BIFACIAL DESIGN GUIDE

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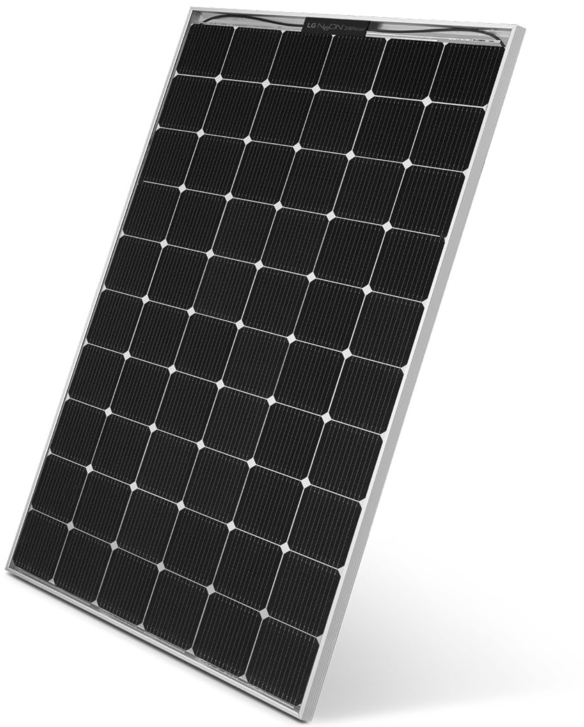


1. Basic of bifacial

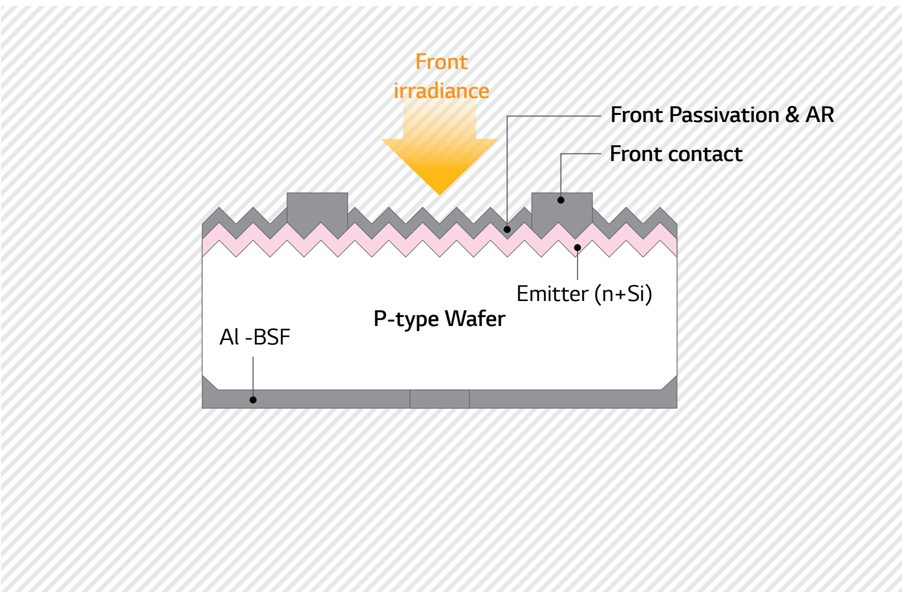
1-1. What is bifacial?

Unlike conventional modules, the bifacial PV Module can produce energy from both the front and backside, utilizing sunlight on the front and reflected light on the back simultaneously.
The bifacial PV module offer greater power output when compared to conventional monofacial PV modules, due to its ability to harvest light that is reflected onto the backside. The reflected light can come from a variety of sources, such as reflection from the ground or from a neighboring row of PV modules.

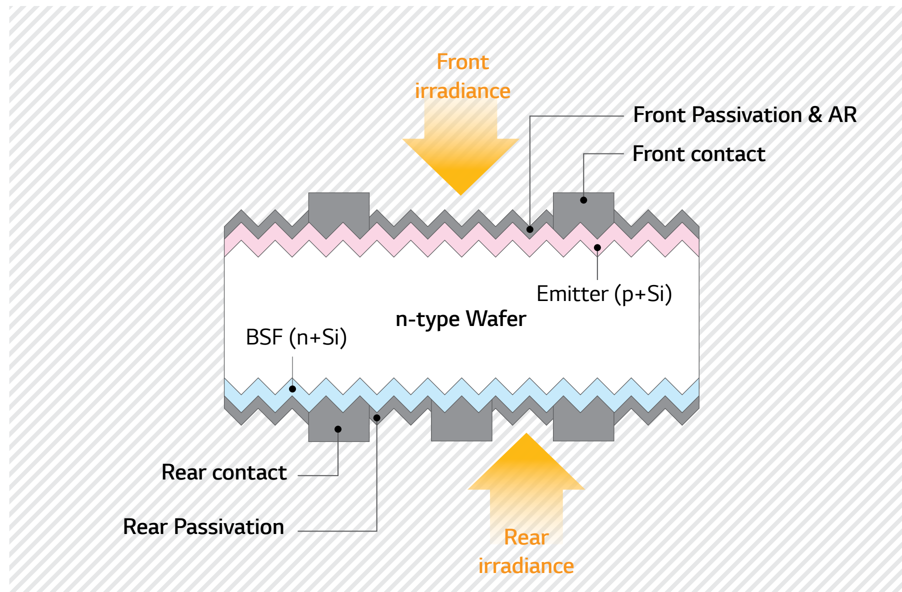
Bifacial Cell Design and Conventional Cell Design

• The bifacial cell is designed to absorb sunlight from both the front and the back.
• It has a symmetrical cell structure on the backside for additional sunlight absorption.

Monofacial (Conventional)



