



LG Bifacial Module Status of development

Date : September, 18th, 2017

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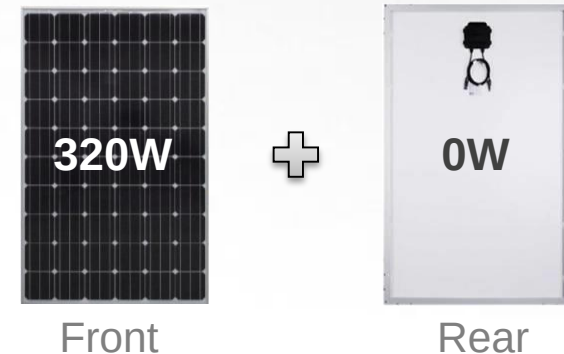
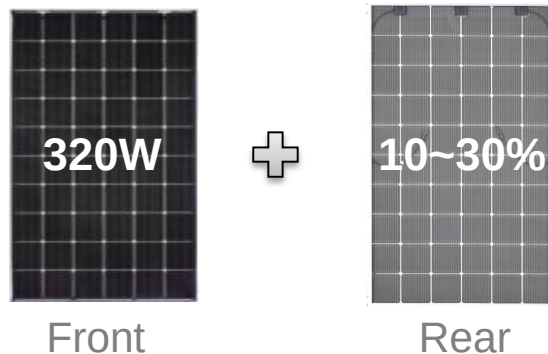
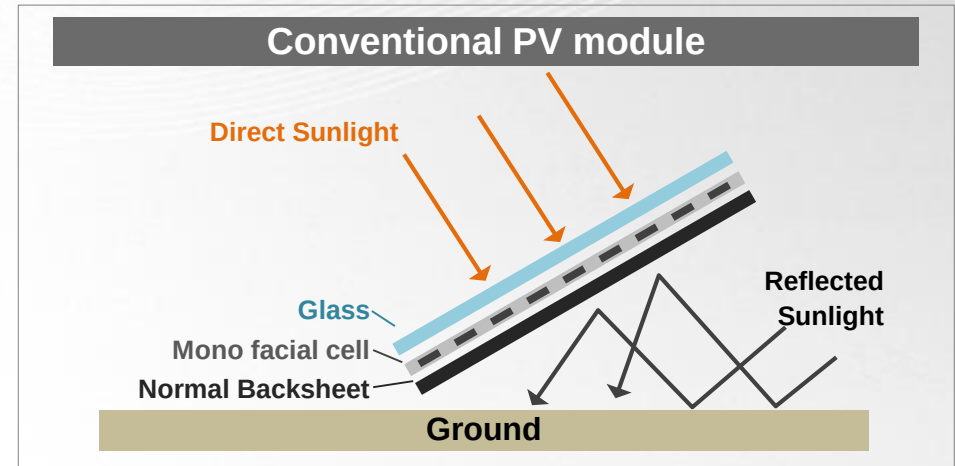
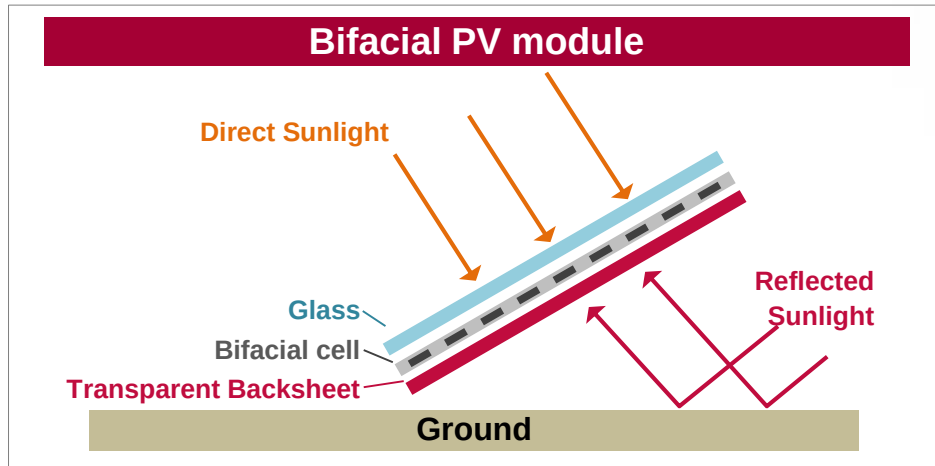
- 1** What is Bifacial?
- 2** PV Bifacial Module Global Market Outlook
- 3** Introduction of LG Bifacial Module
- 4** Bifacial effect
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01 What is Bifacial?

While conventional solar modules limit solar cells to the front panel, the LG NeON[®] 2 BiFacial features transparent solar cells on both sides. This allows the panel to collect light reflected and boosts efficiency.

Bifacial's 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.



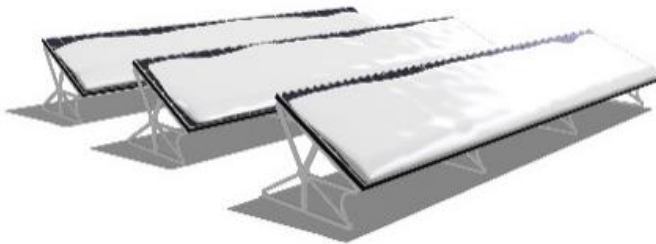
Bifacial module has advantages for the installation at the limited space.



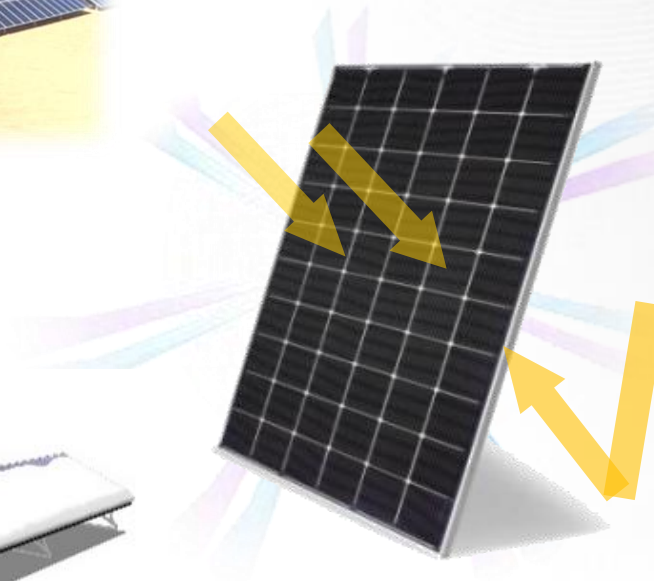
Bright Desert



Carport



Snow condition



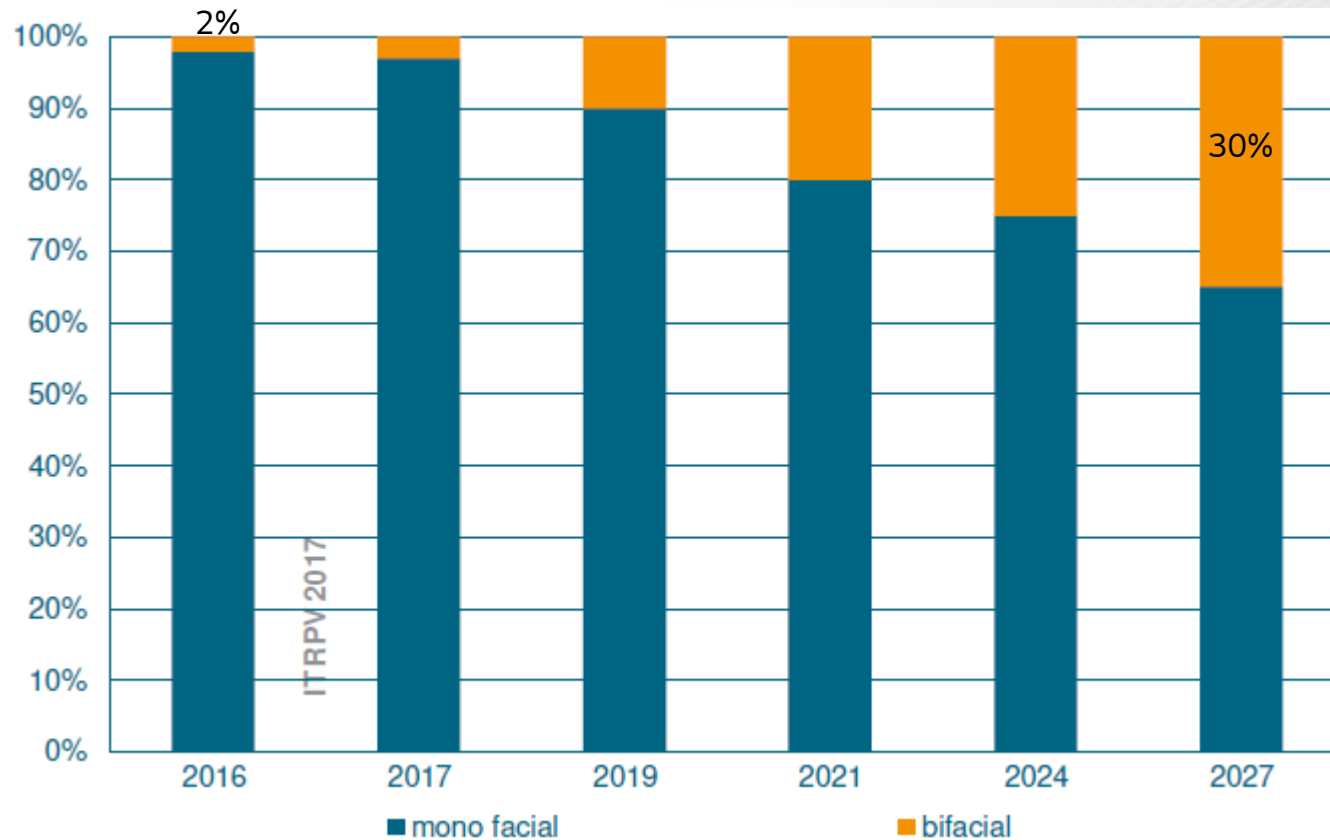
Noise barrier

※ Poster Session : MSI-P-16 (Simulation of Bifacial)

