Green Star Photovoltaic Modelling Guidelines

September 2013

Developed by the Green Building Council of Australia

Contents

Change Log

Version	Date	Description of change
1.0 Draft	July 2012	Draft release for industry review
2.0	September 2013	June 2011 draft version has been in use for approximately 1 year. This document has been reviewed by the GBCA in 2013 and re-issued with minor formatting and editing changes (E.g. this document has been re-branded). There are no notable changes to methodology or requirements.

Introduction

This document provides guidance to projects seeking to claim the benefit of energy generation using on-site photovoltaics (PV) under the Ene-1: Greenhouse Gas Emissions credit in Green Star. It provides guidance to enable robust, transparent and consistent predictions of energy generation by PV systems for use in Green Star submissions. It also outlines framework for assessing modelling and reporting of PV systems in Green Star submissions.

How to use this document

This document supplements the Greenhouse Gas Emissions Calculator Guide and must be referred to by project teams prior to undertaking modelling of PV systems for Green Star.

The following steps are required for any project team including PV system modelling in an Ene-1 'Greenhouse Gas Emissions' credit submission:

- Document the properties of the designed PV system in the modelling summary form, see Table A: System information reporting requirements;
- Identify a third party data source for climate data to be used for the modelling of predicted energy generation of the PV system. The data used must be consistent (in terms of location) with that used to model the building's annual energy consumption for Ene-1 Greenhouse Gas Emissions and other modelling credits throughout the rest of the submission. This must be documented in the modelling summary form as described in Table B: Site data reporting requirements;
- Establish whether there is significant shading of the proposed array by referring to the guidance given in Shading analysis requirements (page 10). If a shading analysis is required, provide the items listed in Submission requirements for PV arrays with shading (page 10). If a shading analysis is not required, provide the items listed in Submission requirements for PV arrays without shading (page 11);
- Establish whether any self-shading of the array exists and provide the items listed in Self-shading (page 11).
- Nominate derate factors for the PV system being modelled. Please refer to 'Derate factors' (page 12).
- Choose a modelling package that complies with the framework provided in Third-party modelling tool compliance (page 9).
- Model energy generation of the PV system and document results using the summary form as per Table C: Modelling considerations reporting requirements.
- Assemble the documents required for your Design or As-Built submission as appropriate in line with Documentation requirements (page 13).
- Enter the predicted annual energy generation of the PV system into the Energy Calculator, where provided in the calculated this figure should be placed under 'Energy Generation from Renewable Energy' and include the completed report with the submission for Ene-1: Greenhouse Gas Emissions credit.

Reporting guidelines

This chapter contains guidelines describing the reporting requirements for submissions, and is broken down into three sections:

- Table A: System information reporting requirements
- Table B: Site data reporting requirements
- Table C: Modelling considerations reporting requirements

Each section contains a table which has a short description of each reporting requirement and lists the information to be provided in the submission. The guidelines have been written to ensure a consistent and transparent assessment of PV systems can be carried out; there are many PV generation technologies, ways of configuring PV systems, and a diverse range of tools used to model the energy output of such systems.

System information

It is vital for transparency that system and modelling information is presented clearly in your modelling report. These modelling inputs will have an impact on predicted energy generated of your PV system. For the purposes of Green Star it is imperative that this information is clearly reported so the modelling outputs can be assessed in a rigorous, consistent and efficient manner. Table A outlines the system information that must be reported, with an appropriate justification.

Item	Parameter	Description	Reporting requirements
A1	PV Technology	The most common types of PV technology are: • mono-crystalline silicon; • thin-film amorphous for example cadmium telluride (CdTe), copper indium gallium selenide (CIGS), amorphous silicon (a-Si); and, • poly-crystalline silicon.	List the type of PV technology used in the project.
A2	Description of PV Components	This is a general description of the system to be used. Note that all performance data should be at Standard Temperature Conditions (STC): 1000W/m2 irradiance, AM1.5 solar spectrum, and 25°C module temperature.	• List the specific brand and model of the PV modules used; • List the rated power of the PV modules used including references to any testing data; and, • List the number of PV modules being used and the total solar collector area in m^2.
A3	Photovoltaic Efficiency	This is the module efficiency factor for the specific PV module used in the project.	Provide the PV module efficiency percentage as either:

		• Typical ranges are: – Mono-crystalline ≈ 12-14% – Poly-crystalline ≈ 8.5-11.5% – Thin-film ≈ 5-9% These values are approximate and for reference only.	• An efficiency curve of the PV module; or • Module efficiency percentage when operating at 80% rated power output. Give a description of testing conditions i.e. efficiencies as at standard test conditions.
A4	Performance Degradation	Generally PV modules deteriorate in conversion efficiency after the first few years of operation.	List the annual performance degradation factor including years over which this is applicable.
A5	Mounting Type	The mounting of PV systems influences the amount of solar irradiance the PV system is exposed to. Mounting types used are generally: • Fixed; • One-axis tracking; • Two-axis tracking; or, • Azimuth tracking.	State the mounting type used for the PV array.
A6	Inverter Information	Inverter efficiencies depend on the inverter when sized according to the PV system. For example, typical ranges are: Typically 92-98% when operating between 40-100% of the rated output power.	• State the capacity, make and model of proposed inverters to be used; and, • Provide inverter efficiency curves, or values at varying rated output percentages. All values are to be quoted from tested inverters or equivalent, where possible.
A7	Single Line Diagram	This provides transparency on the system, how it is designed, how it interfaces with the building, costs, and intended use of the PV system. Please note, parasitic loads of tracking system motors will impact the net energy generation of the PV system.	A single line diagram must be provided showing : • PV system configuration • Electrical connection of the PV system to the building. • The layout and the AC or DC network. Where a tracking system is in place, parasitic loads of motors should be stated.
A8	Layout Drawings	This provides transparency on the system, how the system spatially and practically fits with the	Provide drawings showing the layout of PV modules on the practical and available space of a

		building form. This also prevents over-estimation of energy generation when using incorrect assumptions based on PV systems over an entire roof area e.g. spatial interference with plant space, maintenance access routes and other building features.	roof or facade.
A9	On-Site Shading	This provides some appreciation of the potential impacts due to shading and how this has been taken into consideration Shading could be due to elements of the building itself (chimneys, vents, aerials), other existing features, trees etc.	Give a description of the site including comment on potential shading impacts from current or planned future buildings and trees. This must be supported with site plans and/or aerial photographs

Table A: System information reporting requirements

Site data

The amount of Global Horizontal Irradiance at the face of the PV module has a direct impact on the output of typical (non-concentrated) solar PV systems. Global Horizontal Irradiance incorporates both direct normal irradiance coming from the sun and diffuse horizontal irradiance. It varies with location, time of day/year and local climatic conditions, all of which are documented in weather files that are normally sourced from third parties.

Note that unlike a typical solar PV system, concentrated solar PV systems are operated to utilise direct normal solar irradiance only. These systems are not currently comprehensively covered in this PV guide. If your project includes a concentrated solar PV system please submit a Credit Interpretation Request to determine an acceptable modelling approach.

Table B outlines the external factors which have an impact on energy generation of a PV system and must be included in the report with appropriate justification.

Item	Parameter	Description	Reporting requirements
B1	Location	Location information will inform appropriate selection of solar irradiance (weather file) information.	• Give a general description of the site location; and, • List the coordinates of the site.
B2	Third Party Data Source	Some of the more common sources of data for Australian conditions include: • IWEC - Industry-standard in Australia. Contains hourly data, dry-bulb and dew point temperatures. This file builds on previous years' weather data and	State the data source. The data used must be consistent with that used to model the building's annual energy consumption for Ene-1 Greenhouse Gas Emissions and other modelling credits throughout the rest of the submission.

		assembles a "typical" weather file. • TRY – "Test Reference Year" data. One full-year of weather data is selected as a "typical" year of weather. Contains hourly data.	
B3	Climatic Data Type	Measured data is preferable but may not be available in all areas. References should also include weather data location – closest in proximity to the proposed site.	• State whether the data used is measured or simulated (through a theoretical algorithm); • State references e.g. reference year(s), averaged data; and, • State the location of the weather data and the distance from the project location.
B4	Hourly Climatic Data	Hourly time periods account for daily and seasonal variations in solar irradiance received by PV panels, providing robustness in available of sunlight. Hourly time intervals assist in accounting for factors such as: variations in direct normal and global horizontal solar irradiance due to weather, sun angle and shading.	State the frequency of data used for the simulation e.g. hourly, 10 minute intervals. At a minimum, data used must be at hourly intervals.