Bifacial

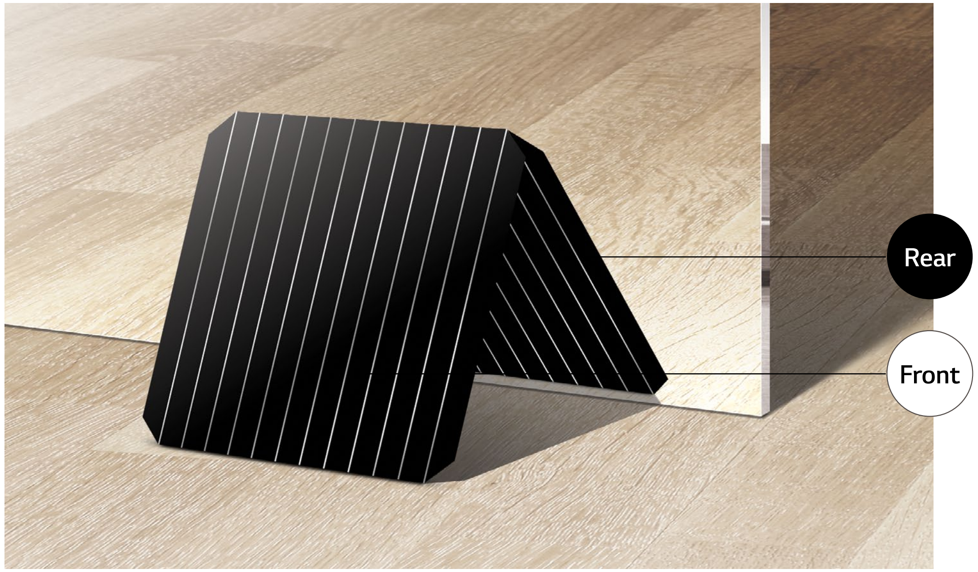


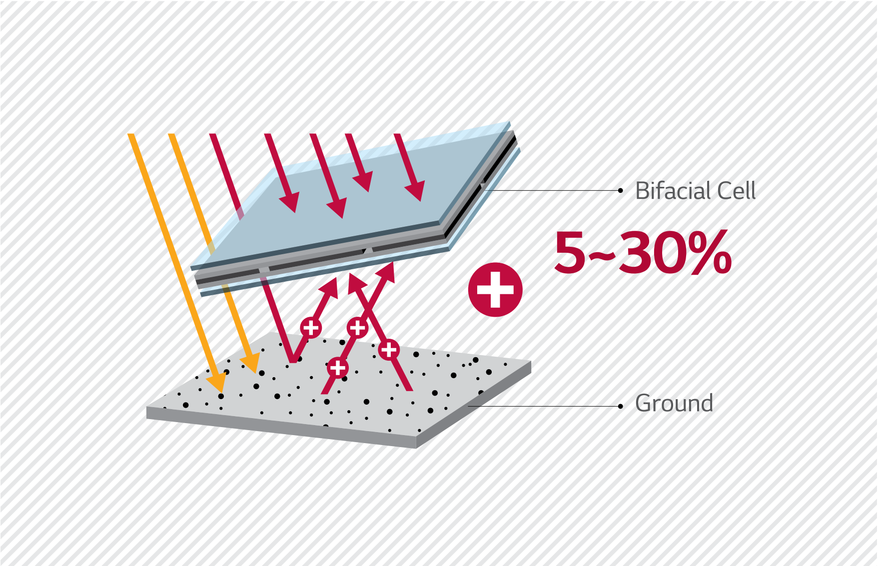
1. Basic of bifacial

1-1. What is bifacial?

Bifacial PV Module

- The bifacial PV Module doesn't use a white backsheet but uses a transparent backsheet (or glass) on the back.
- (Total produced energy) = (Energy from the front) + (Energy from the back)
- The bifacial PV Module's performance depends on various conditions, such as system design, installation methods, location, etc.





Benefits

- Competitive LCOE can be achieved
  - Increased Energy
  - Cost saving effect depends on the amount of bifacial gain

1. Basic of bifacial

1-2. Terms related to bifacial

Bifaciality Coefficient / Bifaciality Factor (BiFi)

Ratio of rear power to front power at STC

* Source: IEC standard 60904-1-2 draft

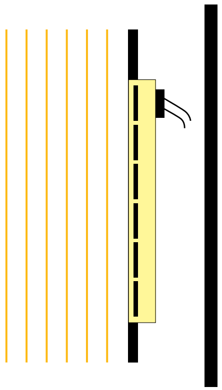
Bifaciality Coefficients

$$\varphi_{Isc} = \frac{Isc_r}{Isc_f}$$

$$\varphi_{Voc} = \frac{Voc_r}{Voc_f}$$

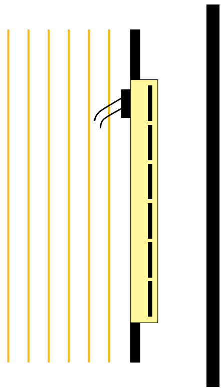
$$\varphi_{Pmax} = \frac{Pmax_r}{Pmax_f}$$

Front-side characterization



G = 1 kWm^{-2}

Rear-side characterization



G = 1 kWm^{-2}

Bifacial Gain

Ratio of additional rear side energy production (kWh) and front side energy production (kWh)

$$\text{Bifacial Gain (BG)} = \frac{\text{Energy}_{\text{(Rear)}}}{\text{Energy}_{\text{(front)}}}$$

* Source : Fraunhofer Institute for Solar Energy Systems ISE / PV Performance Modelling and Monitoring Workshop, Cologne, 2015

2. Design guide for bifacial

2-1. Albedo

Albedo

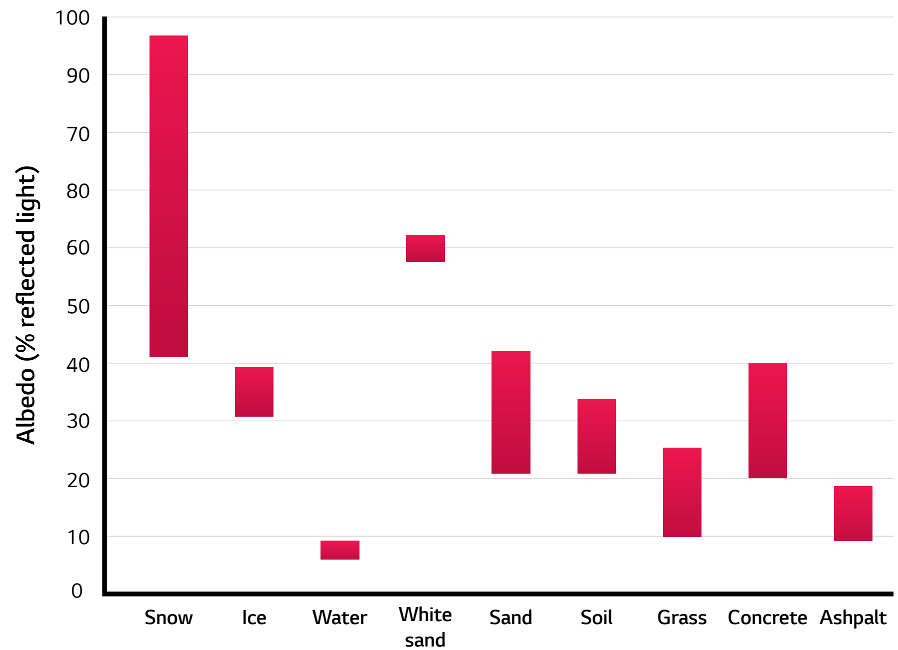
Albedo is represented as the ratio of light reflected from various sources of surface compared to incident radiation. The albedo has a range across a variety of surfaces, where 0% equates to no reflected light, and 100% represents perfect reflection. The more reflected light (i.e., higher albedo) shining on to the backside of a bifacial module, the more power generated.

$$\text{Albedo} = \frac{\text{Reflected Light}}{\text{Incident Light}}$$

Albedo is the most critical factor that affects the energy production from the backside of the bifacial module.
Albedo and reflectance have different definitions. Albedo refers to the overall solar radiation reflectance (full spectrum of light) whereas reflectance refers to the visible light spectrum only.
However, Albedo is also referred as Solar Reflectance.

Albedo has a various range of values because it is dependent on environmental conditions. (i.e. weather conditions, time change, surface conditions)
It is not easy to predict the exact albedo value of a specific area.

Albedo range for a variety of surface

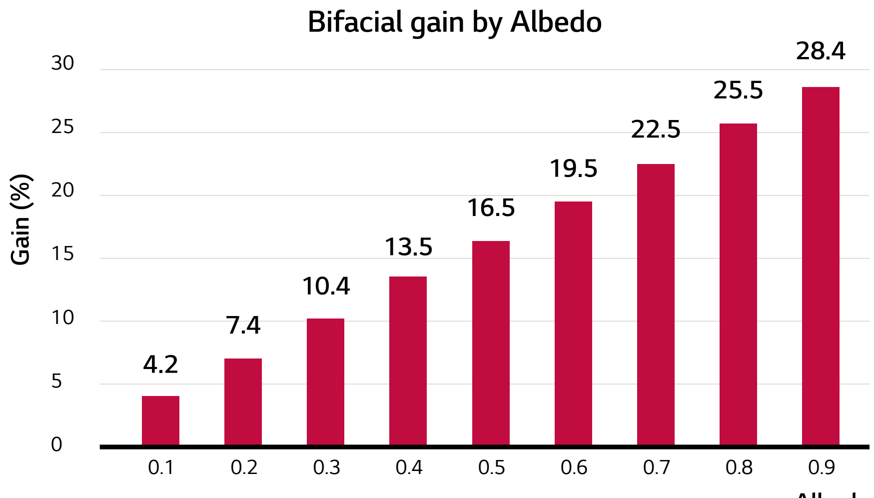


* Source : Helmholtz Alfred-Wegener Institute and the National Renewable Energy Laboratory (NREL)

