error of ~10 mrad (which produces a total reflected beam spread of 0.13 rad or 7°) appears to be a reasonable value. Not used if correlate slope error to module surface type is checked. In this report, the worst-case scenario was assumed. Therefore, a light-textured PV panel with an anti-glare coating was selected for modelling. The properties of the selected panel are as follow: 9.16mrad average RMS slope error; 119.00mrad average beam spread; 3.17 standard deviation of slope error; and 38.00 standard deviation of beam error.

ATCT: *Air Traffic Control Tower*
BESS: *Battery Energy Storage System*
FAA: *Federal Aviation Authority*
FACT: *Airport Code for Cape Town International Airport*
FASH: *Airport Code for Stellenbosch Airport*
FoV: *Field of View*
FP: *Flight Path*
mRad: *milliradian*
OP: *Observation Point*
PV: *Photovoltaic*
RMS: *Root Mean Square*

1 INTRODUCTION

1.1 TERMS OF REFERENCE

This report aims to determine the effect that potential solar PV 'glint and glare' may have on various aviation receptors due to the Paardevlei Solar Photovoltaic (PV) panels in Somerset West ("The proposed project"). The main receptors of concern are the aviation receptors (i.e. the pilots and ATCT operator) at the Cape Town International Airport (FACT) and Stellenbosch Airport (FASH).

At certain angles, the sun may reflect light in a specular manner off the surface of the Photovoltaic panels and affect the receptors vision, thereby causing an 'after-image' or 'temporary blindness' depending on the strength of the specular reflection. In South Africa, there is limited literature and no regulatory framework with regards to the 'glint and glare' effects from solar panels in relation to airspace use. In the absence of a regulatory requirement, the United States Federal Aviation Authority's (FAA) Technical Guidance for Evaluating Selected Solar Technologies on Airports, version 1.1 of April 2018 was used as the main reference. Within this guideline are numerous case studies of solar projects similar to this project. The FAA approved ForgeSolar software package was used to predict the effects of the glint and glare from the PV panels.

1.2 ASSUMPTIONS AND LIMITATIONS

The design specifications of the project were supplied by the client. These have not yet been finalized and the modelling has therefore been conducted within a range of feasible parameters to represent the worst-case scenarios.

A summary of assumptions and abstractions required by the ForgeSolar analysis methodology is provided below:

- 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, the software developers have validated the 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 USA, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.
- 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.
- 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 Air Traffic Control Towers (ATCT's). The ForgeSolar methodology relies on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.
- 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.)

- 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.
- The variable direct normal irradiance (DNI) feature 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.
- The ocular hazard predicted by the tool depends on several environmental, optical, and human factors, which can be uncertain. The developers 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 system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round.
- Hazard zone boundaries shown in the Glare Hazard plot (based on Figure 4) are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
- Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.

2 LEGAL REQUIREMENTS

There are no legal requirements or guidelines that are applicable in South Africa. The US FAA guidelines were used as a reference[1].

[1] *There is no approved software package or guidelines in South Africa for Glint and Glare Studies around airports. All previous glint and glare studies that the author has submitted to SACAA have been accepted and the methodology not questioned.*

3 PROJECT DESCRIPTION

The client is proposing the development of a Solar PV Facility and Battery Energy Storage System (BESS) on land owned by the City of Cape Town, near Somerset West. The total extent of the land portions is 152ha. The proposed project will be connected an existing 132kV switching station near the site and have a total generation capacity of between 30 MW and 60 MW.

