Design Guide for Bifacial Solar Modules

This Design Guide was created to aid in the understanding and optimization of Prism Solar's PV modules. This document should be used as a supplement for individuals and system designers who are skilled in the art of photovoltaic design. This guide highlights the unique properties of the bifacial technology, but is not intended to cover all aspects of PV system design. See our installation instructions for further details.

Summary of the Major Differences:

1. Electrical calculations such as string and wire sizing, inverter inputs, and overcurrent protection devices should be based on the "**Bifacial STC*** **ratings"** found below, according to for the Bi60 and Bi72 modules. The Bifacial STC is based on an additional **300W/m^2** to the rear of the module; the Bifacial STC values for current and power can be approximated as **127%** of the current and power values at STC.
2. System yield calculations are based on STC peak output, less the derating for losses such as shading, orientation and soiling, multiplied by the Bifacial Gain in Energy (BGE), which is a function of the module used and the local installation conditions.
3. Inverter size for AC output is selected using the peak AC power of the system. Bifacial systems have a higher KWh_{AC}/KW_{DC}, allowing for proportionately smaller inverters and reduced BOS costs.

Prism's products have a greater average backside to front side power ratio (95%) than other bifacial modules and is warrantied at 90%. Please review this design guide carefully to maximize the output of your bifacial system.

Electrical Design:

In any application where the backside of the array could receive significant light contributions from a high albedo background (>0.6), such as an *ENERGY STAR™* roof, snow, or white paint, the following electrical performance "**Bifacial STC**" should be used in place of the standard **STC** data for the following:

- Wire and string sizing
- Inverter short circuit current (Isc) input limit
- Overcurrent protection devices (OCPD)

Table 1: **Electrical Data for Prism Solar Bi60-343BSTC (LEFT) and Bi48-273BSTC (RIGHT) modules**

Bi60-343BSTC		Bifacial STC* (+300 W/m²)	STC** Front Only	STC** Rear Only
Nominal Power (Pmax)	Pmax [W]	343	270	243
Voltage at Max Power	Vmpp [V]	31.7	31.7	31.7
Current at Max power	Impp [A]	10.8	8.52	7.67
Open Circuit Voltage	Voc [V]	39.2	38.8	38.7
Short Circuit Current	Isc [A]	11.4	8.98	7.96

Bi48-273BSTC		Bifacial STC* (+300 W/m²)	STC** Front Only	STC** Rear Only
Nominal Power (Pmax)	Pmax [W]	273	215	194
Voltage at Max Power	Vmpp [V]	26.1	25.4	25.4
Current at Max power	Impp [A]	10.5	8.48	7.67
Open Circuit Voltage	Voc [V]	31.3	31.0	31.0
Short Circuit Current	Isc [A]	11.4	8.94	8.04

***Bifacial STC= Irradiance 1000W/m2 (front) and an additional 300W/m2 (rear), 25ºC, AM 1.5 **STC= Irradiance 1000W/m2, 25ºC, AM 1.5**
The Bifacial STC can be approximated for current and power values as 127% of the STC values.

Optimizing and Estimating the Bifacial Energy Yield:

Bifacial modules, unlike traditional PV modules, are able to capture light on the front and back surfaces of the module. The total energy output of the module can be given as $E_{Total} = E_{Front} + E_{Back}$ or as as $E_{Total} = E_{Front}*(100\%+BGE)$, where BGE (Bifacial Gain in Energy) is the percentage energy gain by a bifacial module at its relative local conditions. As the BGE increases, the total energy output of the module will increase. Figure 1 shows the components of the solar irradiance that affect the performance of a bifacial module.

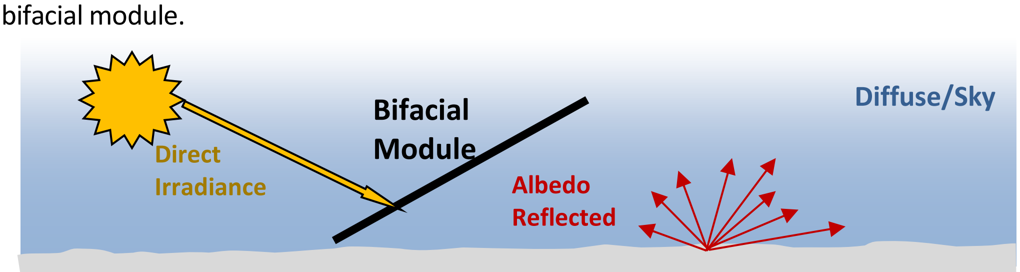

Figure 1. Components of the solar irradiance that affect the output of a bifacial module.