2. Design guide for bifacial

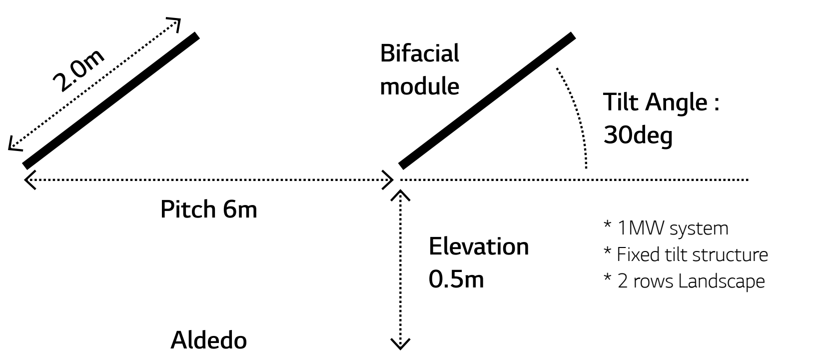
2-1. Albedo

Relation of albedo and bifacial gain

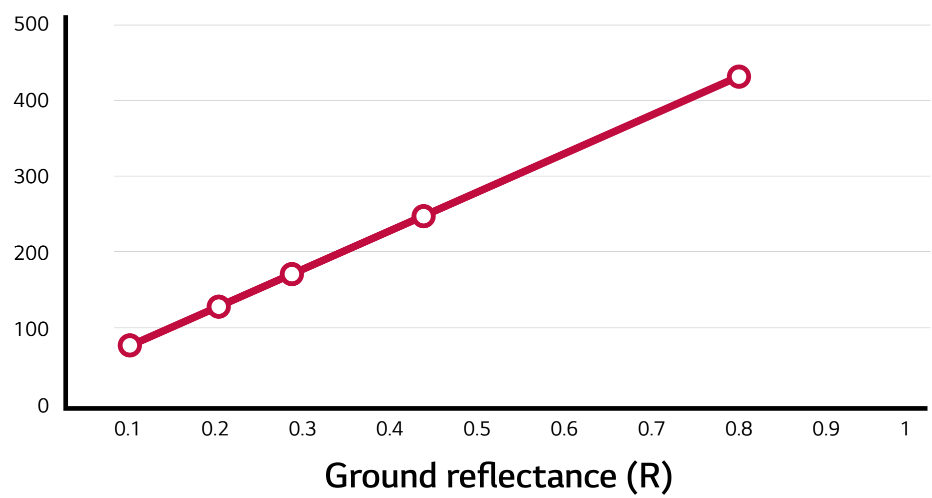


* LGE internal simulation result

Simulation condition



Relation of albedo and irradiation on backside



Material	Reflectance*(R)	Grear at 1000Wm-2 front
Asphalt	0.1	70 Wm-2
Light soil	0.21	130 Wm-2
Concrete	0.28	170 Wm-2
Beige built-up roofing	0.43	250 Wm-2
White EPDM roofing	0.8	430 Wm-2

* Source : Deline et al., IEEE PVSC 2016; Deline et al., IEEE JPV (submitted)
(National Renewable Energy Laboratory)

2. Design guide for bifacial

2-1. Albedo

How to determine the Albedo

The first step towards project design is to identify the albedo. This is very important because the albedo directly impacts the bifacial gain. There are 3 main methods for determining the albedo value:

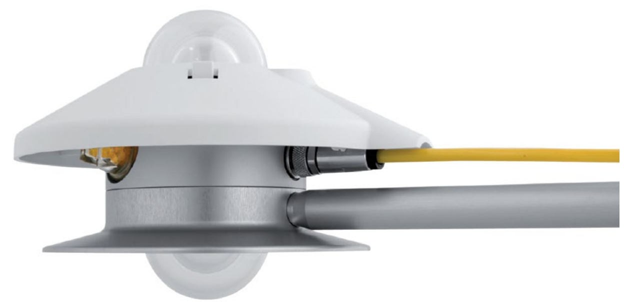
1. Using Albedo reference table
- Site inspection (Ground color, material, ground condition, etc.)
- Look for expected albedo from table (i.e. PVsyst)

2. Measure the albedo of the site with a pyranometer (recommended)
- Install the albedometer on the center of the site (ISO-9060 first class rated device is recommended)
- Install the albedometer at least 0.5m from the ground
- Collect data with the equipment
- Avoid obstacles and shading around the albedometer
- Measure albedo over 5 different spots around the site for greater accuracy

3. Measurement with PV module
- Install the PV module on a mounting structure (installation site)
- Note that the PV module will measured while being installed in different locations of the array for better albedo accuracy
- Measure the module in each location: one measurement(Isc) while facing the sky and another measurement(Isc) while facing the ground
- Measure the Isc of the module over 5 different locations on the installation site using the same procedure
- Find the albedo using the equation shown on the right
- Determine the mean value of albedo from every measured location

Surface	Albedo
Grass	0.15 - 0.25
Fresh snow	0.82
Wet snow	0.55-0.75
Dry asphalt	0.09-0.15
Concrete	0.25-0.35
Aluminum	0.85
New galvanized steel	0.35
Very dirty galvanized	0.08

* Source : PVsyst



Albedometer

$$\text{Albedo} = \frac{Isc_{\text{ground}}}{Isc_{\text{sky}}}$$

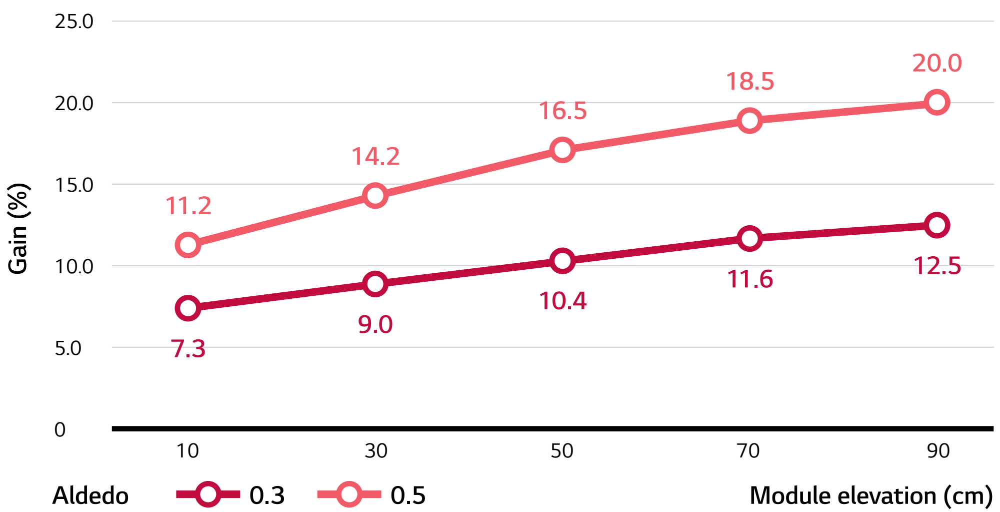
2-2. Module Elevation

Module Elevation

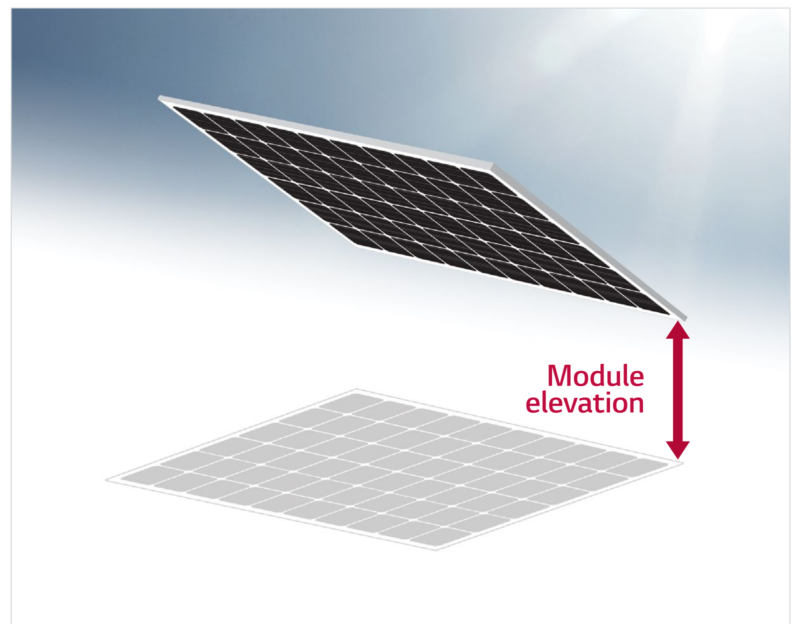
IIt is important to secure enough space between the module and the ground for more sunlight reflectance, resulting in a greater bifacial gain. Thus, the height of the module is also one of the main factors that has a significant impact on bifacial gain.