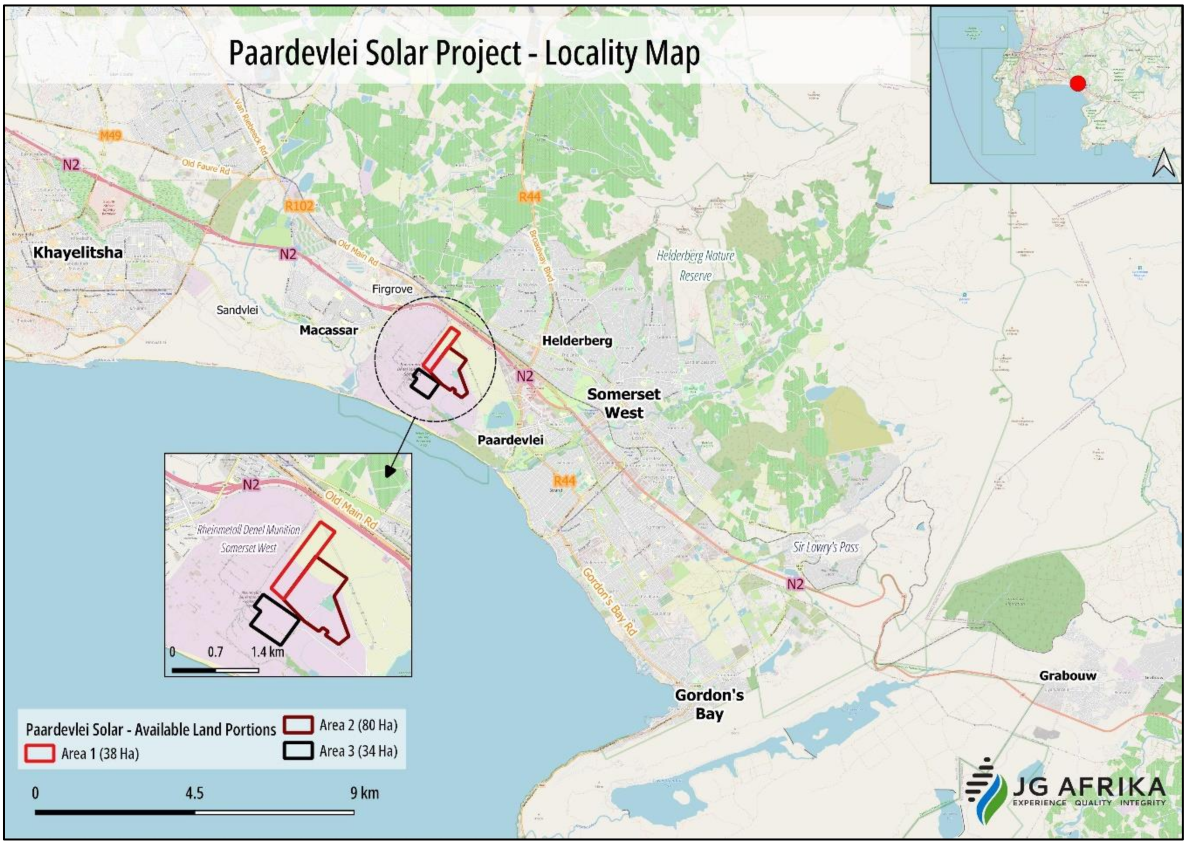

Figure 5: Paardevlei Solar PV Layout (JG Afrika, 2023).

The technical design parameters have not yet been confirmed, this report assesses a sample of configurations that may be feasible. Not all configurations have been included in this report, instead the worst-case scenario configurations have been included.

4 THE RECEIVING ENVIRONMENT

As previously mentioned, the project is situated in the vicinity of the Cape Town International Airport and the Stellenbosch Airport.

Cape Town International Airport is located approximately 19km to the North-West of the proposed project and consists of two runways. Runway 01/19 is orientated north to south, and Runway 16/34 is orientated North-West to South-East. The one Air Traffic Control Tower (ATCT) is approximately 35m above ground level. The sensitive receptors identified for Cape Town International Airport therefore include four 2-mile flight paths and one stationary Observation Point (the ATCT).

Stellenbosch Airport is located approximately 9km to the North of the proposed project and consists of one runway. Runway 01/19 is orientated NNW to SSE. The sensitive receptors identified for the Stellenbosch Airport include two 2-mile flight paths and no Air Traffic Control Tower (ATCT).

Other community receptors have not been modelled, such as the nearby suburbs and motor vehicles, as this report's focus is solely on the aviation receptors. Figure 6 below shows the layout of the receiving environment.