02 PV Bifacial Module Global Market Outlook

The bifacial market will be expected to account for 30% of the total c-Si market In 2027

The worldwide market shares for monofacial and “true” bifacial modules



- Source : ITRPV 2017 (International Technology Roadmap for PV)

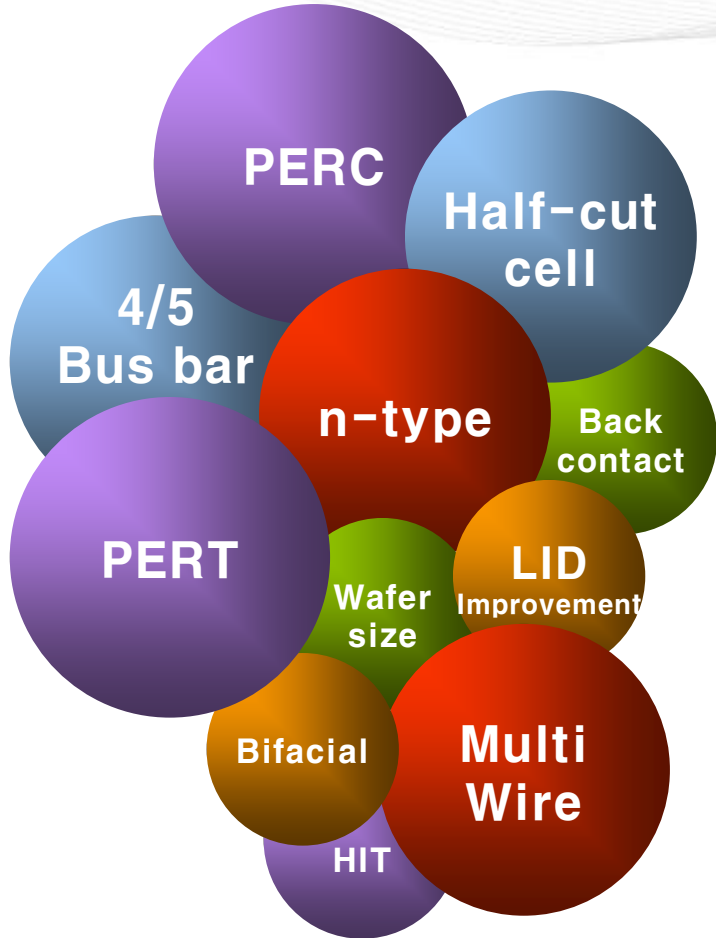
LG N_eON[®] 2*BiFacial*

True bifacial product with optimized design for bifacial effect



03 Introduction of LG Bifacial Module

High efficiency technology?



LG's solution

■ n-type

- Cell tech. : n-PERT, **Bifacial**
- Module tech. : Multi wire

■ p-type

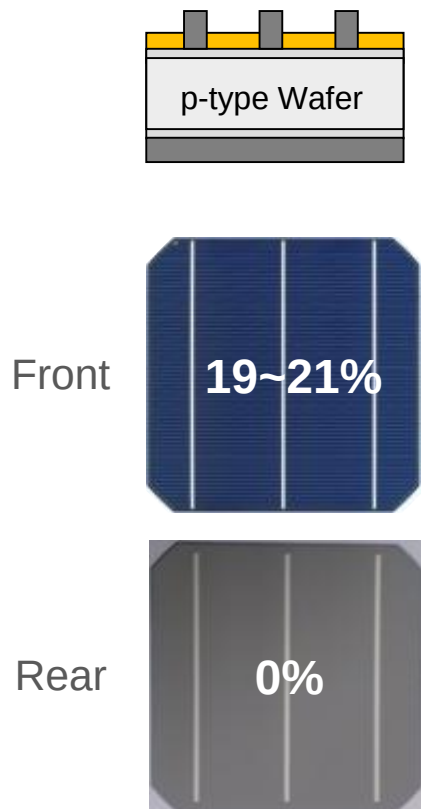
- Controlling fundamental flaw

03 Introduction of LG Bifacial Module

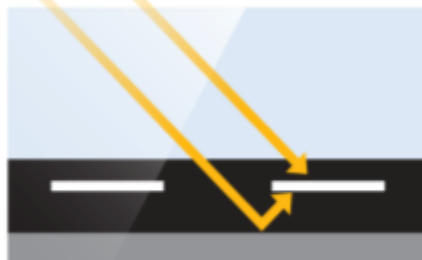
Why n-type?

Compared to the conventional module, LG n-type module generates more power due to the utilization of the reflected light from the back side of the module.

Conventional

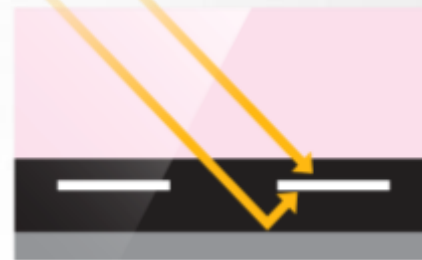


X

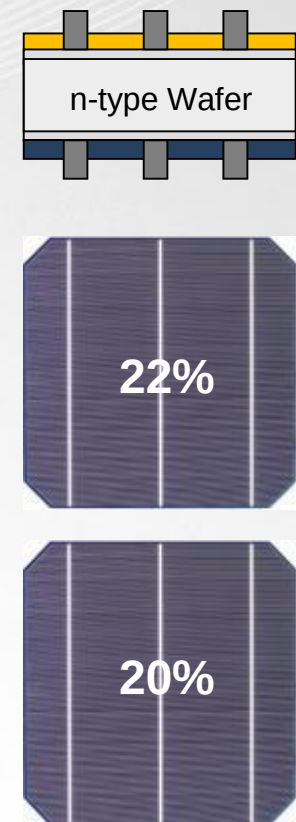


VS.

O



LG n-type (PERT)



- ✓ Improve module power output
- ✓ Maximize harvesting at sun rise and sunset

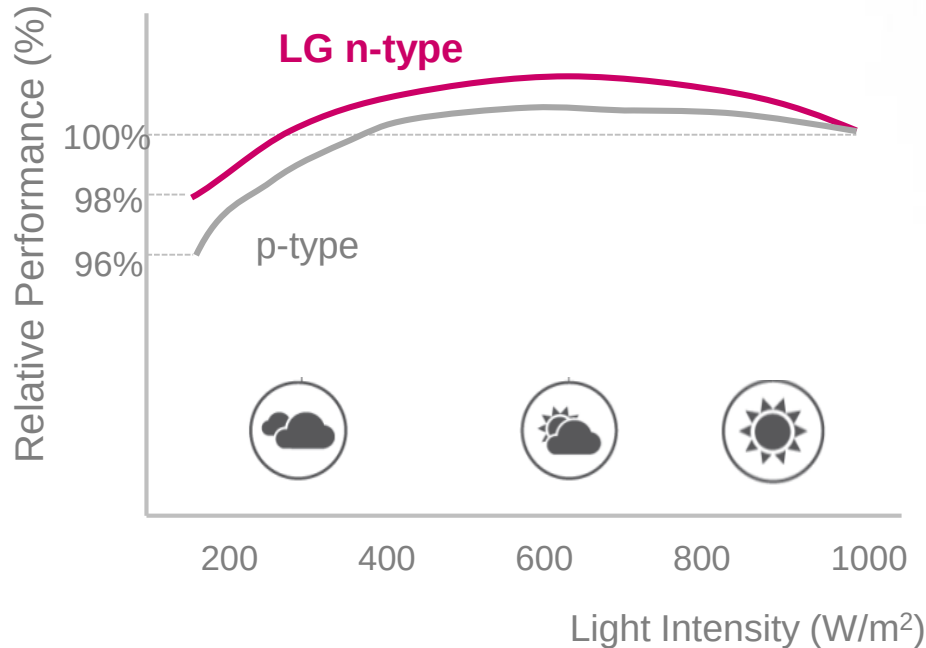
03 Introduction of LG Bifacial Module

Advantages

LG n-type generates more power on both of cloudy and sunny day.

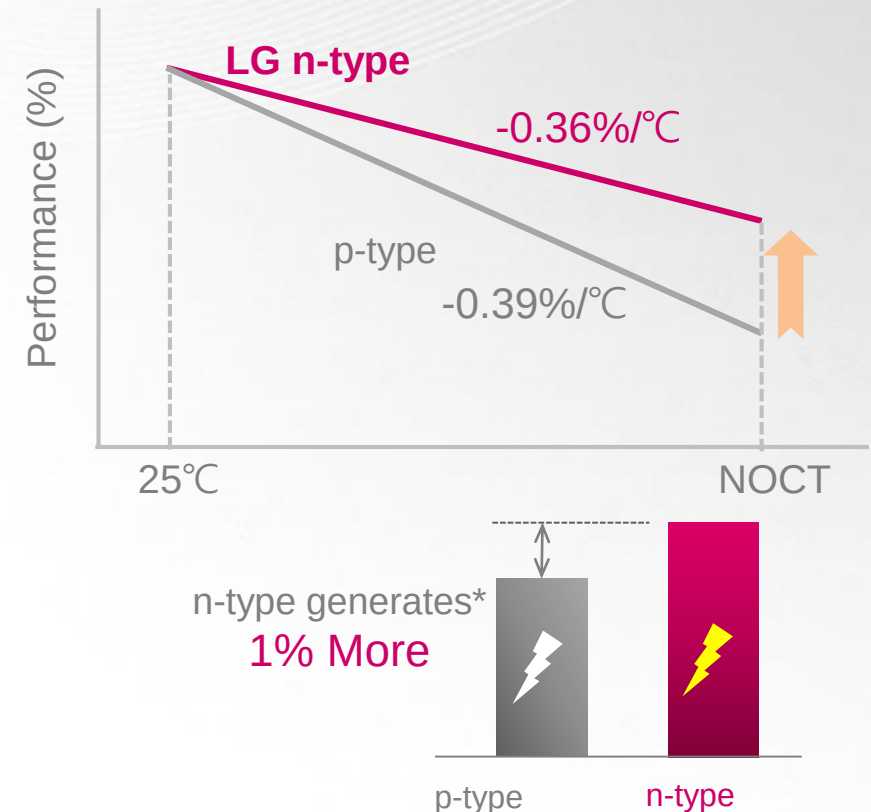
Low irradiation condition

LG n-type generate more power compared to p-type module at low irradiation condition.