The module height (elevation) is defined as the distance between the bottom of the lowest part of the module and the ground (surface). Based on internal simulation, bifacial gain value kept increasing with module height moving up to 1m. However, if the module height went over 1m (39.37 in), the bifacial gain would be saturated.

Bifacial gain by module elevation



* 1MW system
* Fixed tilt structure
* 2 rows Landscape



2-2. Module Elevation

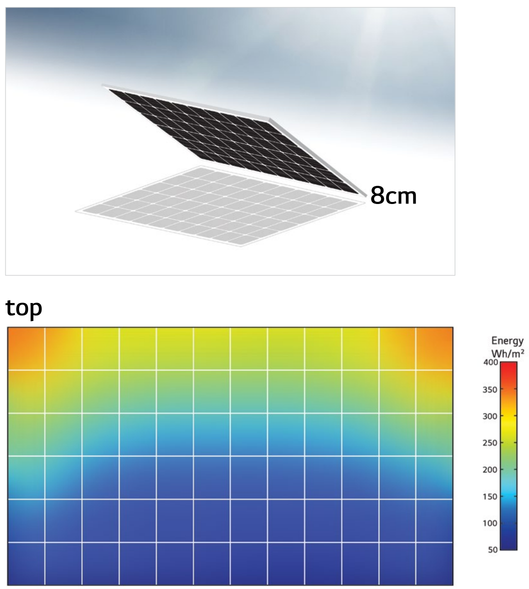
Irradiance uniformity on the backside of the module

Not only does it affect the irradiance on the backside, the module height also affects the reflected light uniformity. If the module height is low, the amount of irradiance on the backside is different on certain parts of the module due to its own shadow. The cells near the top edge of module absorbs more light than the cells on the rest of the module. When the module elevation is at 5cm, the range of irradiance exposed to the backside of the module is rather larger, the highest measurement is 5 times higher than the lowest value recorded. As module elevation increases, the irradiance values are more uniform throughout the module. This is important because irradiance uniformity results in mismatch loss from the module and array, which ultimately leads to energy loss.

Irradiance Distribution of Backside in Single Module

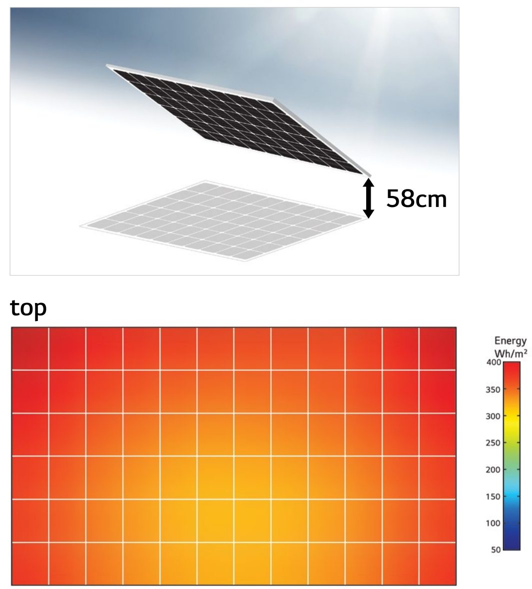
Front Side ▶

Rear Side ▶
(Single Module)



bottom

a) Elevation 8cm : 66 ~ 328W/m²
5times difference



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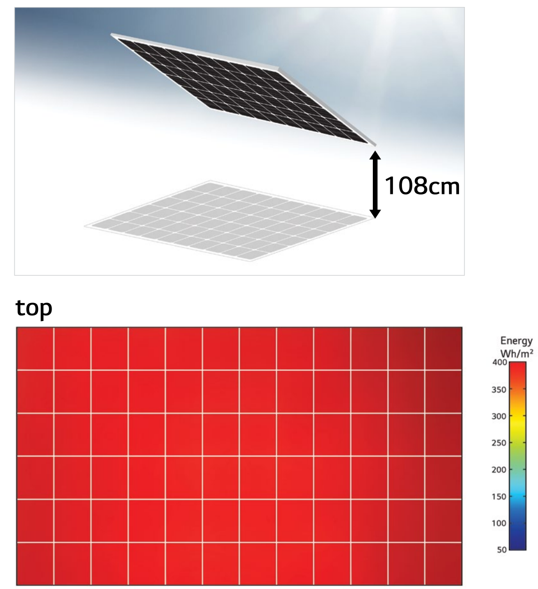
b) Elevation 58cm : 360 ~ 390W/m²
Within 10% difference



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c) Elevation 108cm : 400W/m²
uniform

* Source : PV MODULE POWER GAIN DUE TO BIFACIAL DESIGN. PRELIMINARY EXPERIMENTAL AND SIMULATION DATA. (2010 IEEE)
* Test condition : horizontal irradiation 1006W/m2, Albedo 50%, Tilt angle 30deg

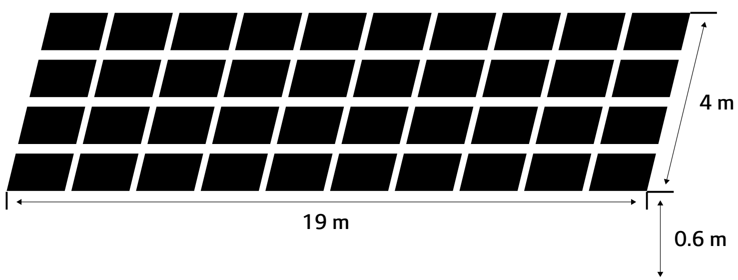
2-2. Module Elevation

Irradiance uniformity on the array

There is also an irradiance uniformity difference by module location in an array regardless of the array being fixed tilt or single axis tracker. The bifacial gain of the array or system is determined by the module performance with the lowest irradiation. It is very helpful to understand irradiance distribution on backside of array to plan cable routes in series and reduce mismatch loss.