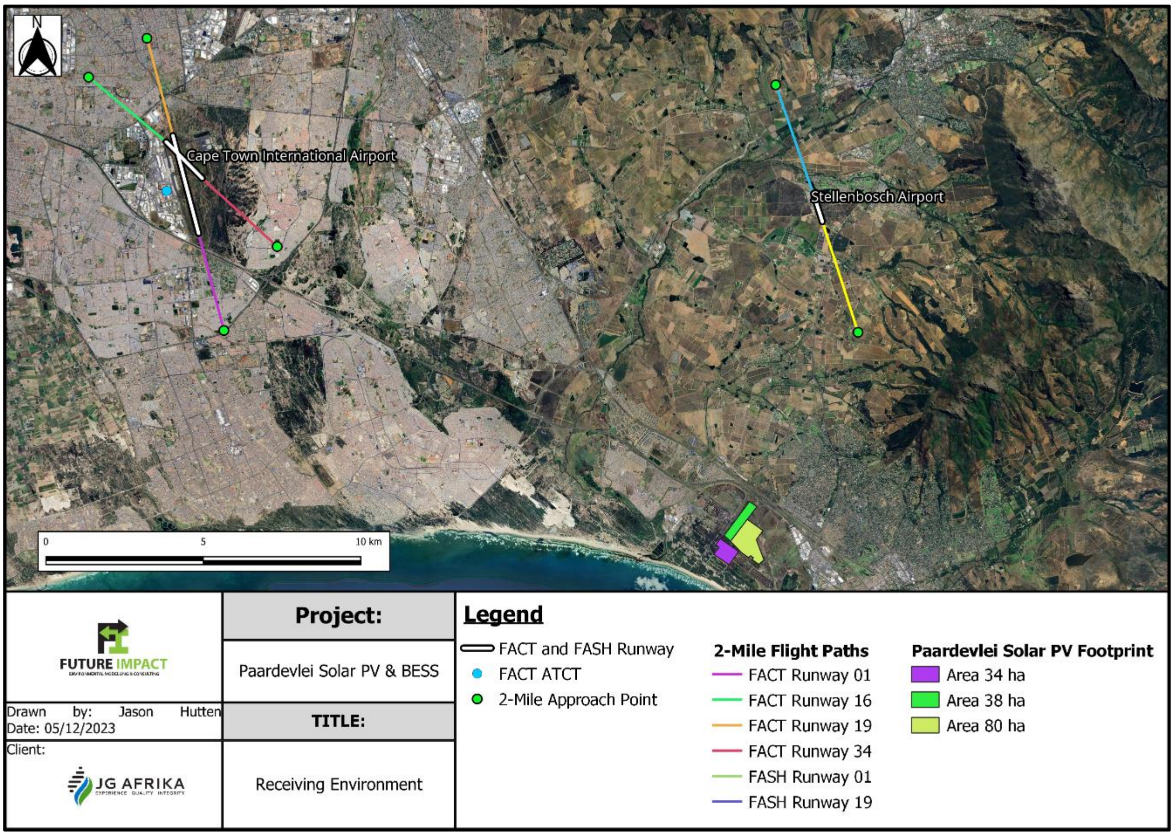

Figure 6: Regional Context and Receiving Environment

5 RESULTS

The Client is considering three configurations. The final design parameters have not yet been confirmed. For the purpose of this study, the worst-case scenario has been assessed to avoid redundancy. This is discussed further in each subsection below. The height above ground level of the panels will be either 1.0m or 0.5m, the latter of which was assessed as a worst-case scenario (although the difference is negligible).

The analysis parameters and observer eye characteristics were as follows:

- Analysis time interval: 1 minute
- Ocular transmission coefficient: 0.5
- Pupil diameter: 0.002 meters
- Eye focal length: 0.017 meters
- Sun subtended angle: 9.3 milliradians

5.1 SITE PLAN 01 – FIXED TILT CONFIGURATION

The first option under consideration is the fixed tilt configuration. The panels will be orientated in rows from East to West and tilt towards the North, as seen in Figure 7 below. The tilt angles being considered are as follows: 20˚, 27˚, 30˚, 33˚ and 34˚. Preliminary modelling indicated that a configuration of 34˚ would result in the most exposure to glint and glare for the aviation receptors and was therefore included in this report. Additional modelling results for the configuration using a fixed tilt angle at 20˚ has been included in Table 1 below. The results of the additional modelling show that no glint and glare exposure will occur when considering a 20˚ fixed tilt angle design.

Table 1: Additional Modelling Results (Fixed Tilt Angle at 20˚)

Receiver Name	Green Glare (mins)	Yellow Glare (mins)	Red Glare (mins)
FACT Runway 01	0	0	0
FACT Runway 16	0	0	0
FACT Runway 19	0	0	0
FACT Runway 34	0	0	0
FASH Runway 01	0	0	0
FASH Runway 19	0	0	0
1-ATCT	0	0	0
Total	**0**	**0**	**0**

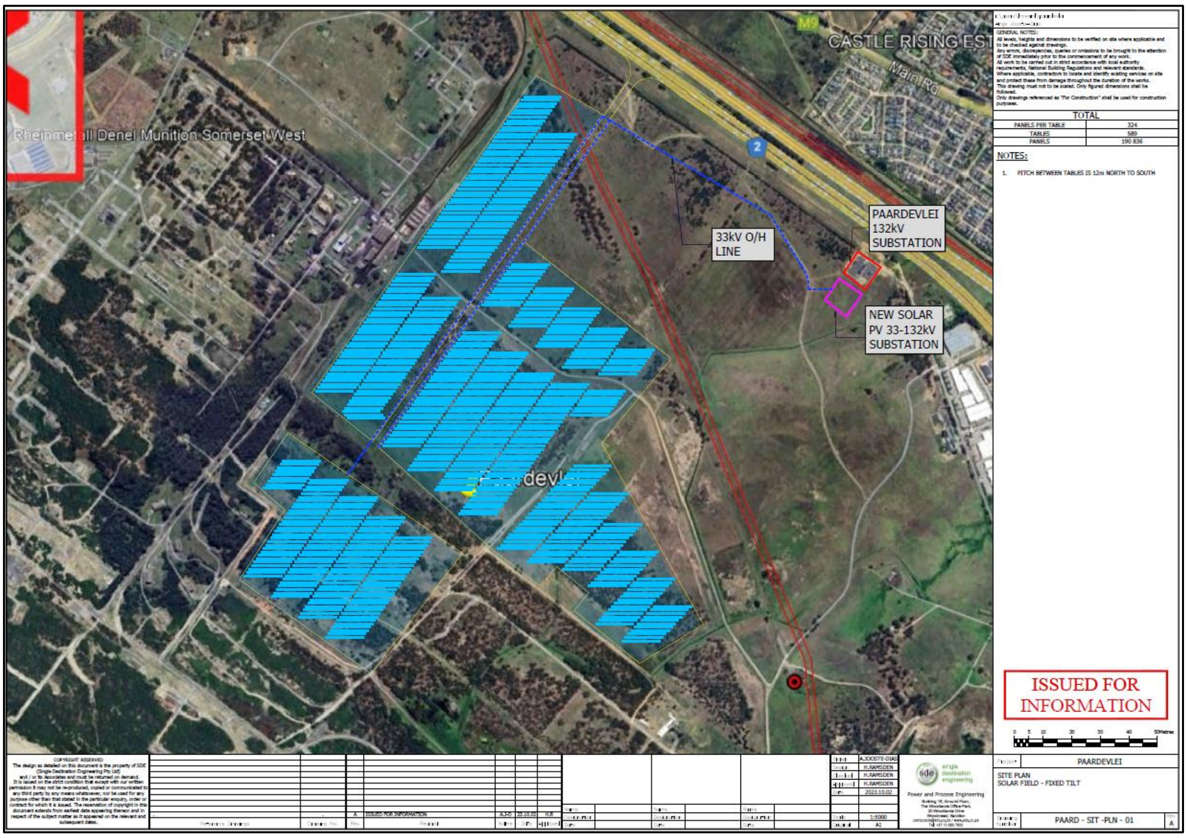

Figure 7: Site Plan 1 - Fixed Tilt Configuration (SDE, 2023)

The modelling results for the fixed tilt angle of 34˚ is shown in Table 2 below. Figures 8-13 provide further information regarding the times of the day and year when glint and glare exposure can be expected.