Temperature Coefficient

LG n-type generate more power compared to p-type module on a sunny day.



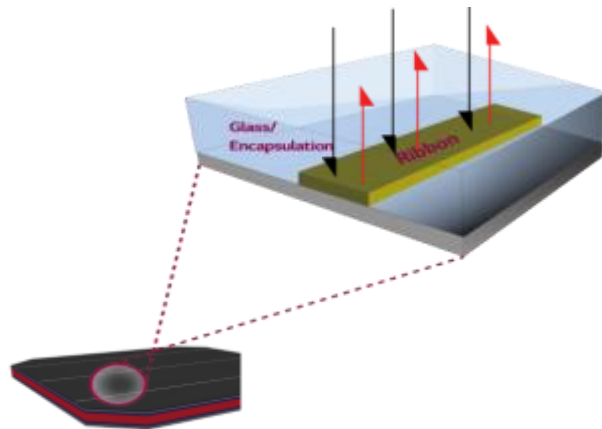
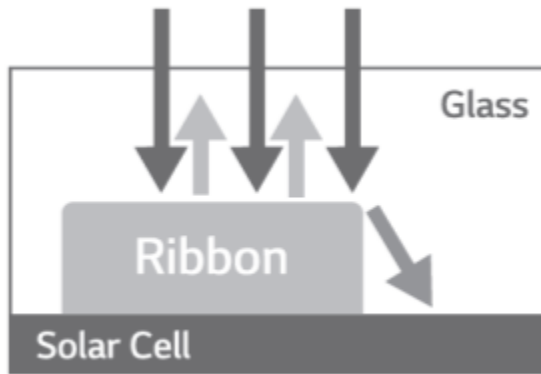
* Base on PV Syst simulation (Sunny day)

03 Introduction of LG Bifacial Module

Advanced module technology

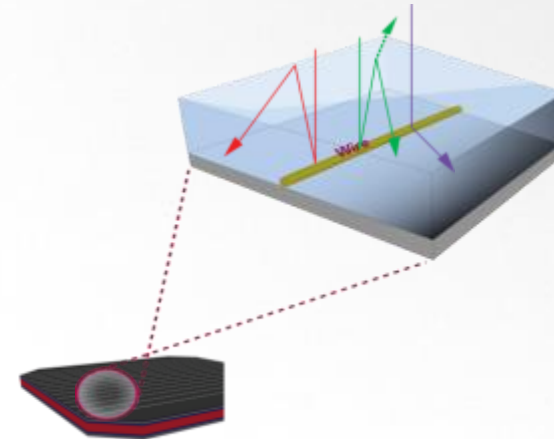
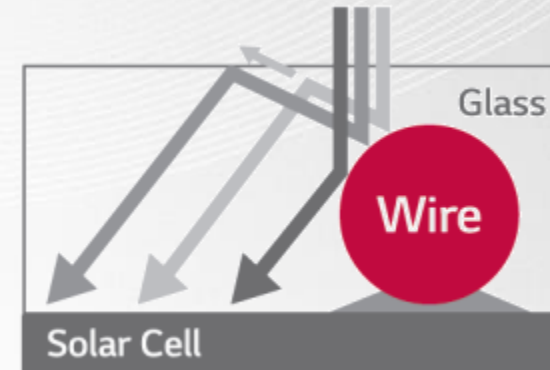
The **Cello*** technology facilitate harvesting of the light by scattering the light hitting on the wire in various angles.

Conventional Structure



VS.

Cello Structure



※ **Cello** : Cell connection with electrically low loss, low stress and optical Absorption enhancement
→ applicable for both of n-type & p-type

03 Introduction of LG Bifacial Module

Advanced module technology

The **Cello** technology reduces the electrical loss by spreading the current of 3 ribbons to each of 12 wires, designed to reduce electrical resistance.

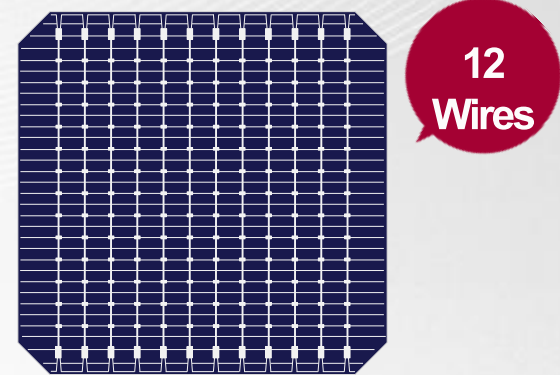
Conventional Structure



Higher current
in each path



Cello Structure



VS.



Lower current
in each path

Electrical
Loss

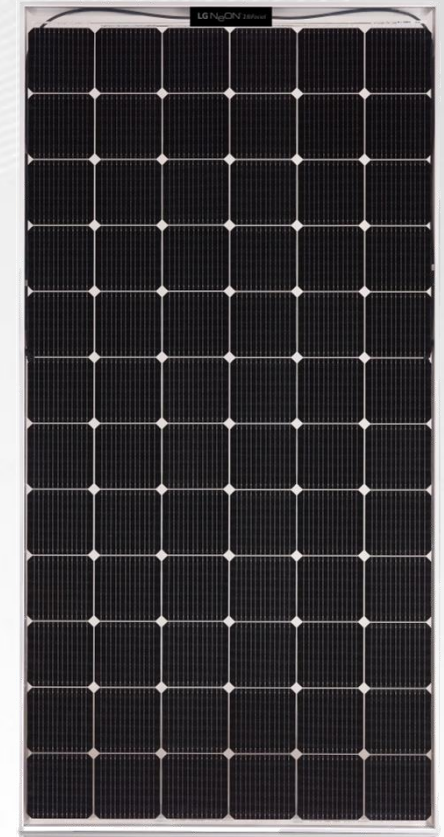


03 Introduction of LG BiFacial Module

LG NeON[®] 2 BiFacial

Specification

# of cell	60	72
Power(w)	315 ~ 325	385 ~ 395
Efficient(%)	17.8 ~ 18.3	18.2 ~ 18.7
Dimension(mm)	1,730 x 1,024 x 40	2,064 x 1,024 x 40
Weight(kg)	18.2	22.0
Key feature	• High BiFacial coefficient • Best choice in areas with snowfall and low irradiation • Optimized module design for BiFacial generation	



03 Introduction of LG Bifacial Module

Competitiveness

The LG LG NeON® 2 BiFacial module has the competitiveness at the weight and out-put power.

Items		NeON 2 BiFacial	S Company
Visual	Rear material	Backsheet	Glass
	J-Box Shading	x	O
	Frame Shading	O	O
	Label Position	Frame	Transparency
	Weights	18.2kg	21.5kg
Power	Front (Spec.)	320W (spec. : 320W)	268W (spec : 270W)
	Rear	265W	155W
	BIFI	82%	58%
Reliability	Initial Degradation	-0.18%	-3.36%
	Damp Heat	-2.16% (DH1000) DH3000 (on going)	+2.61% (DH1000) +2.36% (DH3000)
	Thermal Cycle	-1.9% (TC600)	+1.05% (TC200) -0.56 (TC400)
	PID	PID Free	-0.36%
Out-door Performance (PR) Comparison		Ref	-15%

1) LGE Reliability test results were performed using 72cell Module

03 Introduction of LG Bifacial Module

Bifaciality Coefficient

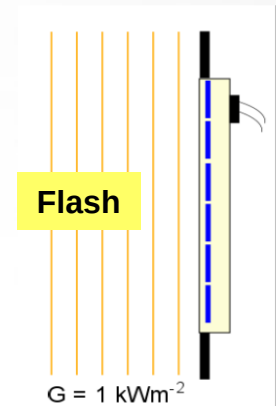
LG Electronics has implemented a new bifacial module that adds 315 W of rear power to the 385 W front power thanks to the high Bifaciality Coefficient of 82%.

$$\text{LG NeON}^{\text{®}}2 \text{ BiFacial Bifaciality Coefficient} = \frac{P_{\text{max, rear-side}}}{P_{\text{max, front-side}}} = 82\%$$

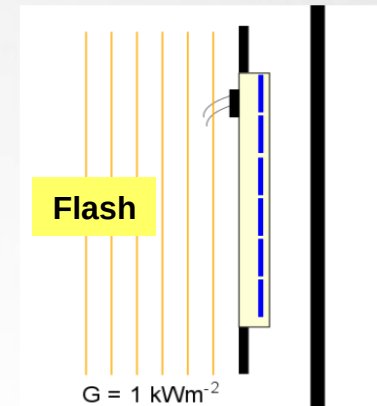
Front & Rear Power Output

		P-max (at STC)		
		Front(W)		Rear(W)
#of Cell	72	390	Bifaciality coefficient 82%	315.7
		385		311.6
	60	325		258.3
		320		254.2