Fixed Tilt

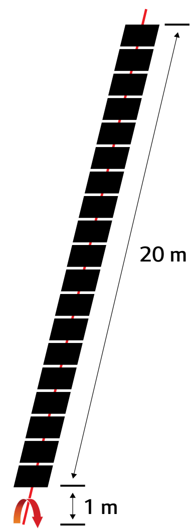
Front Side ▶



Rear Side ▶

239	165	131	120	116	116	120	131	165	239
214	138	109	101	98	98	101	109	138	213
188	111	90	84	82	82	84	90	111	187
185	116	106	103	214	101	103	106	116	184

Single axis tracker



Front Side

Rear Side

176
123
106
100
97
96
96
95
95
95
95
95
95
96
97
98
102
111
139
215

Install condition

	Fixed Tilt	Single Axis Tracker
Location	Cairo (1760kWh/m²/year)	
Albedo	0.2 (close to grass)	
Array	10 modules 4 rows	20 modules 1 rows
Tilt angle	30deg	-60 ~ +60deg
Module Elevation	0.6 m	1.0 m
Install orientation	Landscape (for south)	Portrait (rotate E-W)

* Not considered structure shading on backside

* Source : MODELLING OF SINGLE-AXIS TRACKING GAIN FOR BIFACIAL PV SYSTEMS (32nd European Photovoltaic Solar Energy Conference and Exhibition)

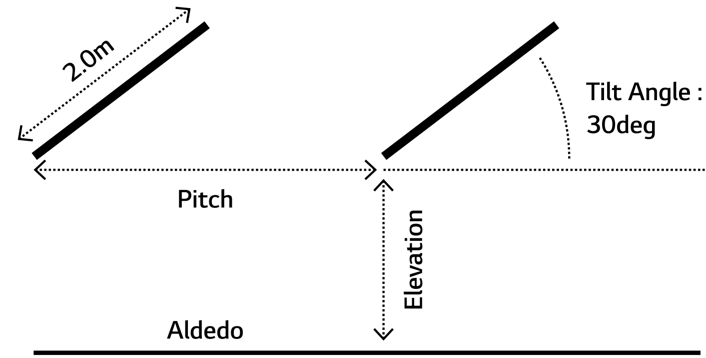
2. Design guide for bifacial

2-3. Pitch

Pitch (GCR)

Pitch is the distance from front array to behind. Pitch is directly correlated with the Ground Coverage Ratio(GCR). The Ground Coverage Ratio (GCR) is the ratio of the PV modules area and the total ground area.

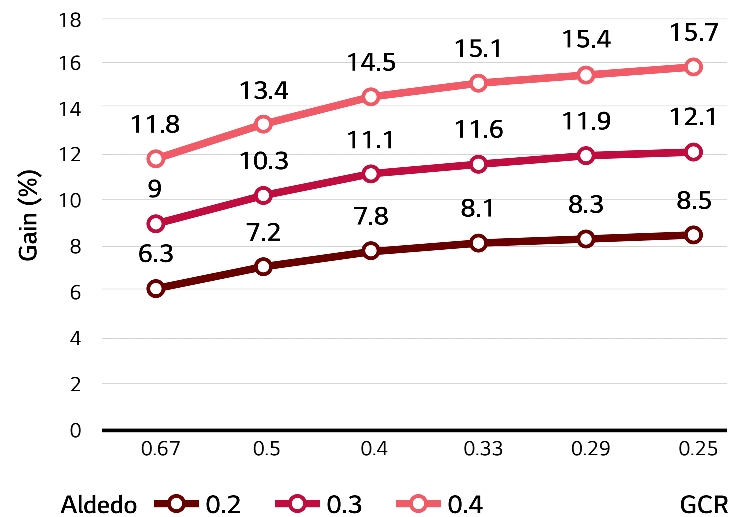
$$GCR = \frac{\text{module area}}{\text{ground area}}$$



As the value of GCR increases, both the Pitch value as well as the installation area decreases.

i.e. Typical GCR value with low shading loss (<2%)
Fixed tilt : 0.55
Single axis tracker : 0.35
Dual axis tracker : 0.20

Bifacial gain by GCR



Pitch (or GCR) is another important factor that affects the bifacial gain. A high Pitch value (low GCR) provides a greater possibility of more energy production. As a result, the Pitch should be considered while designing the system.

2. Design guide for bifacial

2-4. Shading

Mounting structure

The mounting structure, especially the mounting rail, blocks reflected sunlight that comes to the backside of module. The shading produced by the mounting structure decrease bifacial gain. The loss of the backside gain depends on various factors associated with the module and the mounting structure, shown below:

1) Rail thickness and width
2) Number of rails below module
3) Rail design
4) Distance

The best way to minimize loss is to use and install a mounting structure optimized for the bifacial PV Module
(i.e. rail edge on module frame)

Other ways to maximize bifacial gain from the backside are
1) To make smaller array configurations
2) To minimize number of rows in array

The optimized design for bifacial PV module gives more energy
production because of better irradiance uniformity.

Mounting structure for bifacial (Rail on edge of module)

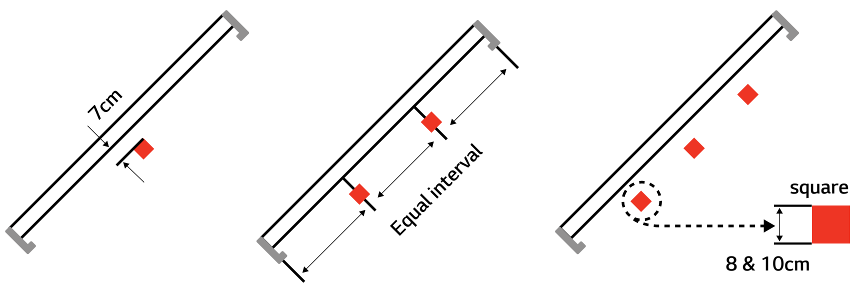
* Source : OPSUN bifacial Racking System.

2. Design guide for bifacial

2-4. Shading

Simulation results for bifacial gain with shading

Mounting conditions



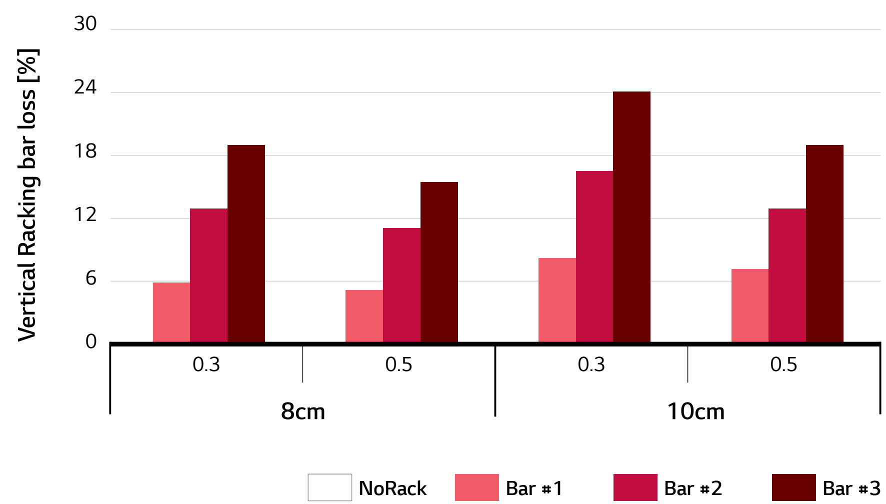
1 Rail   2 Rails   3 Rails

Installation condition (Fixed tilt)

Location	Las Vegas, NV (GHI 2032 kWh/m^2)	**Layout**	Portrait, 1stack
Tilt angle	36deg	**Pitch**	4.5m (0.44)
Height	1m	**Albedo**	20%

* Latitude 36.1 / Longitude -115 / GHIYear 2032 kWh (LAS VEGAS MCCARRAN INTL AP)