CAUTION: Read the Installation Manual and Product Specifications carefully before using this guide.

When the back of the module is introduced to increased light conditions, the output of the module is increased. By selecting installation conditions that maximize the light reflected onto the back of the module from ground and sky components, the energy generated by the backside of the module will increase. This increase in output power can be achieved by installing the modules over surfaces with a high albedo or surface reflectivity (SR), higher module tilt angles and installation heights, etc. All sources of shadowing which may lead to partial shadowing of the reflected light to the back of the module should be avoided; special care should be taken with the module racking/support structure to make sure it does not shadow the back of the module.

Figure 2. Albedo examples at 0.3, 0.6, and 0.9 for green grass, fresh white concrete and fresh snow, respectively.

The energy output of the module will vary from the Bifacal-STC (BSTC) in the same way that standard modules vary from standard STC. Use the following steps to calculate and optimize the Bifacial Gain in Energy.

Step #1: Choose the highest possible Surface Reflectivity/Albedo: The optimization of the solar reflectivity or albedo reflected light of the surface under the module installation increases the amount of light that is reflected to the backside of the solar module. Optimization of this surface is the predominate factor for increased module output. Use crushed white rock, bright white paint, or an *ENERGY STAR™* roof for best results.

Step #2: Place the array at least 0.15m (0.5ft) above the reflective surface: Placing the modules too close to the roof surface creates a self-shading effect, blocking available albedo light. In a module that is tilted, the cells closest to the installation surface receive less light than the higher cells reducing the overall module output. Additionally the higher temperature near the roof surface reduces the module output. To prevent backside shade, use a mounting rail that runs between modules, not directly under the cells of the module. This height effect can be observed in Table 2 and 3, as the modules closest to the installation surface have a reduced Bifacial Gain in Energy.

Step #3: Estimate the Bifacial Gain in Energy (BGE): From Table 2 and 3 find the intersection of the Albedo and the height of the lowest point of the module above the reflective surface for single row module applications or the Height/Width ratio for larger and overhead installations. These tables are designed to estimate the approximate amount of additional energy that will be produced by the system due to the bifacial effect.

Table 2: Bi48/B200 Bifacial Gain in Energy in (%) for south facing modules mounted at 30°

Albedo	***Height of the lowest point above the roof (m) or Installation Height/Width Ratio***					
	0.15	**0.2**	**0.3**	**0.5**	**0.7**	**1**
0.15	**13.1**	**13.6**	**14.5**	**16.3**	**18.1**	**20.8**
0.3	**14.8**	**15.3**	**16.3**	**18.3**	**20.4**	**23.5**
0.5	**16.5**	**17.1**	**18.3**	**20.5**	**22.8**	**26.3**
0.7	**21.2**	**22.0**	**23.4**	**26.3**	**29.3**	**33.7**
0.85	**22.2**	**23.0**	**24.5**	**27.6**	**30.7**	**35.3**

Table 3: B245/B250/B260/Bi60/Bi72 Bifacial Gain in Energy in (%) for south facing modules mounted at 30°

Albedo	***Height of the lowest point above the roof (m) or Installation Height/Width Ratio***					
	0.15	**0.2**	**0.3**	**0.5**	**0.7**	**1**
0.15	**12.7**	**13.1**	**14.0**	**15.8**	**17.5**	**20.2**
0.3	**14.3**	**14.8**	**15.8**	**17.8**	**19.8**	**22.7**
0.5	**16.0**	**16.6**	**17.7**	**19.9**	**22.1**	**25.4**
0.7	**20.5**	**21.2**	**22.7**	**25.5**	**28.3**	**32.6**
0.85	**21.5**	**22.3**	**23.7**	**26.7**	**29.7**	**34.2**

Bifacial Gain in Energy above 18% in Tables 2 and 3 indicate an excellent application of the product

Step #4: Correction for the BGE based on module installation angle: The BGE value found above should be modified based on the module installation tilt. The modified BGE_{tilt} is based on the BGE value found in Step #3 multiplied by the tilt correction factor.