Characterization



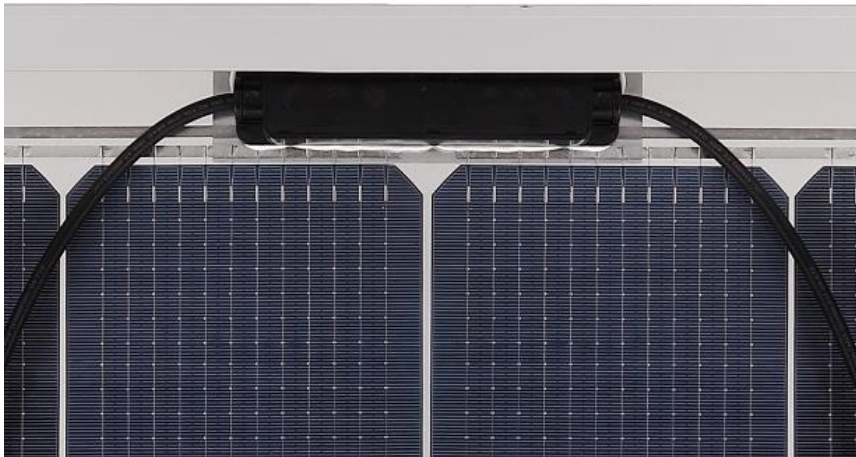
Front side



Rear side

For a high Bifaciality coefficient, LG LG NeON[®] 2 BiFacial was designed to prevent back side shading.

LG NeON[®] 2 BiFacial



LG Internal Test

Bifaciality coefficient **82%**

Using a conventional J/box



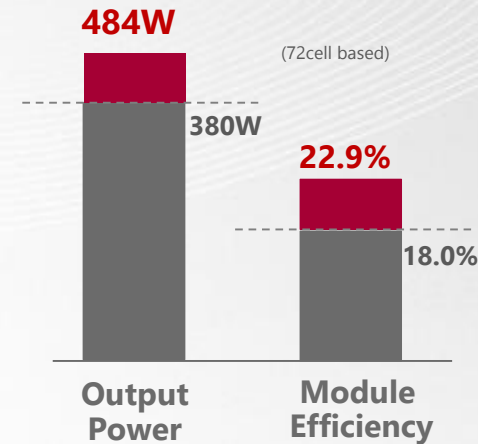
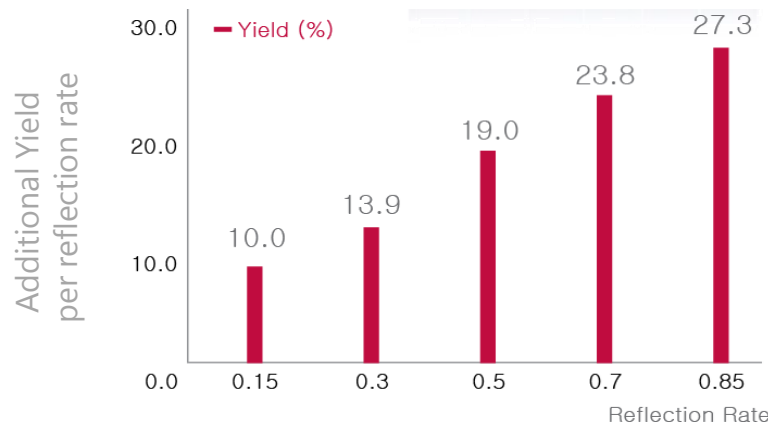
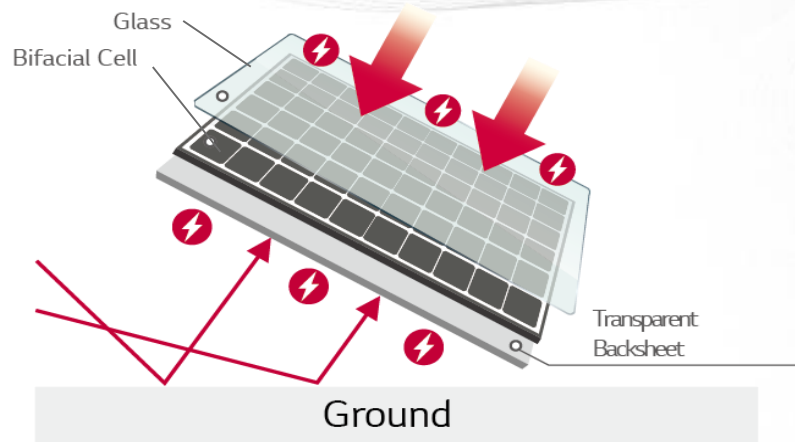
Bifaciality coefficient **70%**

03 Introduction of LG Bifacial Module

Bifacial Gain

Additional yield with bifacial effect

Bifacial Structure



More energy up to 27%!

Base on LG internal Simulation Program
Condition: Ground reflection rate (white color) 0.85, Module height : 1.0m, Tilt angle : 30°

Bifacial Effect



The Bifacial Module can melt snow much faster than Monofacial.

09:00

Monofacial



12:00



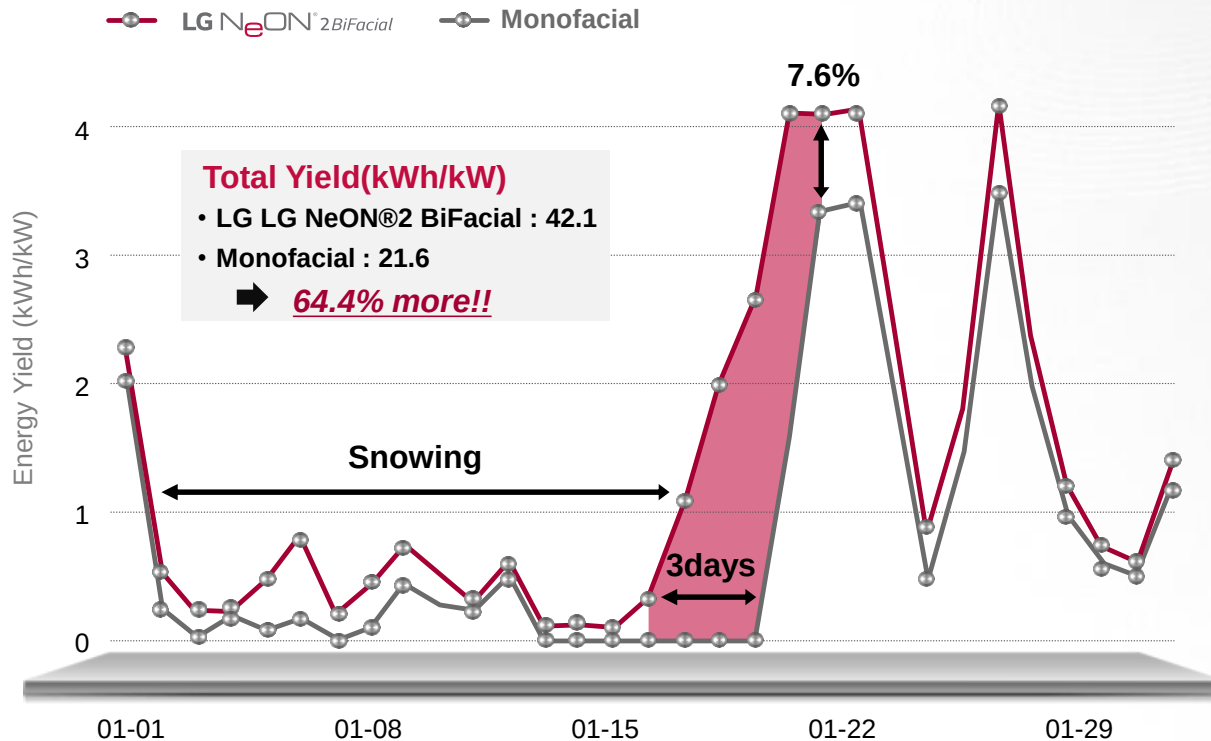
Bifacial



04 Bifacial Effect

Under Snow

The Bifacial module can take advantage of the high reflectance of the snow to produce power by rear side. The reflection on the back also contribute to accelerates the melting of the snow covering the front. During snow season, higher Yield can be expected than monofacial product.