Shading loss by condition



Bifacial Gain by Mounting

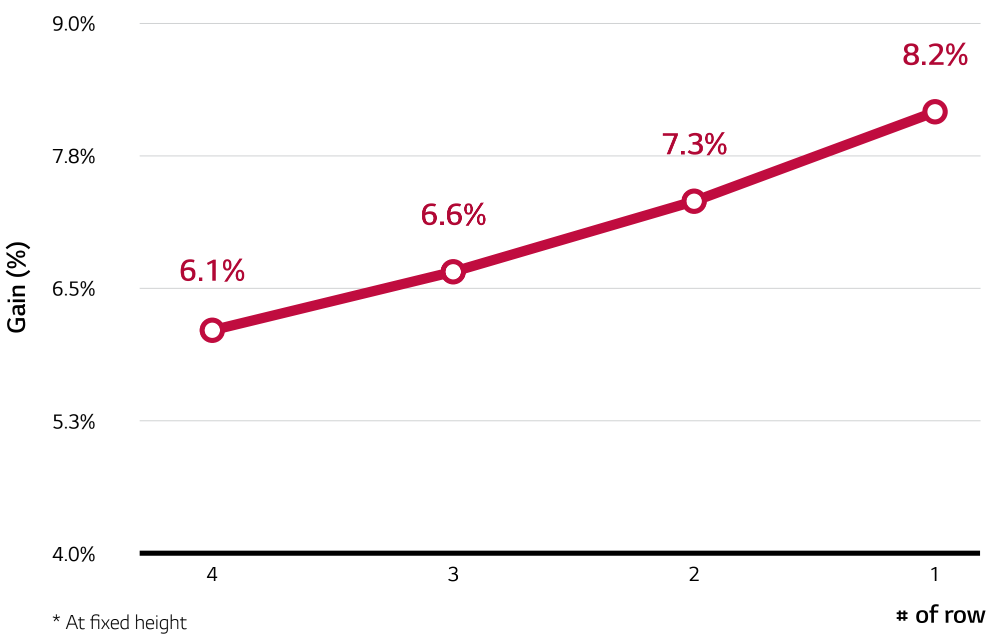
Rail size	Rail reflectivity	Bifacial gain [%]			
		No Rack	1 Rail	2 Rails	3 Rails
8 cm / 3.15 in	30 %	5.95	5.62	5.14	4.79
	50 %		5.65	5.30	5.01
10 cm /3.94 in	30 %		5.42	4.96	4.52
	30 %		5.53	5.16	4.78

2-5. Array Design

Array Design

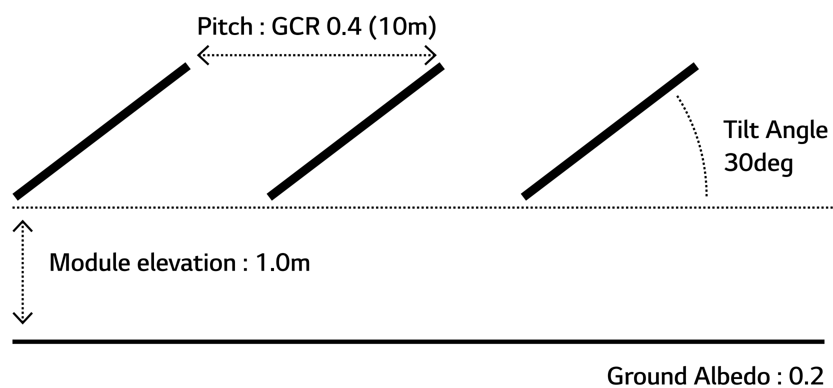
The bifacial gain is affected by the number of rows in the array. Based on the ground mount (fixed tilt system), the bifacial gain increases as the number of rows decrease, from 4 rows to 1 row. Therefore, you will be able to see an increase in overall performance by minimizing the number of rows in your overall system.

Bifacial gain by number of rows



* At fixed height

Fixed mount installation condition



Location : California, USA
Landscape : 4 rows to 1 row
Pitch : GCR 0.4 (10m)
(4 rows : 10m, 3 rows : 7.5m, 2 rows : 5.0m, 1 row : 2.5m)
Albedo : 0.2
Global Horizontal Irradiation (GHI) : 1895 [mW/m^2]

3. Electrical Design Guide for the Bifacial PV System

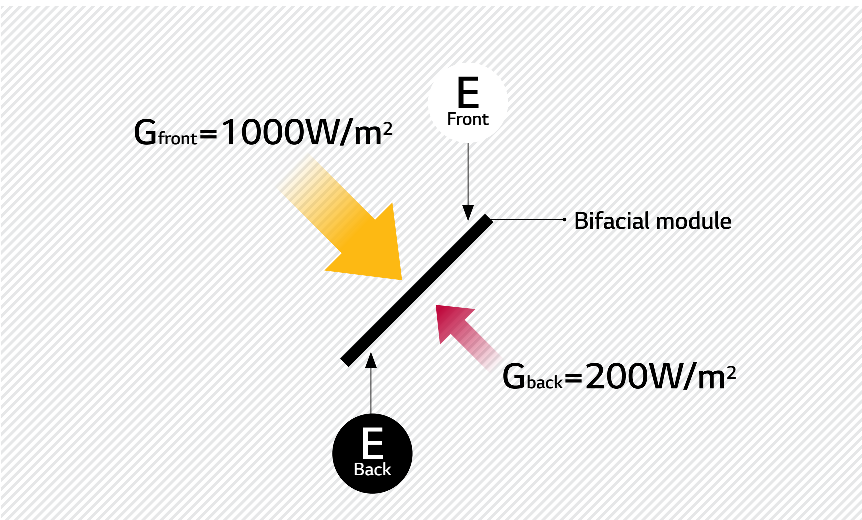
3-1. Electrical Design for Bifacial PV System

Electrical Behavior of Bifacial PV Module

The Bifacial PV Module produces more energy by absorbing the light on the frontside and the backside simultaneously. As a result, the total produced energy of the Bifacial PV Module is calculated by the sum of energy from the frontside and the backside of the module. The bifacial output power can be viewed as a monofacial module producing energy from the total sum of sunlight exposed to the frontside and the backside of the bifacial module.

When there is a certain amount of bifacial gain, the electrical behavior of bifacial PV module is almost equivalent as that of a monofacial with higher output power, which from the sum of the irradiance exposed to the front and the backside of the bifacial module.

Bifacial module



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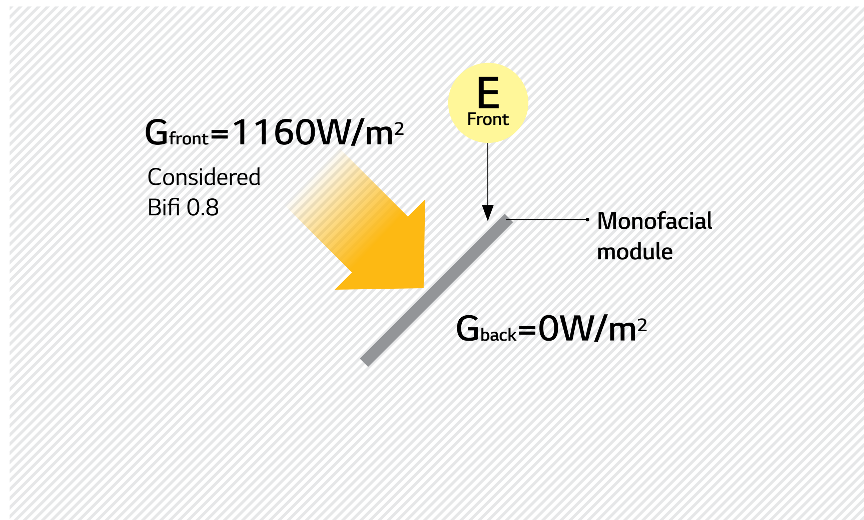
Monofacial module



(under sum of irradiance)

3. Electrical Design Guide for the Bifacial PV System

3-1. Electrical Design for the Bifacial PV system

Electrical Specifications of the bifacial PV module

It is very important to identify the estimated bifacial gain before designing the system. After determining the expected bifacial gain under the conditions mentioned before, the electrical components (inverters, cables, protection devices, etc.) used in the bifacial system must be calculated and selected based on electrical properties of bifacial PV module according to the additional bifacial gain. For example, if the system is expected to produce 10% gain, the electrical properties shown for 10% bifacial gain (highlighted in red below) should be used.