Table 2: Fixed Tilt Configuration Glint and Glare Exposure Time for Aviation Receptors

Receiver Name	Green Glare (mins)	Yellow Glare (mins)	Red Glare (mins)
FACT Runway 01	0	0	0
FACT Runway 16	475	0	0
FACT Runway 19	112	0	0
FACT Runway 34	0	0	0
FASH Runway 01	0	0	0
FASH Runway 19	0	0	0
1-ATCT	1 115	0	0
Total	**1 702**	**0**	**0**

FACT Runway 16

Figure 8 below shows that the green glare will occur in the morning hours (c.a. 08h00) between the months of December to January.

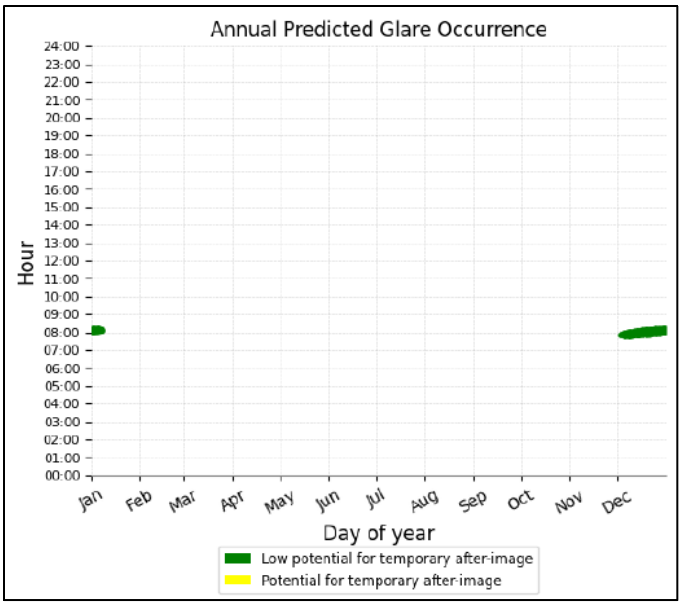

Figure 8: FACT Runway 16 Exposure Times (Fixed Tilt)

Figure 9 below shows the areas of the Solar PV Arrays that will cause the glare exposure to the receptor at FACT Runway 16.

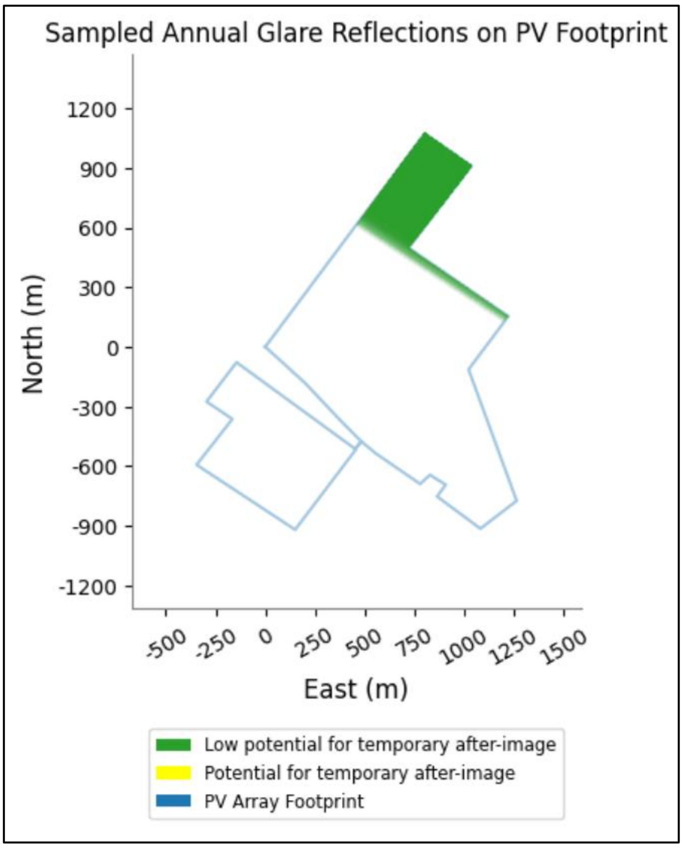

Figure 9: FACT Runway 16 Solar PV Footprint Causing Glare (Fixed Tilt)

FACT Runway 19

Figure 10 below shows that the green glare will occur in the morning hours (c.a. 08h00) between the months of December to the beginning of January.