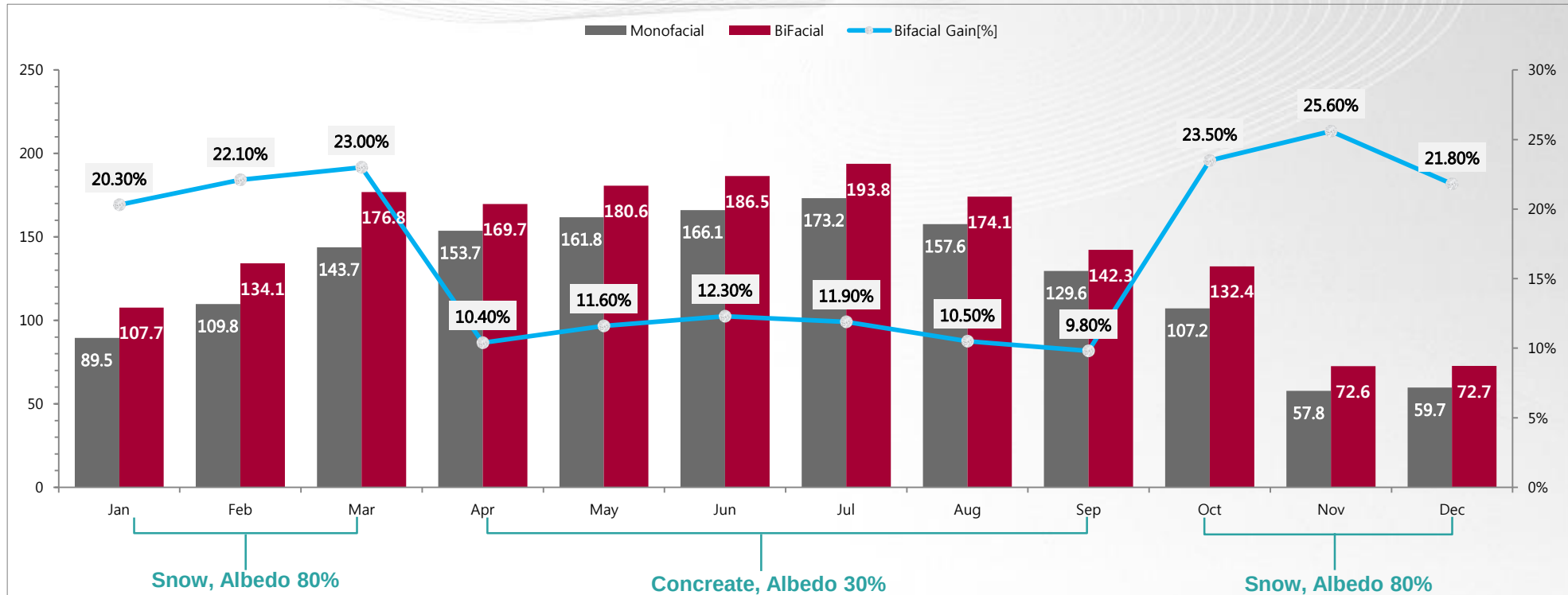
- Module : LG LG NeON[®] 2 BiFacial 300W, 12ea(old ver), LG NeON[®]2 300W, 12ea
- Inverter : SMA SB3000TL
- Location : Nidrum, Belgium, Customer site
- Albedo ≈ 20% (Grass)
- Height : 1.2m

04 Bifacial Effect

Under Snow

Bifacial Effect Simulation 1 - CANADA, Toronto

Fixed Tilt



* Simulation Information

- Location : Toronto, CANADA
- Tilt Angle : 30 deg
- Height : 1m
- Layout : 2 stack, Landscape
- Pitch(GCR) : 7m(0.28)
- GMI(kW/m²) : 1352.2

Total Yield(kWh/kWp, DC)

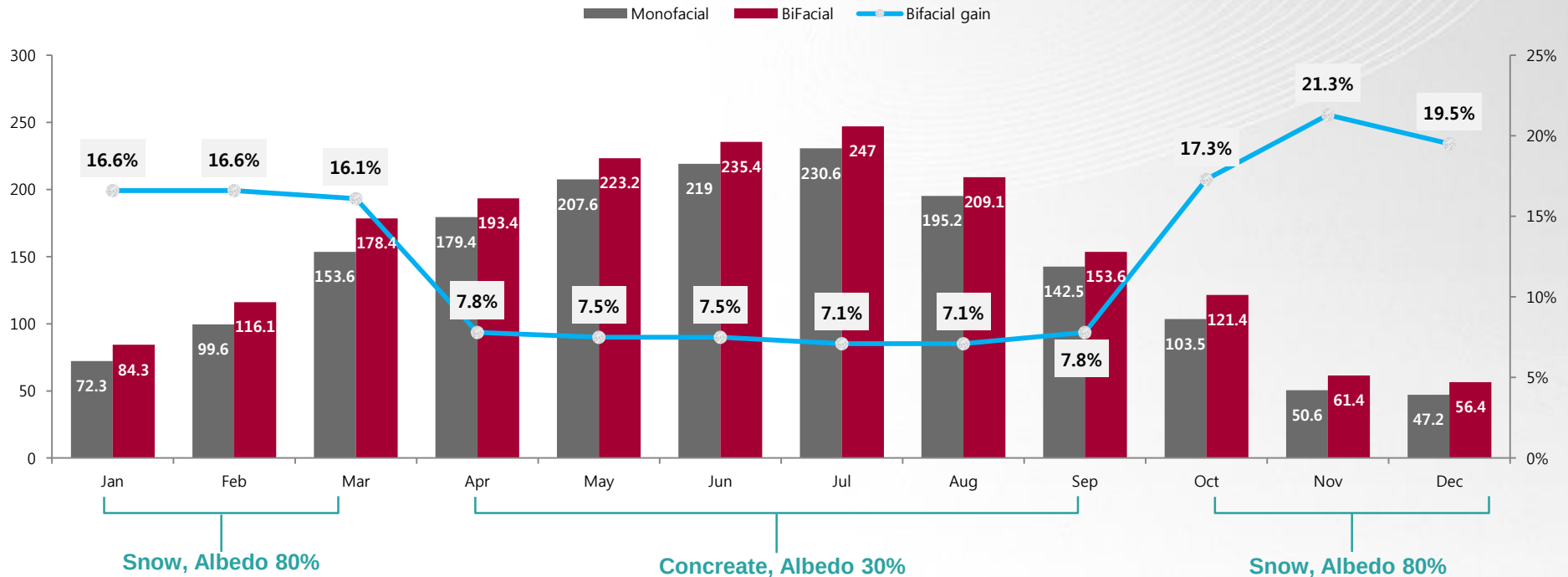
- LG LG NeON®2 BiFacial : 1743.3
- Monofacial : 1509.7

Average BiFacial Gain : 15.5%

- 1) Do not apply change of height by snowfall to simulation result
- 2) Do not apply power drop by snowfall on the front of module to simulation result

Bifacial Effect Simulation 1 - CANADA, Toronto

SAT(Single Axis Tracker)



* Simulation Information

- Location : Toronto, CANADA
- Max Tilt Angle : 60 deg
- Height : 1.2m
- Layout : 1 stack, Portrait
- Pitch(GCR) : 6m(0.33)
- GMI(kW/m²) : 1352.2

Total Yield(kWh/kWp, DC)

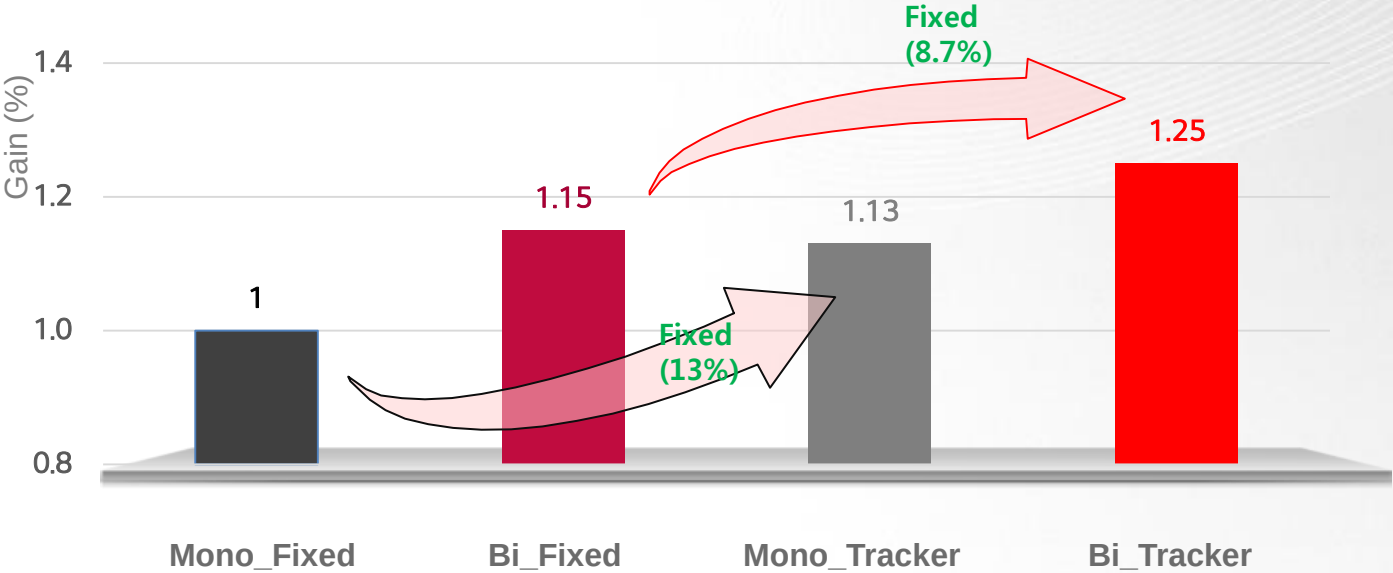
- LG LG NeON[®]2 BiFacial : 1879.7
- Monofacial : 1701.1

Average BiFacial Gain : 10.5%

- 1) Do not apply change of height by snowfall to simulation result
- 2) Do not apply power drop by snowfall on the front of module to simulation result

Bifacial Effect Simulation 1 - CANADA, Toronto

SAT(Single Axis Tracker)