Table 4: Tilt Correction factor for single row module applications

		Installation Tilt Angle (degrees)					
	θ ≤ 10°	θ ≤ 12°	θ = 15°	θ = 20°	θ = 25°	θ ≥ 30°	θ = 90°
Tilt Correction Factor	72%	75%	79%	86%	94%	100%	See below

Step #5: Adjustments for Specific Applications:

Flat Rooftops – Row Spacing: Rows should be spaced slightly larger than the typical row spacing of noon on December 21st. The BGE is reduced linearly up to 14% at row spacing of noon on December 21st vs. 9am. (*Ex.* For a Bi60 and row spacing of 10:30am on December 21st with a SR of 0.7 and height of 0.5m, the BGE would be 7% less than 25.5% or 23.7%). The minimum row spacing should be approximately 1m to increase the sunlight between the rows, especially for tilt angles less than 15 degrees.

Flat Rooftops – Tilt: Tables 2 and 3 were calculated for an optimum mounting angle (30°), near latitude (32°) mounting conditions. For reduced tilt angles, increasing the height under the module will optimize the BGE.

Flat Rooftops – Modules In Portrait: Tables 2 and 3 are designed to calculate BGE based on rows oriented in landscape. For rows in portrait, divide the height of the lowest point of the module by 1.65 to accommodate for the additional shading of a portrait module. (*Ex.* a row in portrait at 0.5m above roof will perform the same as a landscape row only 0.3m above the roof)

Overhead Structures – Canopy/Carports, and Installations with Multiple rows per Structure: In Tables 2, use the Height/Width of the array to estimate the BGE, instead of the lowest point of a module above the installation surface. The width is defined as the length of the array in the North-South direction. The height is defined as the lowest point of a module above the installation surface. Apply all other corrections factors (row spacing, angle, etc.).

Vertical applications: Privacy Fences, Rooftop screens, Etc.: The bifacial module will produce the sum of two monofacial modules back to back. Standard production simulation software will provide accurate results by simulating the addition of two monofacial modules facing opposite directions. The east/west vertical installation shown below will yield up to a 90% backside energy gain compared to a standard module. Shadowing practices still apply for vertical modules.

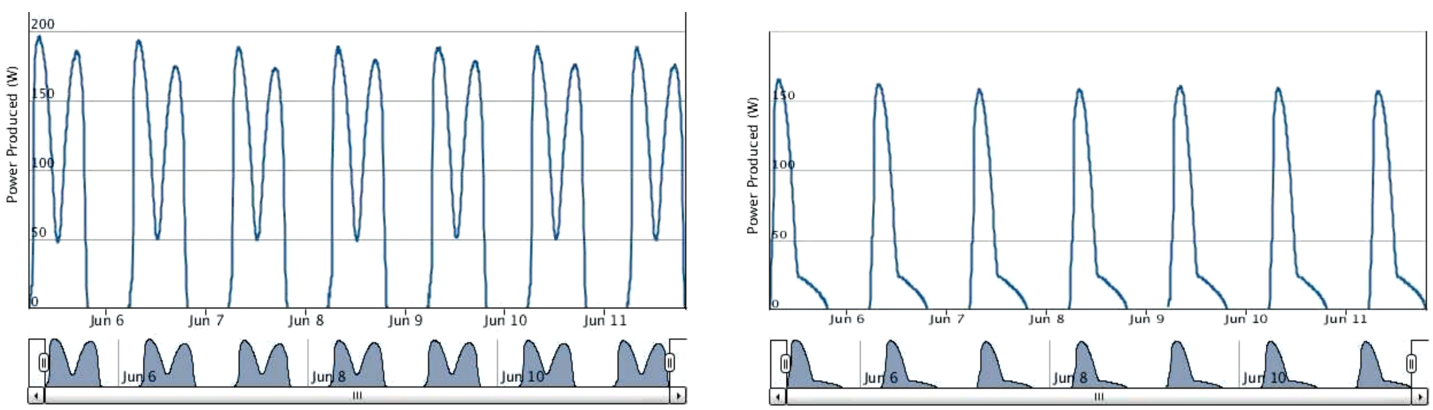

Figure 3. Weekly power output for an East/West vertical installation of a bifacial module (LEFT) and a monofacial module (RIGHT).

Trackers: Estimate the BGE using Table 2. The primary factors of the increased production remain valid regardless of the tracker type.

Lateral Spacing: Spacing modules laterally (within the same row) will produce additional energy gains to the back of the module early/late in the day by providing additional light behind the module that can interact with the surface behind the module and increase the off peak BGE. Please allow for a minimum lateral spacing of at least 10mm or 3/8" between modules to account for thermal expansion and contraction of PV system elements in the field.