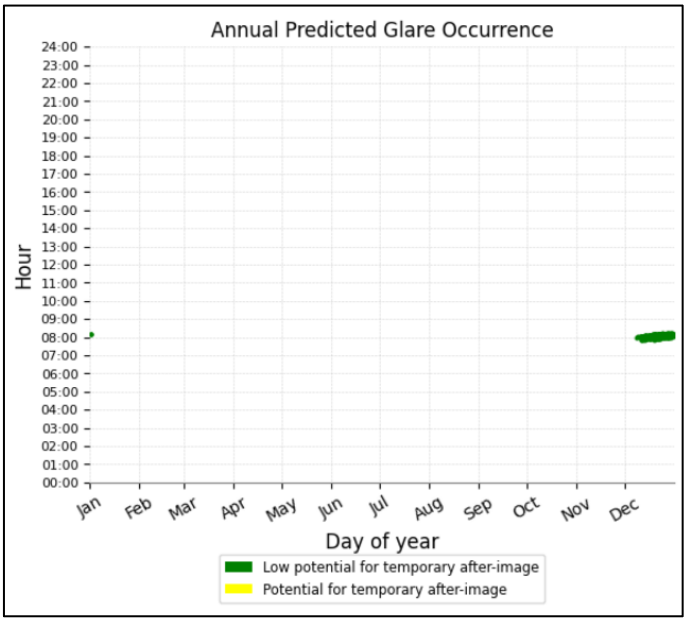

Figure 10: FACT Runway 19 Exposure Times (Fixed Tilt)

Figure 11 below shows the areas of the Solar PV Arrays that will cause the glare exposure to the receptor at FACT Runway 19.

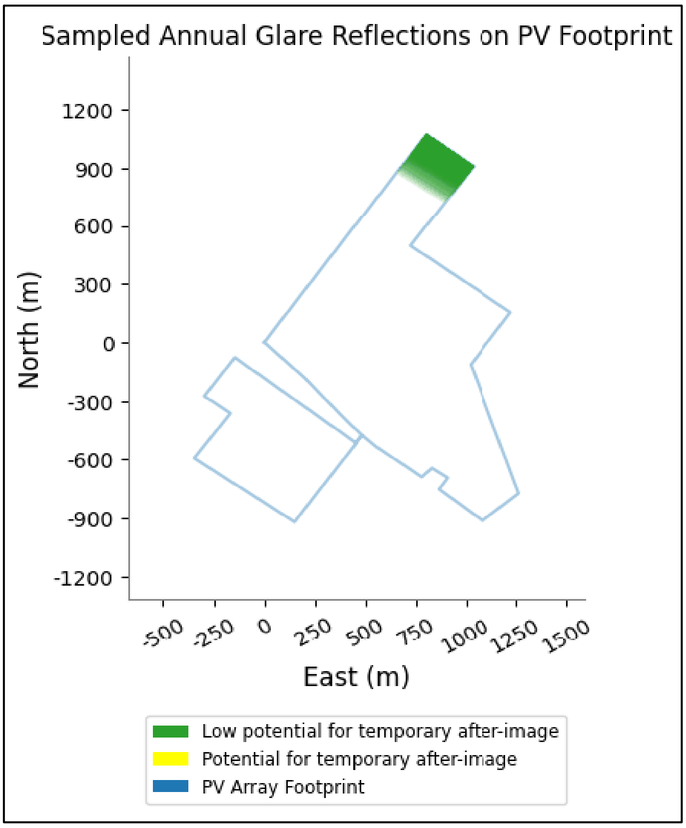

Figure 11: FACT Runway 19 Solar PV Footprint Causing Glare (Fixed Tilt)

FACT ATCT (1-ATCT)

Figure 12 below shows that the green glare will occur in the morning hours (c.a. 08h00) between the months of November to the end of January.

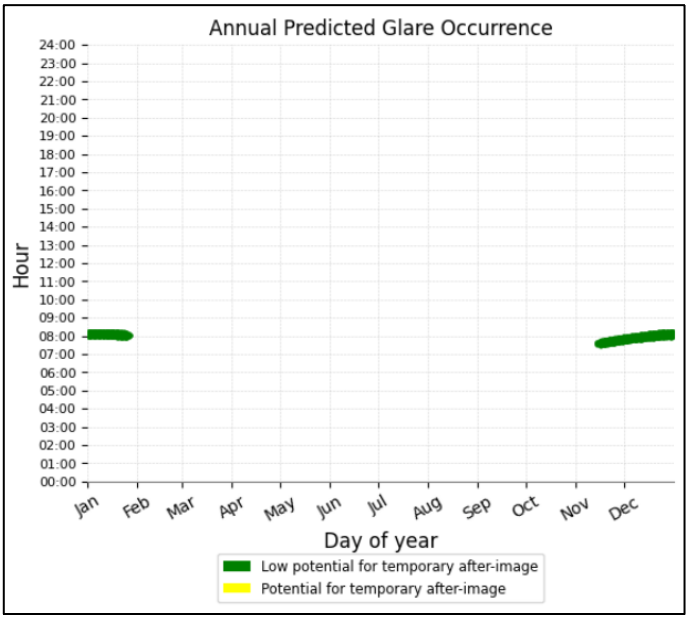

Figure 12: FACT ATCT Exposure Times (Fixed Tilt)

Figure 13 below shows that all areas of the Solar PV Arrays will cause the glare exposure to the receptor at FACT ATCT.