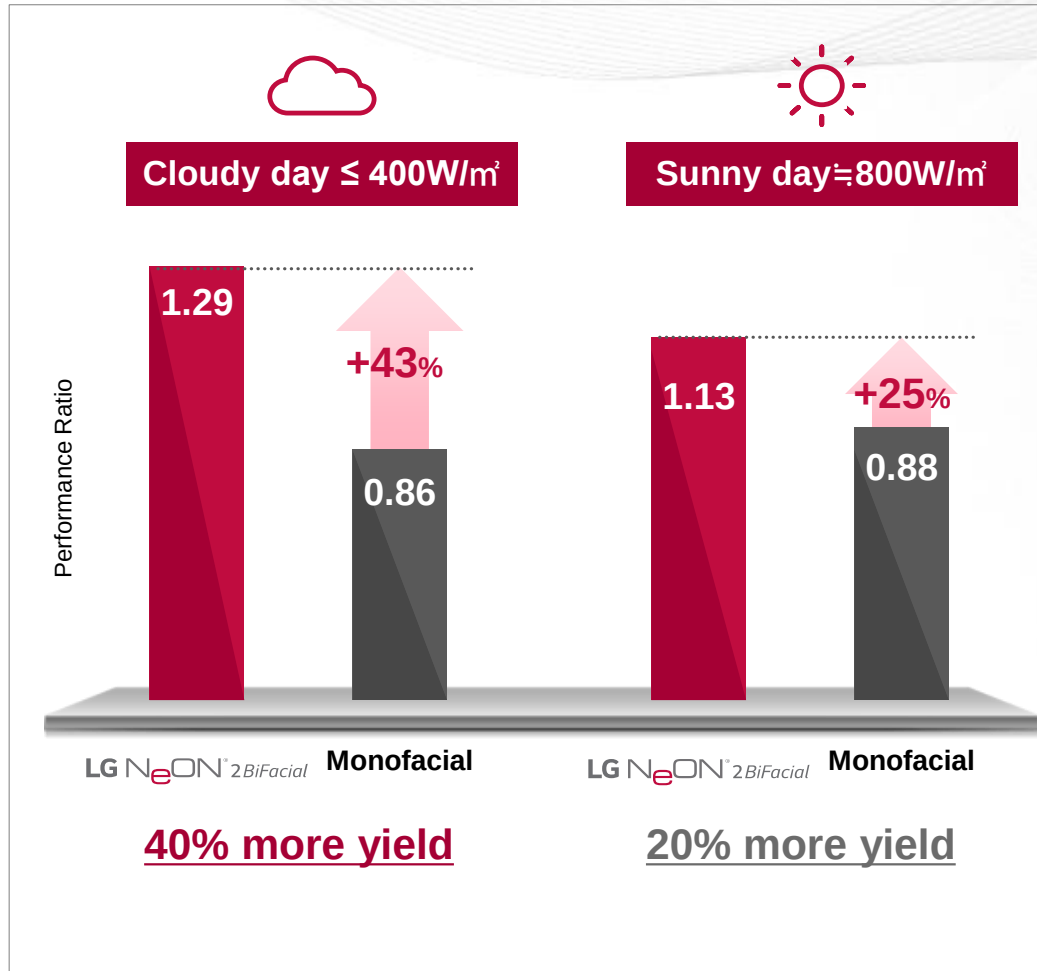


	Mono_Fixed	Bi_Fixed	Mono_Tracker	Bi_Tracker
Yield (Wh/Wp)	1509.7	1743.3	1701.1	1879.7
Gain (%)	-	15	13	25

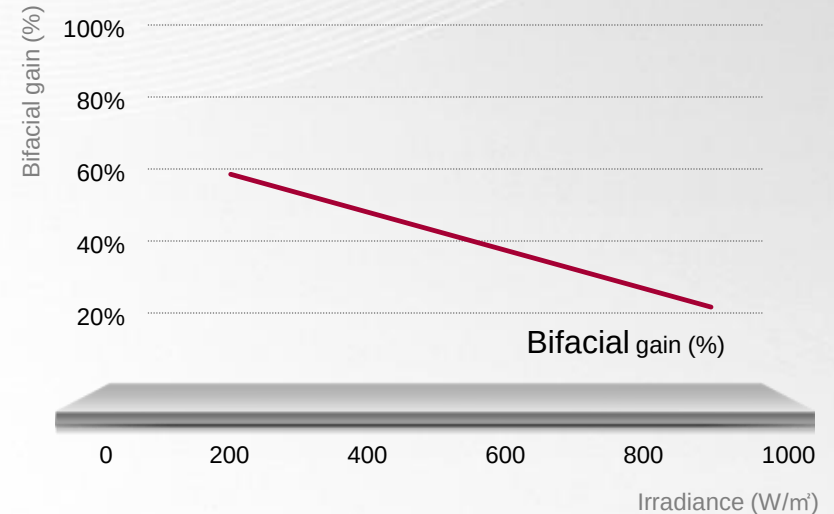
04 Bifacial Effect

Under low irradiance

The Bifacial Gain under low irradiance is relatively high because of scattered light by cloud



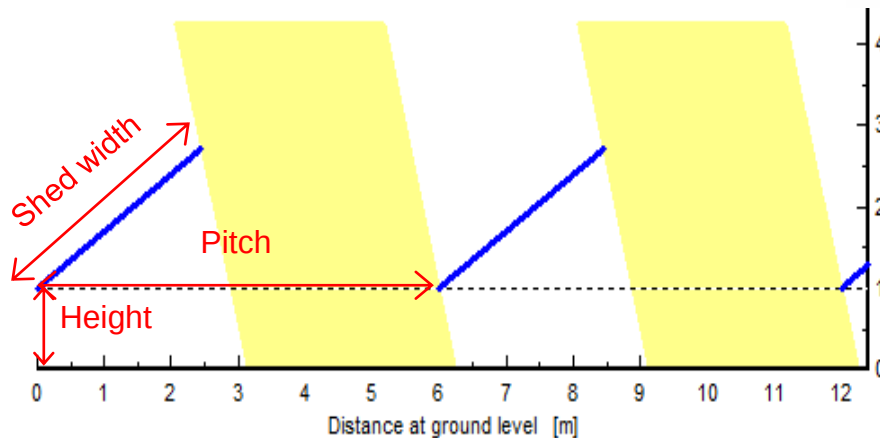
Bifacial gain dew to Irradiance



- Module
 - LG LG NeON² 315W, 5ea
 - LG NeON2 BiFacial 300W, 5ea (old ver)
- Inverter : SMA SB1700
- Location : Gumi city, Korea
- Albedo $\approx 80\%$ ((White membrane)
- Height : 1.0m, Tilt angle : 30°
- LG Internal Test('16 7/22~8/5)

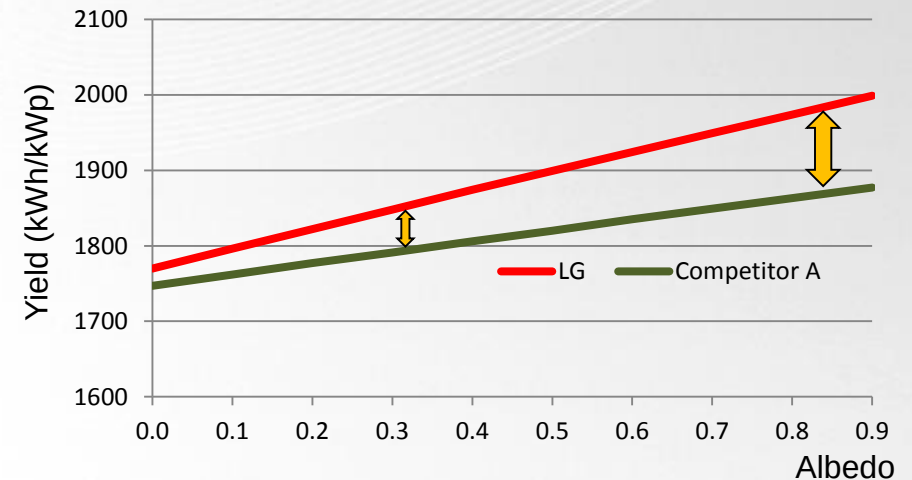
Albedo and Bifaciality are significantly effected on the performance of Bifacial module.
With increasing the Bifaciality and Albedo, the difference of yield also gets increasing .

1. Simulation Condition



1. Location : San Francisco, USA
2. Tilt : 35°
3. Azimuth : 0°
4. Inverter : SMA Sunny Central 1000CPXT (1MW)
5. Pitch : 6m
6. Shed total width : 3m
7. Height above ground : 1m

2. Simulation Results



1. Model : LG390N2T-A5 / Competitor A(G2G)
2. Output Power : 390W / 290W
3. Bifaciality Factor : **0.839** / **0.523**
4. System size : 997kWp / 1002kWp

Field Test



05 Bifacial Test bed results summary

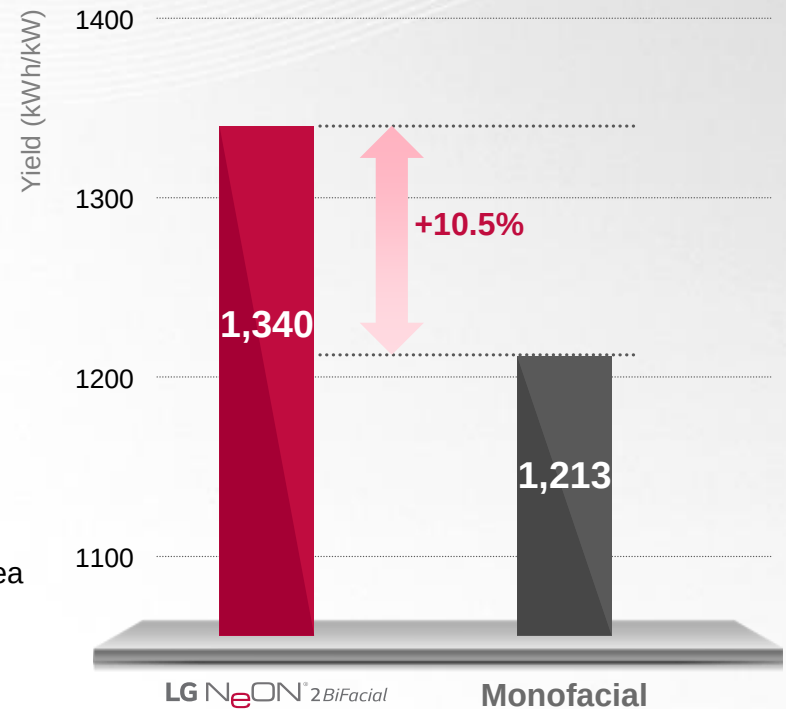
LGE BiFacial Module Test Bed Result

Bifacial Test bed

NO.	Site	Location	Albedo (%)	Period	Bifacial Gain	Remarks
1	Gumi#1	Gumi, Korea	21	'16.05~'17.04	+10.5%	Fixed
2	Gumi#2	Gumi, Korea	79	'17.01~'17.04	+24.8%	Single Axis Tracker
3	California	California, USA	18	'17.01	+6.7%	Fixed
4	Nevada	Boulder, Nevada, USA	21	'16.09	+9.15%	Single Axis Tracker
5	Akata	Akata, Japan	10	'16.09	+22.0%	2 Axis Tracker
6	NSW	Cardiff, NSW, Australia	15	'16.04.08~04.20	+6.5%	Fixed(Roof)
7	Fraunhofer ISE	Freiburg, Germany	80	'16.11.08~'17.05.08	+26.5%	Fixed
8	Fraunhofer ISE	Freiburg, Germany	25	'16.11.08~'17.05.08	+13.0%	Fixed