Table B: Site data reporting requirements

Modelling considerations

Modelling considerations relate to the particular PV modules selected and the assumptions for data inputs used in third-party modelling tools. These parameters have an impact on estimates of energy generation and the modelling considerations provided suffice for a robust estimation of energy generation. Reporting these modelling considerations is required to transparently document the modelling approach and assumptions used.

Table C outlines the external factors that must be included in the modelling, with an appropriate justification. More detailed requirements on the use of third-party modelling tools and shading analyses are described in Third-party modelling tool compliance (page 9).

Item	Parameter	Description	Reporting requirements
C1	Modelling Software	The third party modelling tool used must satisfy the compliance framework included in Third-party modelling tool compliance (page 9). This framework sets out mandatory requirements for models used and also describes additional desirable features for the robust modelling of energy generation from a PV system.	• List the name of model used; • List the developer of model used; and, • List the version / year of the modelling software used • The third party modelling tool used must

			meet all mandatory requirements as specified in Third-party modelling tool compliance (page 9).
C2	Tilt Angle	The tilt angle is the angle of the PV panel to the horizontal.	List the tilt angle of the panel. Or, please note if the PV system tracks sun altitude. Please document each tilt angle for relevant banks of PV panels if tilt angle varies for different panels within an array.
C3	Azimuth	Azimuth angle is the angle clockwise from true north of the direction that the PV array faces.	List the surface azimuth (angle from North). Please document each azimuth angle for relevant banks of PV panels if azimuth angle varies for different panels within an array.
C4	Shading	Shading onto a PV system prevents solar irradiance from contacting the panel. The effects of shading must be considered in accordance with Shading analysis requirements. Not taking shading into account will result in over-estimation of energy generated.	State the derate factor used with reference to any shading analysis undertaken in accordance with Shading analysis requirements (page 10).
C5	PV Array Losses	Derate factors must be used to account for loss of power generated by the PV Array. Please refer to Derate factors(page 12).	State that the standard derate factors have been used. Or, if non-standard factors are used the project team must justify assumptions with appropriate evidence. See Derate factors (page 12) for further information.
C6	Cell Temperature Losses	The temperature of the cell will impact PV efficiencies – higher temperatures lead to lower output.	Document how the model takes PV cell temperature into account. Document the derate factors for PV cell temperature used in modelling. Typically this is shown as a loss coefficient or efficiency derate based on PV cell temperature compare with a reference temperature (e.g. %/°C difference from reference temperature). In addition, if model software takes into account PV cell temperature based on weather file and panel mounting type, document the mounting type selected and reference to design of the actual system.

Table C: Modelling considerations reporting requirements

Third-party modelling tool compliance

Modelling tools deemed automatically compliant.

The following list of programs are deemed automatically compliant with the requirements for third party modelling tools used to model PV systems in Green Star submissions. No supporting information needs to be provided for these programs to demonstrate compliance with Table D: Compliance framework for third-party modelling tools.

- System Advisory Model (SAM), produced by the National Renewable Energy Laboratory (USA);
- PVsyst, produced by PVsyst SA (Switzerland).

Note: The above list is based on modelling tools deemed automatically compliant by the GBCA at the time of publication of this guide. This list will be reviewed and updated by the GBCA on an as-need basis.

Compliance framework for third party modelling tools

Table D sets out the requirements for third-party modelling tools used to estimate the energy generation of the PV system. The modelling tool used must incorporate ALL of the features listed under Mandatory Requirements; the additional features listed in the right hand column are not mandatory but will contribute to a more robust estimation of energy generation. If a project team wishes to use different software, they must demonstrate the software is compliant with the framework in this Table D.

Item	Mandatory requirement	Additional features
Climatic Data	Use Australian weather data in accordance with items B2 and B3; Use hourly data in accordance with B4;	
User Defined Model	Allow the user to input the PV module orientation for the specific system designed and as reported in items A5, C2 and C3;	
	Allow the user to input the PV module efficiency for the specific system designed and as reported in A3;	The modelling tool includes a database of tested product specific information which allows efficiency curves of PV modules and inverters to be applied hourly as part of the model simulation;
	Allow the user to input the PV Array Losses for the specific system designed as derate factors listed in C5. This can be either as individual values or one combined value;	
	Allow the user to input the System Losses for the specific system designed as derate factors listed in C6. This must include the inverter efficiency for specific inverter used in the project as reported in A6;	System design included within the model i.e. number of strings etc.