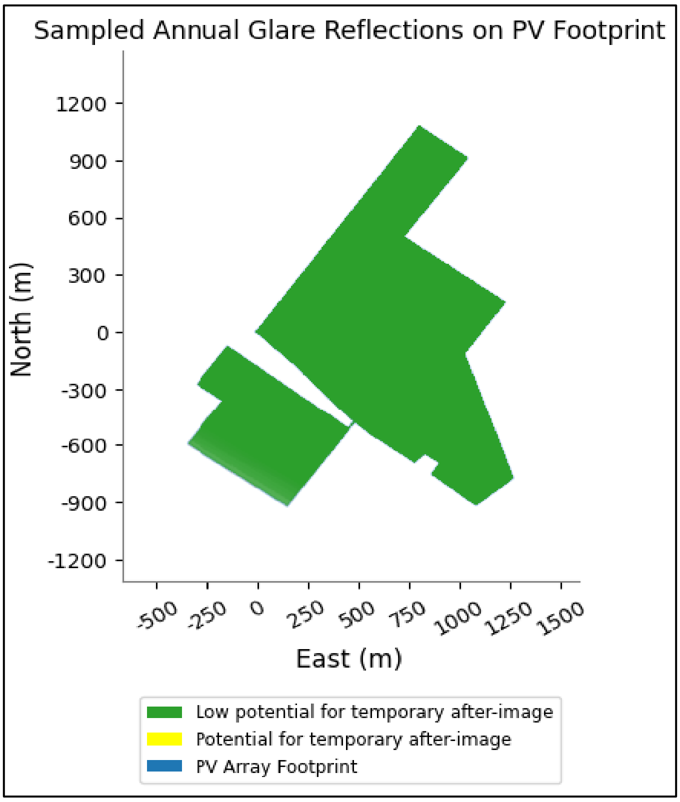

Figure 13: FACT ATCT Solar PV Footprint Causing Glare (Fixed Tilt)

5.2 SITE PLAN 02 – SINGLE AXIS TRACKER

The second option under consideration is the single axis tracker configuration. The panels will be orientated in rows aligned North to South and will track the movement of the sun, from east to west, throughout the day. The maximum tilt angle has not yet been confirmed, however, a typical configuration utilizes a 60˚ maximum tracking angle has been used in this model. Figure 14 below shows the layout of this configuration.

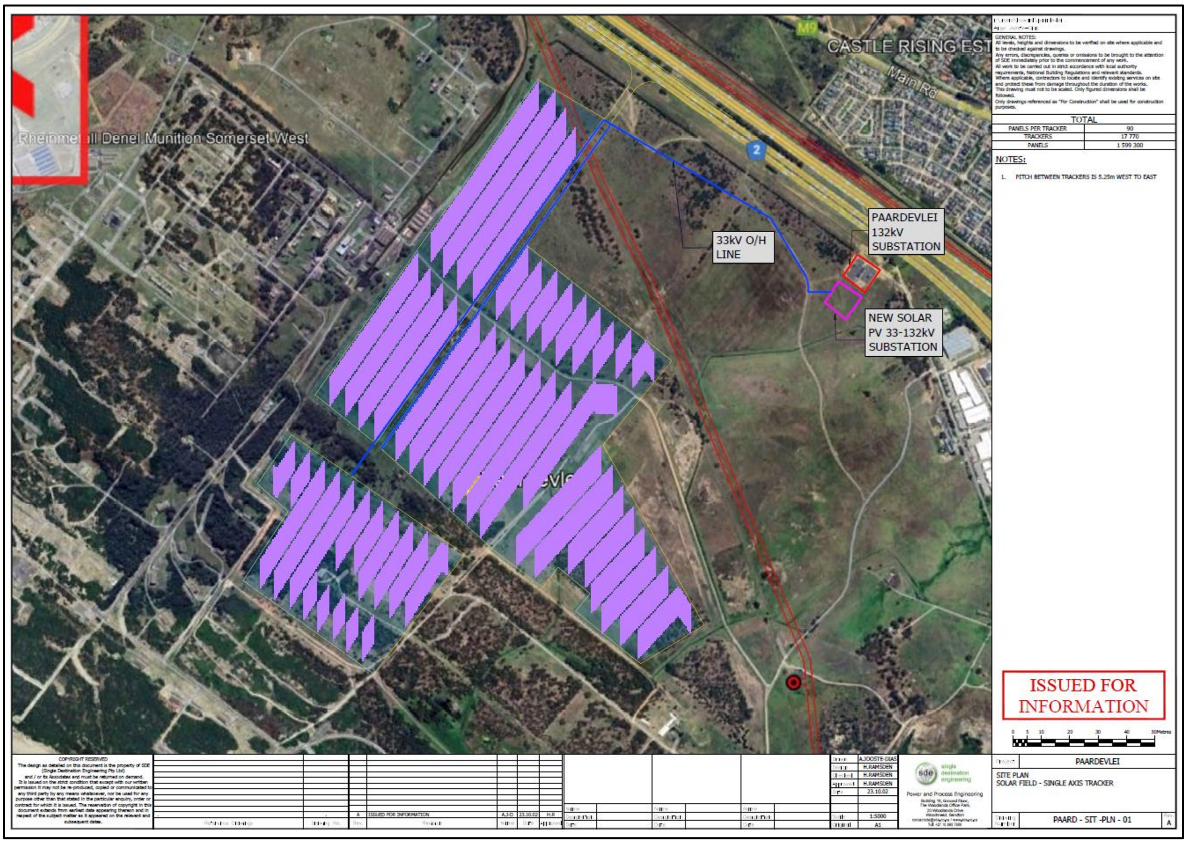

Figure 14: Site Plan 2 – Single Axis Tracker Configuration (SDE, 2023)

The modelling results for the single axis tracking system are shown in Table 3 below. Figures 15-16 provide further information regarding the times of the day and year when glint and glare exposure can be expected.