05 Field Test 1

Gumi city, KOREA 1



1. Testbed information

- Location : Gumi city, Korea
- Test duration : 2016. 05.~2017.04.
- Sunny/Partly cloudy_233days, Cludy/Rainy_118days, Snow_14days

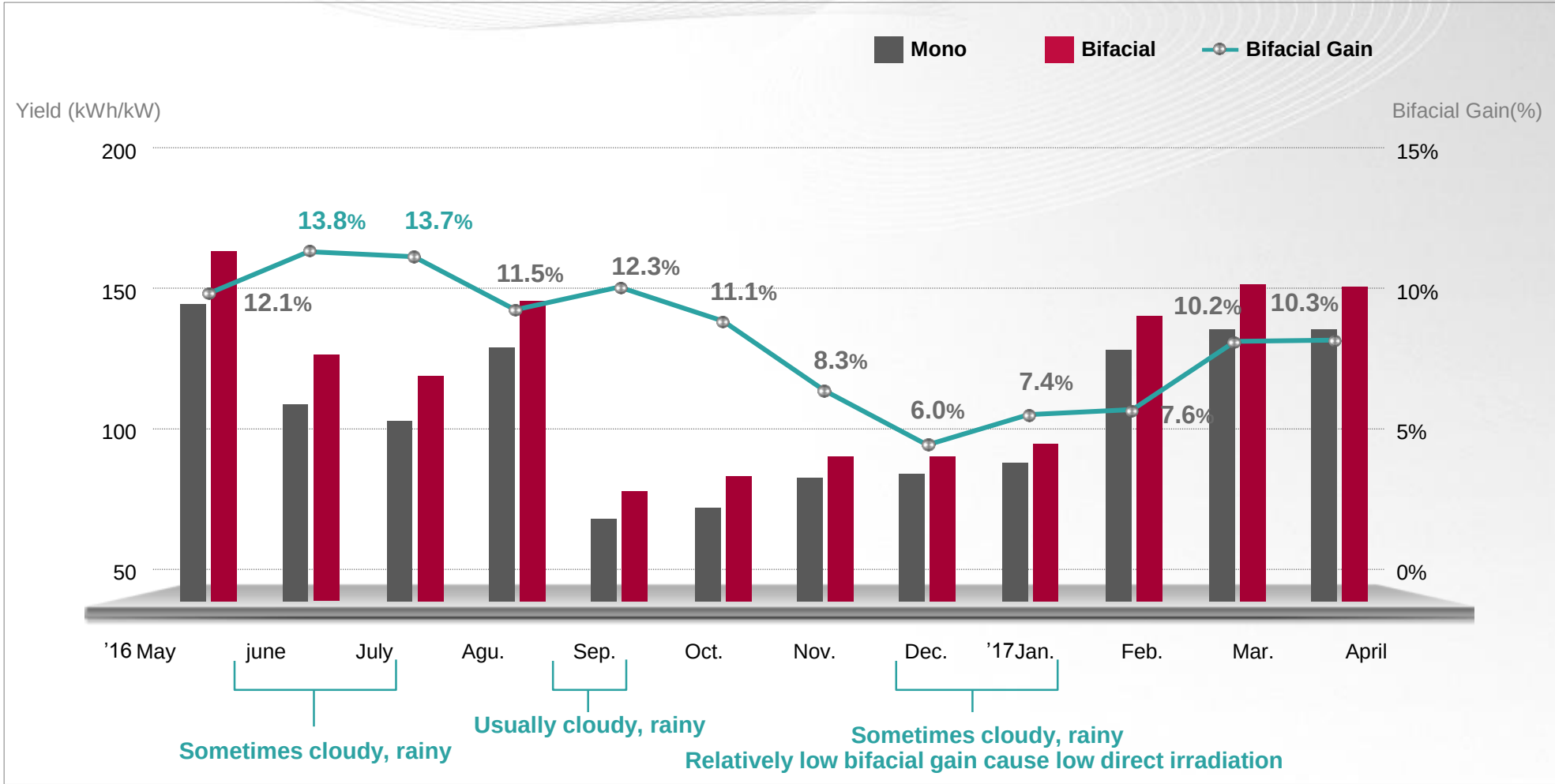
2. Installation information

- Module : LG NeON®2 BiFacial 300W 5ea (Old ver), LG NeON®2 315W 5ea
- Inverter : 1.7kW 2EA (SMA SB1700)
- Ground Mount
- Albedo $\approx$ 21% (Old concrete)
- Test duration : 2016. 05.~2017.04.

3. Bifacial Gain : +10.5%

[REDACTED]

Yield Performance (2016/5 ~ 2017/4)



05 Field Test 2

Gumi city, KOREA 2



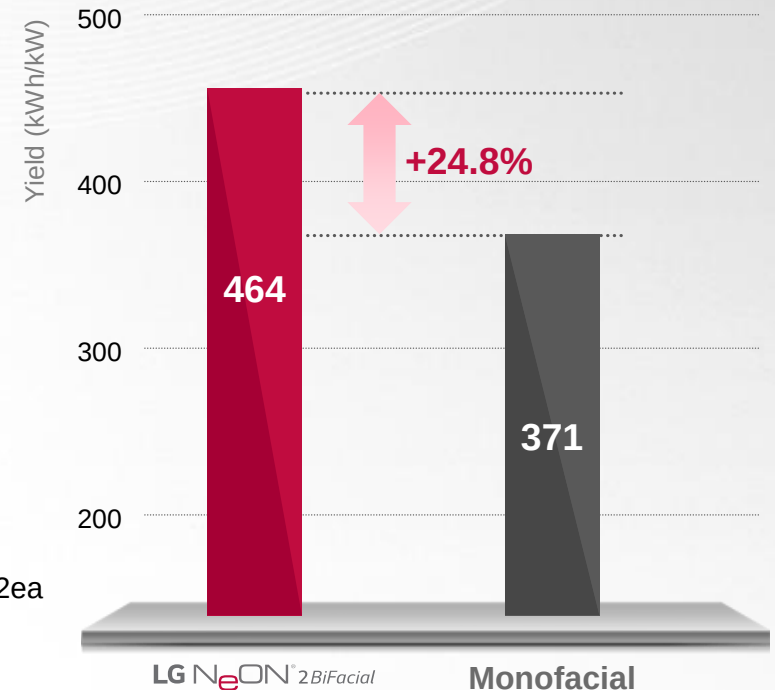
1. Testbed information

- Location : Gumi city, Korea
- Test duration : 2017.01~2014.04
- Sunny/Partly cloudy_79days, Cloudy/Rainy_29days, Snow_12days

2. Installation information

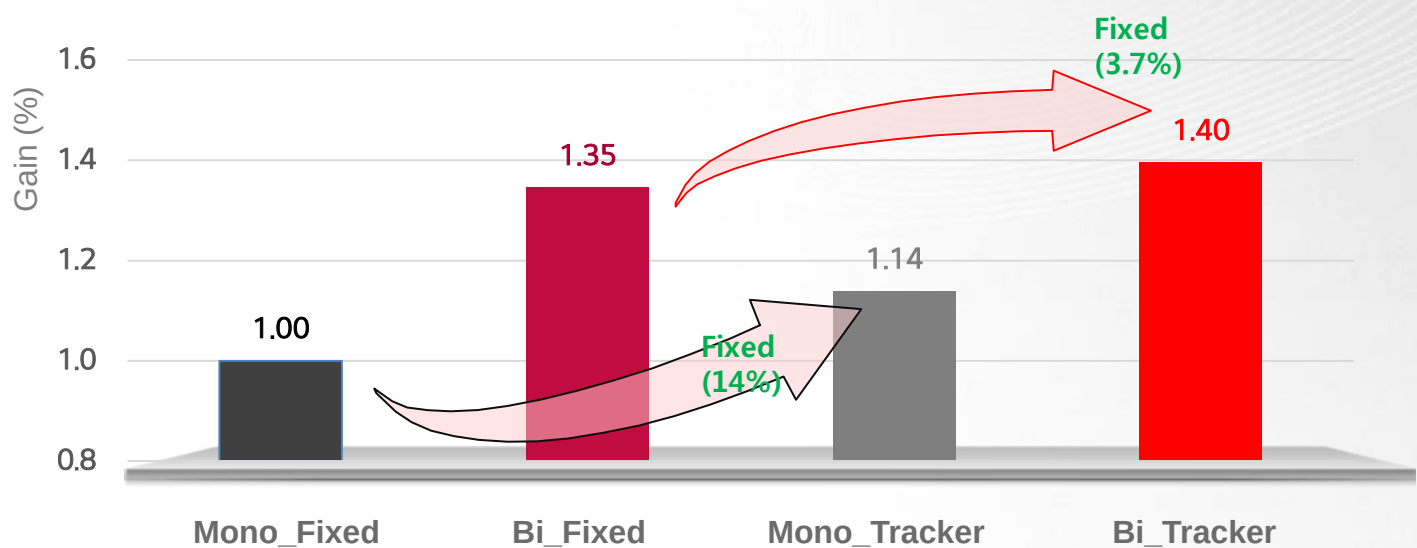
- Module : LG LG NeON® 2 BiFacial 370W 2ea(Old ver), LG NeON®2 370W 2ea
- Inverter : Ontest Capturestar (Module level IV tracer)
- Single Axis Tracker
- Albedo $\approx$ 79% (White membrane)

3. Bifacial Gain : +24.8%



05 Field Test 2

Performance Comparison with Tracker and Bifacial Module.