Orientation: The minimum BGE contribution occurs with the system oriented due south. As the orientation moves away from south, the percentage of backside energy contribution will increase. This change in the BGE can be estimated with a multiplicative factor, as shown in table 5.

Table 5: Azimuth Correction factor for single row module applications

	Azimuth deviation from south (degrees)									
	0	10	20	30	40	50	60	70	80	90
Azimuth Correction Factor	100%	100%	102%	106%	111%	118%	126%	137%	148%	162%

Inverter Sizing and Selection:

In order to properly size an inverter for an array it may be necessary to understand the relationship between the BGE and Peak Power output (P_{MAX}). Inverters are selected based on the expected peak DC power output. To prevent undersizing the inverters and AC system, it is important to take into consideration the total amount of power produced by the module, $P_{MAX} = P_{Total} = P_{Front} + P_{Back}$. The Bifacial Gain in Power (BGP) as compared to a monofacial module over a day with a BGE=35% is shown in Figure 4.

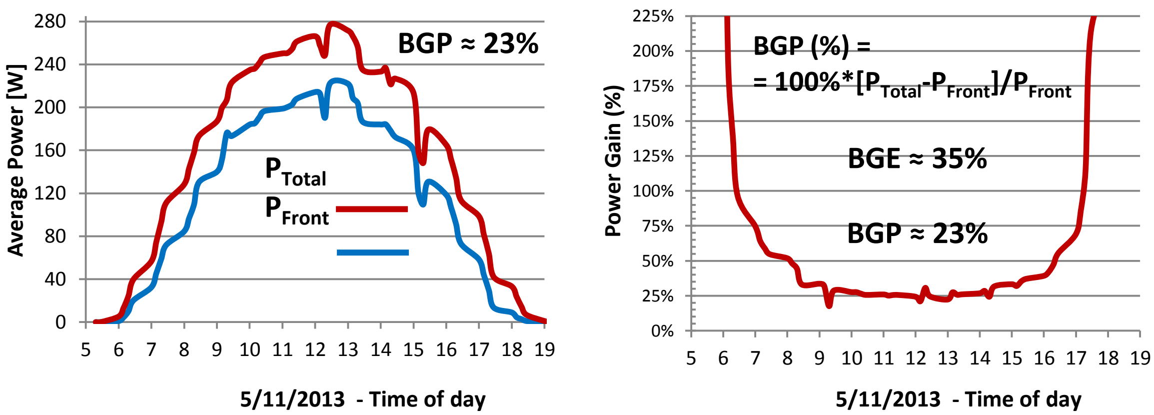

Figure 4. Total and front power outputs for a Prism Solar B245 bifacial system (LEFT) and the instantaneous BGP (%) for the same system (RIGHT); the BGE for the day was ~35%.

For south facing, single row module applications, the BGP can then be estimated as:

$$\mathbf{BGP = 65\%*BGE_{Tilt}}$$

To determine the Peak Power output (P_{MAX}) production to size your system inverters, use the following equation:

$$\mathbf{P_{MAX} = (Expected\ Peak\ Front\ DC\ Power)*[BGP+100\%]}$$

For example, a single module array of Bi60 modules, 0.3m above an aged energy star roof (SR=0.7) at 30 degrees would result in a BGE of 22.7%. 65% of the BGE value would be expected as the peak increase in instantaneous bifacial gain in power (BGP) from the back of the module. The P_{MAX} of this system would be:

$$\mathbf{P_{MAX} = (Expected\ Peak\ Front\ DC\ Power)*[(22.7\%)*65\%+100\%] = (Expected\ Peak\ Front\ DC\ Power)*114.76\%}$$

Please note that the P_{MAX} is a calculated value, the actual instantaneous value can vary depending on local conditions. The bifacial peak power can exceed the calculated peak power (P_{MAX}) due to snow, cloud edge effects, reflections, local elevation, etc.

Inverter Grounding: the inverter should be configured in the negative grounding setting for use with Prism Solar modules.

For site specific energy yield analysis and power reports, please contact Prism Solar.

These Design Guide recommendations for bifacial modules are based on Prism's proprietary simulators. All numbers and calculations are subject to change without notice. The performance of any solar PV system is difficult to predict with certainty due to the variability of solar radiation from year to year and local conditions.