Table 3: Single Axis Tracking Configuration Glint and Glare Exposure Time for Aviation Receptors

Receiver Name	Green Glare (mins)	Yellow Glare (mins)	Red Glare (mins)
FACT Runway 01	0	0	0
FACT Runway 16	0	0	0
FACT Runway 19	0	0	0
FACT Runway 34	0	0	0
FASH Runway 01	0	0	0
FASH Runway 19	0	0	0
1-ATCT	268	0	0
Total	**268**	**0**	**0**

FACT ATCT (1-ATCT)

Figure 15 below shows that the green glare will occur in the morning hours (c.a. 05h00 – 06h00) between the months of November to January.

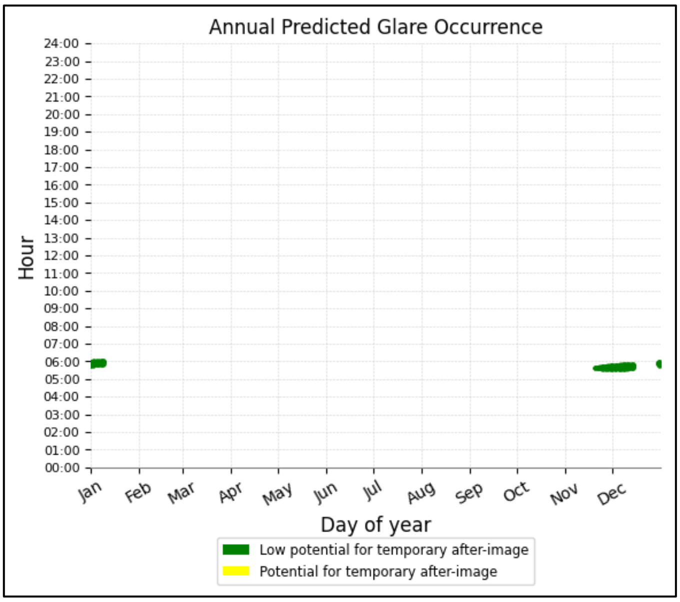

Figure 15: FACT ATCT Exposure Times (Single Axis Tracking System)

Figure 16 below shows the areas of the Solar PV Arrays that will cause the glare exposure to the receptor at FACT ATCT.

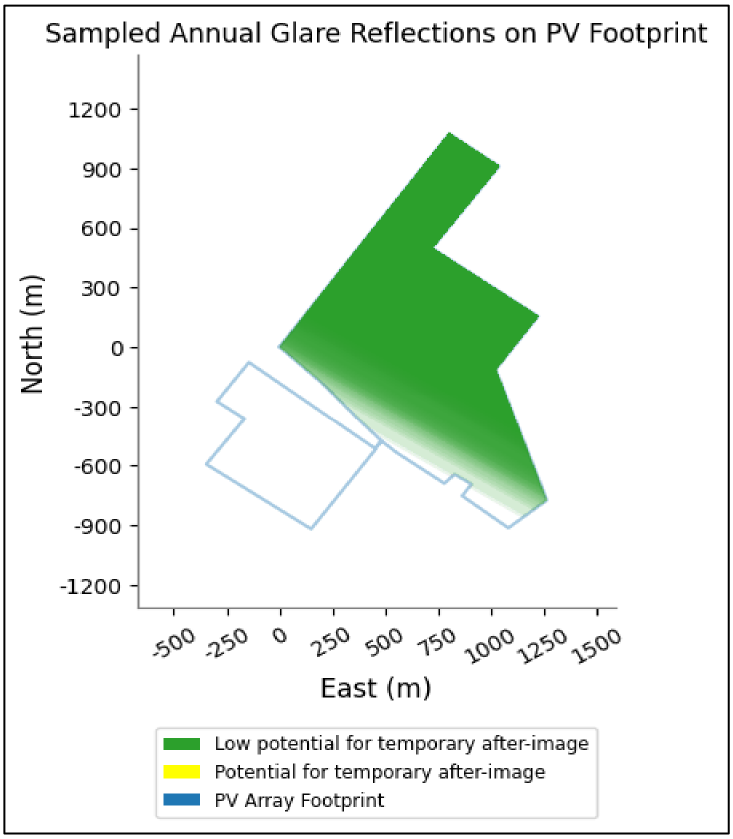

Figure 16: FACT ATCT Solar PV Footprint Causing Glare (Single Axis Tracking System)

5.3 SITE PLAN 03 – EAST/WEST SHEDS

In the third configuration under consideration, a fixed-axis system is proposed, wherein one-half of the Solar PV panels are oriented eastward, and the remaining panels face westward in an "inverted V" configuration, each set at an angle of 20˚.

Figure 17 below shows the proposed configuration.