Shading Analysis	The modelling tool used must satisfy one of the following conditions: • The modelling tool incorporates an hourly shading analysis included as part of the model simulation. The tool may achieve this through creation of a 3D model of the array and shading elements, or, by assigning hourly shading derate factors for expected shading; OR, • The modelling tool has a function to import results of a third-party hourly shading analysis.	The modelling tool includes a self-shading calculation based on the configuration of the PV array. The modelling tool accounts for the effect of shading caused by obstacles sufficiently far for considering the sun over or under the horizon line at a given time, i.e. the beam component of solar irradiation is considered off for the shaded time. This could be either as part of the model simulation itself or as separate derate factors per azimuth by altitude.

Table D: Compliance framework for third-party modelling tools

Shading analysis requirements

Where there are shading elements close enough to create shades 'drawn' on the PV modules, the resultant shading may have a significant impact on the potential for energy generation from the PV system. Consideration of these effects through appropriate shading analysis must be included as outlined below in Submission requirements for PV arrays with shading (page 10).

Not all projects may have significant shading impacting the installed PV array; in such cases a shading analysis is not required. The submission must include justification as to why there is no significant shading on the PV modules in accordance with Submission requirements for PV arrays without shading (page 11).

Further, all projects are required to consider the issue of self-shading as described in Self-shading (page 11). This can occur for low sun-angles where PV modules may create a shadow on adjacent PV modules of the array.

Submission requirements for PV arrays with shading

Where there are significant objects shading the PV array the project team must include the following in the report:

- State the nature of shading, for example, vegetation, other buildings, and roof structures i.e. chimney, mast, etc. The shading assessment should be undertaken at the mid-point of the PV cell lifespan as such if young vegetation is present, the shading analysis should be undertaken assuming full grown/10 year old trees

- Discuss the hourly shading analysis undertaken to determine the extent of shading on the PV array over the course of the year. The project team must state the modelling tool used and how it satisfies the requirements listed in Table D;

- State the derate factor specified due to shading or describe how the effect of shading has been accounted for in the predicted energy generation of the PV system. Noting that for standard arrays the impact of shading will generally be disproportionately larger than just the area of the panel shaded, and in many situations if only a portion of one panel is shaded, the entire string in which the panel sits will operate at a much lower power output. The GBCA has not yet finalised a standard methodology for calculating shading losses so it is up to the project team to propose a conservative methodology. As long as the proposed methodology provides a methodology for calculating the impact of the following issues, it will be accepted. Issues which must be considered when calculating shading losses:

  - String length.
  - Estimation of cell output loss in relation to amount of panel shaded.
  - The impact of the lowered output from one panel on the entire string.
- The results of the shading analysis must be used to determine an appropriate derate factor on the annual energy generation of the system; and,
- Include images to describe the model and the impact of shading. These can be extracted from any software used or can be photographs from the project site.

Submission requirements for PV arrays without shading

Where there are no significant objects shading the PV array, the project team must include an appropriate justification as to why there are no significant objects shading the PV array. This may be in the form of:

- Site plans or photographs (showing the surrounding building/vegetation context); or,
- A written description of the surrounding objects to the PV array that has been written by the project architect or building owner.

Note: the issue of self-shading must be considered regardless of the absence of external shading.

Self-shading

All projects are required to consider the issue of self-shading. Self-shading occurs when PV modules create shades on adjacent modules; this most commonly occurs for low sun-angles where the spacing between modules is not sufficient enough to avoid shading. The project team must include the following with the submission:

- A brief description of the PV array layout and how the issue of self-shading has been taken into account during design; and,
- Elevation drawings showing the spacing between modules with worst case scenario sun-angle superimposed, highlighting any shaded area.

If self-shading is present and unless it is demonstrated otherwise through a shading analysis, a default derate factor of 0.9 must be applied for the time during the year that self-shading occurs.

Derate factors

Derate factors must be used to account for loss of power generated by the PV Array attributed to the following:

- Mismatch: Losses accounting for manufacturing tolerances in PV modules with slightly different current/voltage characteristics. When modules are connected together electrically, they do not operate at peak efficiency;
- Diodes and Connections: Losses from voltage drops across diodes used to block reverse flow of current;
- DC Wiring: Resistive losses in the wiring between modules and the wiring connecting the PV array to the inverter;
- Array Soiling: Losses due to dirt, snow, other foreign matter on the surface of the PV module that reduces amount of solar radiation reaching the cells;
- Tracking Losses: Parasitic loads of tracking system motors will impact the net energy generation of the PV system.