Model		LG315N1T-A5	Bifacial gain					
			5%	10%	15%	20%	25%	30%
Maximum Power (Pmax)	[W]	315	331	347	362	378	394	410
MPP Voltage (Vmpp)	[V]	33.5	33.5	33.5	33.5	33.6	33.6	33.6
MPP Current (Impp)	[A]	9.41	9.88	10.36	10.80	11.25	11.72	12.20
Open Circuit Voltage (Voc)	[V]	40.8	40.8	40.8	40.8	40.9	40.9	40.9
Short Circuit Current (Isc)	[A]	10.12	10.63	11.14	11.64	12.11	12.65	13.12

3. Electrical Design Guide for the Bifacial PV System

3-2. Inverter sizing

Inverter sizing

Two factors should be considered when choosing an inverter for the bifacial PV System.

1. Max Input Current of the Inverter

The current (Isc) value of the Bifacial PV Module is increased by backside boost, where the voltage of the bifacial is constant. As a result, the current increases around 20% when the bifacial gain is at 20%. Check the max input current rating of the inverter and see if the inverter is rated to satisfy the increased current from the bifacial module.

2. Inverter Sizing

If there is no compulsory regulation for inverter sizing, use the inverter sizing methodology of a conventional monofacial module. However, use the real power (gained power) rather than the nominal power of the bifacial PV module. For example, if a 10% gain is expected, then refer to the power associated with the 10% gain instead of the nameplate rating of the module.

It is important to consider the DC-AC ratio and the clipping loss rate when selecting the inverter size. The DC-AC ratio and the clipping loss will be increased by the power gain. If you would like to maintain the same clipping loss value related to a monofacial module with the same nameplate rating, you should use the total power from the bifacial module and either scale down the DC capacity of the system or scale up the AC inverter capacity. However, if the clipping loss only increases slightly (increases under 1-2%), it may be more efficient to use same capacity of inverter without sizing up.

* DC-AC ratio = DC capacity/AC capacity

3. Electrical Design Guide for the Bifacial PV System

3-2. Inverter sizing

Inverter sizing (Example)

The system configuration below is for a site using a 380W bifacial module with a bifacial gain of about 10%.
The bifacial PV system has more clipping loss due to the higher DC-AC ratio caused by the increased module output power.

	Monofacial	Bifacial (10% gain assumed)		
		1. same configuration (DC-AC ratio up)	2. same clipping loss (reduce module qty)	3. same clipping loss (increase AC capacity)
DC capacity	90.44kW	99.48kW	90.29kW	99.48kW
- Module nominal power	380W	380W	380W	380W
- Module real power	-	418W	418W	418W
- Module quantity	238	238	216	238
AC capacity (Inverter)	75kW	75kW	75kW	Above 83kW
DC-AC ratio	120.6%	132.6%	120.4%	120.0%
Clipping loss	0.6%	1.8%	0.5%	0.5%

1. If the increased clipping loss of the bifacial system is in an acceptable range, use Method No.1.
2. If clipping loss is required to be equivalent as that when using a monofacial system with the same nameplate rating (380W), then either :
- Decrease DC capacity by reducing the module quantity (Method No. 2)
- Increase AC capacity by sizing up the inverter (Method No. 3)

3. Electrical Design Guide for the Bifacial PV System

3-2. Inverter sizing

Guideline for inverter sizing considering clipping loss

Expected Clipping Loss (Europe)

	Monofacial	Bifacial gain			
		5%	10%	15%	20%
Output power [Wp]	380W	399W	418W	437W	456W
DC:AC ratio	112%	118%	123%	129%	134%
Clipping loss rate [%]	0	-0.2	-0.5	-1	-1.7
DC:AC ratio	121%	127%	133%	139%	145%
Clipping loss rate [%]	-0.3	-0.8	-1.5	-	-
DC:AC ratio	130%	136%	143%	149%	156%
Clipping loss rate [%]	-1.1	-1.9	-	-	-

Expected Clipping Loss (US)

	Monofacial	Bifacial gain			
		5%	10%	15%	20%
Output power [Wp]	380W	399W	418W	437W	456W
DC:AC ratio	112%	118%	123%	129%	134%
Clipping loss rate [%]	0.0	-0.1	-0.4	-1.0	-
DC:AC ratio	121%	127%	133%	139%	145%
Clipping loss rate [%]	-0.2	-0.7	-1.8	-	-
DC:AC ratio	130%	136%	143%	149%	156%
Clipping loss rate [%]	-1.2	-	-	-	-

* Values in table are calculated by simulation and should be used for reference. The values can change under real conditions.
You should decide the DC-AC ratio based on the clipping loss calculation.

Recommended

Not Recommended (over 2% Clipping Loss)

3. Electrical Design Guide for the Bifacial PV System

3-3. Consideration for using MLPE

Guideline for using MLPE devices

When using power optimizers on Bifacial PV modules, use the specifications of associated with the nominal power of the module (highlighted by the red box below). Power optimizer manufacturers suggest that the electrical properties of the module shall not exceed the input spec of the power optimizer. *Following user guideline by the power optimizer manufacturer is highly recommended.

Check the electrical values associated to the nominal power.

(1) Check Isc, Voc and Pmax value of bifacial module.

ex) LG380N2T,
Isc = 9.71A,
Voc = 49.2V,
Pmax = 380

(2) Find compatible MLPE devices that satisfy module input specs.

- Maximum input current and voltage of devices should be higher than Isc and Voc of the module.
  (Applying safety factor 1.25 is recommended)

Electrical Properties(STC*)

Model		LG380N2T-A5	Bifacial Gain		
			10%	20%	30%
Maximum Power (Pmax)	[W]	380	418	456	494
MPP Voltage (Vmpp)	[V]	41.1	41.1	41.1	41.1
MPP Current (Impp)	[A]	9.25	10.18	11.10	12.02
Open Circuit Voltage (Voc)	[V]	49.2	49.2	49.2	49.2
Short Circuit Current (Isc)	[A]	9.71	10.68	11.65	12.62
Module Efficiency	[%]	18.0	19.8	21.6	23.4

Front at STC

(3) Using an optimizer that has a lower input power than the nominal power of the bifacial module is not allowed according to manufacturer guide.

- For example, the power optimizer rated for 370W should not be operated with 380W bifacial even if the current and voltage ratings are compatible.
- In contrast, a microinverter is allowed to be used regardless of the Pmax of the bifacial.
  (clipping loss will occur depending on the operating conditions of the bifacial module.)

* MLPE : Module Level Power Electronics

4. LG NeON® 2 BiFacial

4-1. LG NeON® 2 BiFacial Specification

Electrical properties of 310W and 315W (60 cell)

Model		LG310N1T-A5						
		0%	5%	10%	15%	20%	25%	30%
Maximum Power (Pmax)	[W]	310	326	341	357	372	388	403
MPP Voltage (Vmpp)	[V]	33.1	33.1	33.1	33.1	33.2	33.2	33.2
MPP Current (Impp)	[A]	9.38	9.85	10.30	10.77	11.20	11.67	12.14
Open Circuit Voltage (Voc)	[V]	40.7	40.7	40.7	40.7	40.8	40.8	40.8
Short Circuit Current (Isc)	[A]	10.08	10.58	11.09	11.59	12.06	12.60	13.07

Model		LG315N1T-A5						
		0%	5%	10%	15%	20%	25%	30%
Maximum Power (Pmax)	[W]	315	331	347	362	378	394	410
MPP Voltage (Vmpp)	[V]	33.5	33.5	33.5	33.5	33.6	33.6	33.6
MPP Current (Impp)	[A]	9.41	9.88	10.36	10.80	11.25	11.72	12.20
Open Circuit Voltage (Voc)	[V]	40.8	40.8	40.8	40.8	40.9	40.9	40.9
Short Circuit Current (Isc)	[A]	10.12	10.63	11.14	11.64	12.11	12.65	13.12