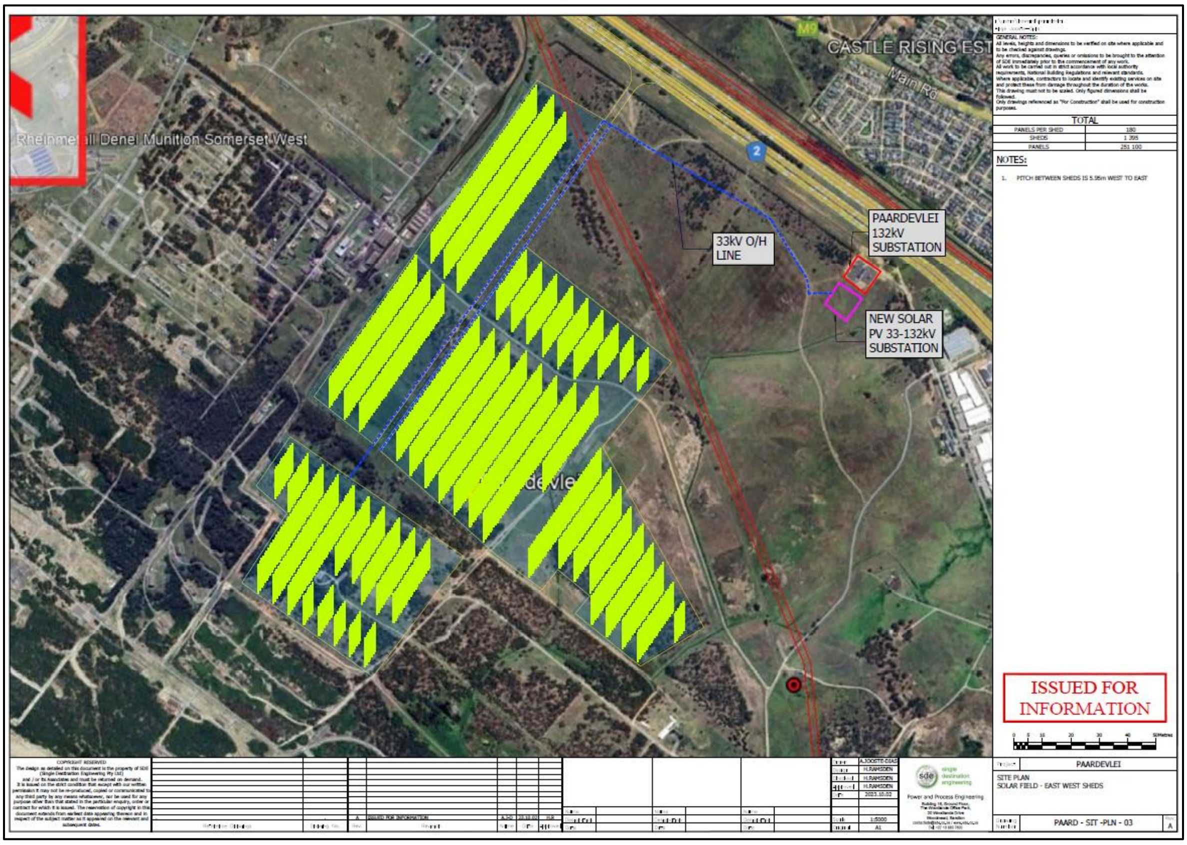

Figure 17: Site Plan 03 Layout – East-West Sheds (SDE, 2023)

Due to constraints within the modelling software, representation of the inverted V shape as a unified configuration was not possible. Therefore, two distinct model sets were compiled, one depicting all panels facing west and the other, all panels facing east. Subsequent simulation runs were conducted to evaluate glint and glare exposure to aviation receptors. The analysis of both models revealed that, no discernible glint and glare exposure is anticipated.

5.4 SUMMARY OF RESULTS

The modelling results indicate that receptors will experience green glare if Site plan 01 and Site Plan 02 are implemented. Site Plan 03 will cause no glint and glare exposure to aviation receptors throughout the year.

No yellow or red glare is anticipated when considering the three configurations.

Table 4 shows the glare minutes for the receptors when considering the three configurations (including additional modelling of the 20˚ Fixed Tilt design being considered for Site Plan 01).

Table 4: Glint and Glare Exposure Time for all three configurations

Receiver Name	Green Glare (mins)	Yellow Glare (mins)	Red Glare (mins)
Site Plan 01 (Fixed Tilt 20˚)	0	0	0
Site Plan 01 (Fixed Tilt 34˚)	1 702	0	0
Site Plan 02 (Single Axis Tracker)	268	0	0
Site Plan 03 (East-West Sheds Fixed 20˚)	0	0	0

6 CONCLUSIONS AND RECOMMENDATIONS

The aim of this study was to determine the impact that solar glint and glare would have on various aviation receptors. The FAA model considered the 2-mile receptors on the approach to the various runways. The Air Traffic Control Towers were also considered.

The modelling results indicate that the receptors at the airports will be exposed to green glint and glare if Site Plan 01 or Site Plan 02 is implemented. Site Plan 3 will cause no glint and glare exposure to the receptors.

It should be noted that although green glare could be experienced by the Air Traffic Controllers at the FACT Control Tower, the intensity of the glare will be mitigated by the distance from the project to the Control Tower, the short duration thereof as well as the window tinting that is already in place, and that the project is not on the extended centre line of the main runway (FACT Runway 01/19), but 19km to the South-East of the field.

It is therefore recommended that the project receive approval from the Civil Aviation Authority from a glint and glare perspective.

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7 BIBLIOGRAPHY

- Federal Aviation Administration (2018). Technical Guidance for Evaluating Selected Solar Technologies on Airports Version 1.1(Report no. FAA-ARP-TR-10-1). Retrieved from https://www.faa.gov/airports/environmental/policy_guidance/media/FAA-Airport-Solar-Guide-2018.pdf