Derate factors must be used to account for loss of power between the Array and the connection to grid/storage device due to:

- Inverter and Transformer: Derate factor for the efficiency of inverter in converting DC power to AC power.
- AC Wiring: Resistive losses in wiring between the inverter and connection to the utility service.

The following default values should be used:

- Mismatch: 0.98
- Diodes and Connections: 0.995
- DC Wiring: 0.98
- Array Soiling: 0.95
- Tracking Losses: 0.95[1]
- Inverter and Transformer: 0.92[2]
- AC Wiring: 0.99

If a project team wishes to apply derate factors different to those listed above, this must be supported with appropriate evidence/documentation.

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[1] Only if a tracking system is used.
[2] The project team may use the inverter efficiency or efficiency curve for the specific inverter being used in the project in place of the default value.

Documentation requirements

Documentation: Design rating

- ☐ Short report
- ☐ Completed modeling summary form (included as Appendix A of short report)
- ☐ Extracts from third party modeling tools (included as Appendix B of short report)
- ☐ Tender layout drawings (included as Appendix C of short report)
- ☐ Single line diagram (included as Appendix D of short report)
- ☐ Specification extracts
  OR
  Manufacturer's datasheets (included as Appendix E of short report)

Where the PV system is connected to a public network:

- ☐ Correspondence with local network provider (included as Appendix F of short report)

Short report prepared by a suitable professional describing how the PV system has been modeled in accordance with the guidelines described in Reporting guidelines (page 4).

Completed modeling summary form must contain all the reporting requirements listed in Reporting guidelines (page 4).

Extracts from third party modeling tools showing all input and output parameters used in the model. The extracts must show the predicted annual energy generation of the system and following items (as listed in Table A, page 6) should also be visible in the modeling extracts: A1, A3, A5, A6, B1, C1, C2, C3, C4, C5, and C6.

Tender layout drawings in accordance with A8. Plan view drawings must show the layout of PV modules on the available space of a roof or facade, and elevations must show the spacing between modules with worst case scenario sun-angle, highlighting any shaded area.

Single line diagram in accordance with A7.

Specification extracts containing information and data used to produce the modeled annual energy generation of the system. The items listed in A1, A2, A3, and A6 must be highlighted for the assessors' reference.

Manufacturer's datasheets must show the items listed in A1, A2, A3, and A6. Datasheets must be supplied for the following items:

- PV modules;
- Inverters;

- Tracking systems (if used); and,
- Energy storage (if used).

Correspondence with local network provider which shows that the project has both the necessary infrastructure and approval from the relevant authority to export power from the system to the local electricity grid.

Documentation: As-built rating

☐ Short report

☐ Completed modeling summary form (included as Appendix A of short report)

☐ Extracts from third party modeling tools (included as Appendix B of short report)

☐ As-Built layout drawings (included as Appendix C of short report)

☐ Single line diagram (included as Appendix D of short report)

☐ Manufacturer's datasheets (included as Appendix E of short report)

Where the PV system is connected to a public network:

☐ Correspondence with local network provider (included as Appendix F of short report)

Short report prepared by a suitable professional describing how the PV system has been modeled in accordance with the guidelines described in Reporting guidelines (page 4).

Completed modeling summary form must contain all the reporting requirements listed in Reporting guidelines (page 4).

Extracts from third party modeling tools showing all input and output parameters used in the model. The extracts must show the predicted annual energy generation of the system and following items (as listed in Table A, page 6) should also be visible in the modeling extracts: A1, A3, A5, A6, B1, C1, C2, C3, C4, C5, and C6.

As-Built layout drawings in accordance with A8. Plan view drawings must show the layout of PV modules on the available space of a roof or facade, and elevations must show the spacing between modules with worst case scenario sun-angle, highlighting any shaded area.

Single line diagram in accordance with A7.

Manufacturer's datasheets must show the items listed in A1, A2, A3, and A6. Datasheets must be supplied for the following items:

- PV modules;

- Inverters;
- Tracking systems (if used); and,
- Energy storage (if used).

Correspondence with local network provider which shows that the project has both the necessary infrastructure and approval from the relevant authority to export power from the system to the local electricity grid.