* Note : the specification may change without notice at any time

4. LG NeON® 2 BiFacial

4-1. LG NeON® 2 BiFacial Specification

Electrical properties of 375W and 380W (72 cell)

Model		LG375N2T-A5						
		0%	5%	10%	15%	20%	25%	30%
Maximum Power (Pmax)	[W]	375	394	413	431	450	469	488
MPP Voltage (Vmpp)	[V]	40.2	40.2	40.2	40.2	40.3	40.3	40.3
MPP Current (Impp)	[A]	9.34	9.80	10.27	10.72	11.17	11.64	12.11
Open Circuit Voltage (Voc)	[V]	48.9	48.9	48.9	48.9	49.0	49.0	49.0
Short Circuit Current (Isc)	[A]	10.03	10.53	11.01	11.53	12.00	12.53	13.00

Model		LG380N2T-A5						
		0%	5%	10%	15%	20%	25%	30%
Maximum Power (Pmax)	[W]	380	399	418	437	456	475	494
MPP Voltage (Vmpp)	[V]	40.6	40.6	40.6	40.6	40.7	40.7	40.7
MPP Current (Impp)	[A]	9.37	9.83	10.30	10.76	11.20	11.67	12.14
Open Circuit Voltage (Voc)	[V]	49.0	49.0	49.0	49.0	49.1	49.1	49.1
Short Circuit Current (Isc)	[A]	10.07	10.57	11.08	11.58	12.05	12.58	13.06

* Note : the specification may change without notice at any time

4. LG NeON® 2 BiFacial

4-1. LG NeON® 2 BiFacial Specification

Electrical properties of 385W (72 cell)

Model		LG385N2T-A5						
		0%	5%	10%	15%	20%	25%	30%
Maximum Power (Pmax)	**[W]**	385	404	424	443	462	481	501
MPP Voltage (Vmpp)	**[V]**	41.0	41.0	41.0	41.0	41.1	41.1	41.1
MPP Current (Impp)	**[A]**	9.40	9.86	10.34	10.80	11.24	11.70	12.19
Open Circuit Voltage (Voc)	**[V]**	49.1	49.1	49.1	49.1	49.2	49.2	49.2
Short Circuit Current (Isc)	**[A]**	10.11	10.61	11.12	11.63	12.10	12.60	13.12

* Note : the specification may change without notice at any time

4. LG NeON® 2 BiFacial

4-2. LG BiFacial gain simulation

*** Site and installation condition**
- Latitude 36.0 / Longitude -85.0
- GHIYear 1414 kWh/m^2
- GCR 0.5
- Landscape 2stacks

Additional yield simulation (Crossville TN,US)

Expected Energy Yield by install condition

Albedo [%]	Surface in practical	Module height from ground [m]				
		0.2	0.3	0.5	0.7	1
15	Soil, meadows	4.1%	4.4%	4.8%	5.1%	5.4%
30	Dirt, Gravel, Concrete	7.0%	7.5%	8.4%	9.0%	9.6%
50	Sand	10.7%	11.6%	13.0%	14.1%	15.2%
70	Snow	14.3%	15.4%	17.5%	19.0%	20.5%
85	White membrane	16.8%	18.3%	20.8%	22.7%	24.5%

* Note 1: Base on LG internal Simulation Program
* Note 2: Shading by mounting structure in not considered.

Tilt angle correction factor

reflection rate [%]	Module Tilt Angle (degrees)					
	θ = 10°	θ = 20°	θ = 25°	θ = 30°	θ = 60°	θ = 90°
30	98%	100%	101%	100%	88%	66%
85	97%	100%	100%	100%	92%	78%

* Note1: this value is calculated by internal simulation using small single array. The bifacial gain value shall change by PV system capacity and installation condition.

4. LG NeON® 2 BiFacial

4-2. LG BiFacial gain simulation

*** Site and installation condition**
- Latitude 36.1 / Longitude -115.0
- GHIYear 2032 kWh/m^2
- GCR 0.5
- Landscape 2stacks

Additional yield simulation (Las Vegas NV,US)

Expected Energy Yield by install condition

Albedo [%]	Surface in practical	Module height from ground [m]				
		0.2	0.3	0.5	0.7	1
15	Soil, meadows	3.1%	3.3%	3.7%	3.9%	4.2%
30	Dirt, Gravel, Concrete	5.6%	6.0%	6.8%	7.3%	7.9%
50	Sand	8.7%	9.5%	10.7%	11.7%	12.6%
70	Snow	11.7%	12.8%	14.6%	15.9%	17.2%
85	White membrane	13.9%	15.2%	17.4%	19.0%	20.6%

* Note 1: Base on LG internal Simulation Program
* Note 2: Shading by mounting structure in not considered.

Tilt angle correction factor

reflection rate [%]	Module Tilt Angle (degrees)					
	θ = 10°	θ = 20°	θ = 25°	θ = 30°	θ = 60°	θ = 90°
30	96%	100%	100%	100%	88%	65%
85	95%	99%	100%	100%	92%	77%

* Note1: this value is calculated by internal simulation using small single array. The bifacial gain value shall change by PV system capacity and installation condition.

4. LG NeON® 2 BiFacial

4-2. LG BiFacial gain simulation

*** Site and installation condition**
- Latitude 48.14 / Longitude 11.57
- GHIYear 1169 kWh/m^2
- GCR 0.5
- Landscape 2stacks

Additional yield simulation (Munchen, Germany)

Expected Energy Yield by install condition

Albedo [%]	Surface in practical	Module height from ground [m]				
		0.2	0.3	0.5	0.7	1
15	Soil, meadows	3.3%	3.5%	3.9%	4.2%	4.5%
30	Dirt, Gravel, Concrete	5.8%	6.3%	7.1%	7.7%	8.3%
50	Sand	9.1%	9.8%	11.3%	12.4%	13.4%
70	Snow	12.2%	13.3%	15.4%	16.8%	18.3%
85	White membrane	14.6%	16.0%	18.3%	20.1%	21.9%

* Note 1: Base on LG internal Simulation Program
* Note 2: Shading by mounting structure in not considered.

Tilt angle correction factor

reflection rate [%]	Module Tilt Angle (degrees)					
	θ = 10°	θ = 20°	θ = 25°	θ = 30°	θ = 60°	θ = 90°
30	98%	101%	102%	100%	90%	70%
85	97%	101%	102%	100%	93%	80%

* Note1: this value is calculated by internal simulation using small single array. The bifacial gain value shall change by PV system capacity and installation condition.

4. LG NeON® 2 BiFacial

4-2. LG BiFacial gain simulation

*** Site and installation condition**
- Latitude -27.46 / Longitude -153.02
- GHIYear 1912 kWh/m^2
- GCR 0.5
- Landscape 2stacks

Additional yield simulation (Brisbane, Australia)

Expected Energy Yield by install condition

Albedo [%]	Surface in practical	Module height from ground [m]				
		0.2	0.3	0.5	0.7	1
15	Soil, meadows	3.1%	3.3%	3.8%	4.1%	4.5%
30	Dirt, Gravel, Concrete	5.6%	6.1%	7.0%	7.7%	8.4%
50	Sand	8.9%	9.6%	11.2%	12.5%	13.7%
70	Snow	12.0%	13.1%	15.3%	16.9%	18.7%
85	White membrane	14.2%	15.6%	18.3%	20.4%	22.4%

* Note 1: Base on LG internal Simulation Program
* Note 2: Shading by mounting structure in not considered.

Tilt angle correction factor

reflection rate [%]	Module Tilt Angle (degrees)					
	θ = 10°	θ = 20°	θ = 25°	θ = 30°	θ = 60°	θ = 90°
30	99%	101%	101%	100%	86%	60%
85	97%	100%	101%	100%	91%	74%

* Note1: this value is calculated by internal simulation using small single array. The bifacial gain value shall change by PV system capacity and installation condition.

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