	Mono_Fixed	Bi_Fixed	Mono_Tracker	Bi_Tracker
Accumulated Energy (kW)	319.8	427.8	366.1	449.8
Specific Yield (Wh/Wp)	869	1169	990	1212
Gain (%)	-	35	14	40

* Accumulating period : Jan to June, 2017th

05 Field Test 3

California, USA



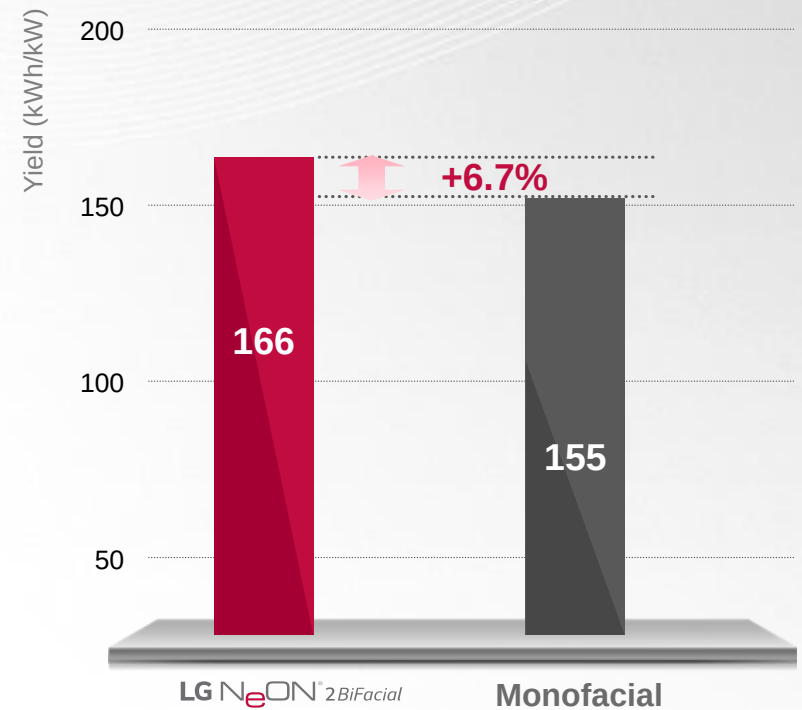
1. Testbed information

- Location : Fremont, California, US

2. Installation information

- Module : LG NeON® 2 BiFacial 370W 20ea(Old ver),
LG NeON®2 380W 20ea
- Inverter : 25kW 1EA (HUAWEI Sun2000)
- Single Axis Tracker(Next Tracker)
- Albedo $\approx$ 18% (Gravel)
- Installation completion date : 2017. 01.

3. Bifacial Gain : +6.7%



05 Field Test 4

Boulder City, Nevada, USA



1. Testbed information

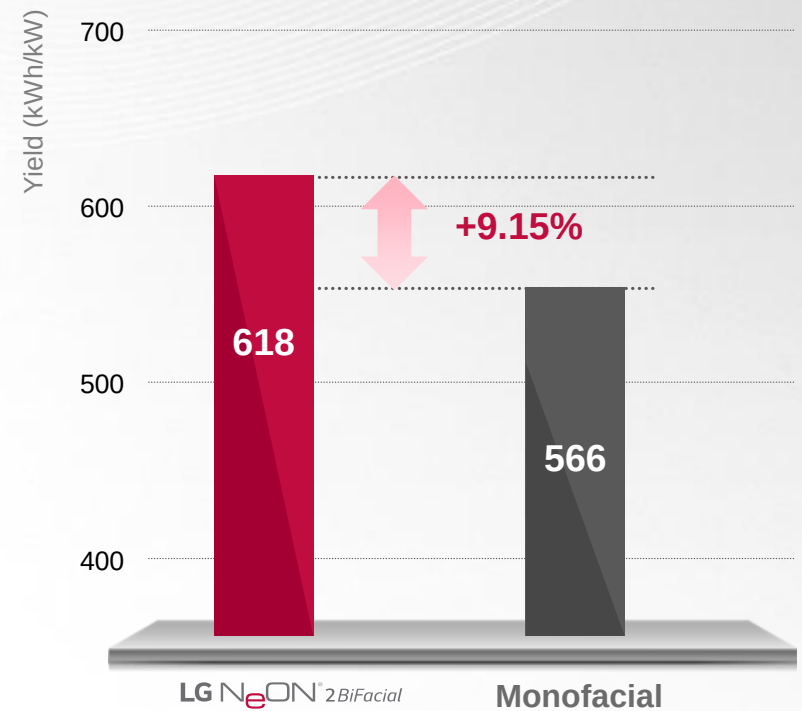
- Location : Boulder City, Nevada, USA

2. Installation information

- Module : LG NeON® 2 BiFacial 365W 6ea(Old ver),
LG NeON®2 370W 6ea
- Single Axis Tracker, Ground Mount
- Albedo $\approx$ 21% (Dirt), 15%(Grass)
- Installation completion date : 2016.09

3. Bifacial Gain : +9.15%

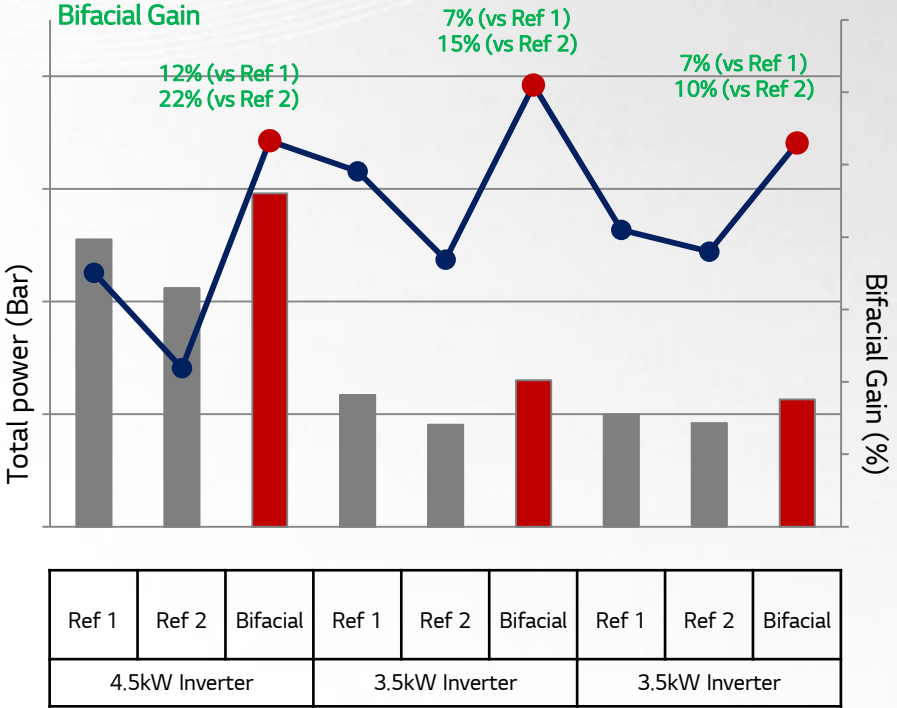
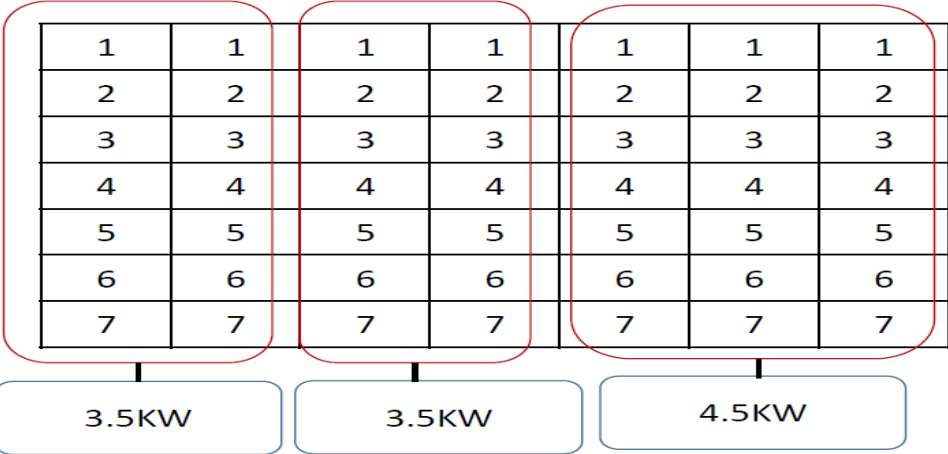
* Including instrument error, flooring material change



05 Field Test 5

AKATA, JAPAN

2 axis Tracker 4ea (Ref 2ea, Bifacial 2ea)
7X7 (49) Modules / 1 Tracker



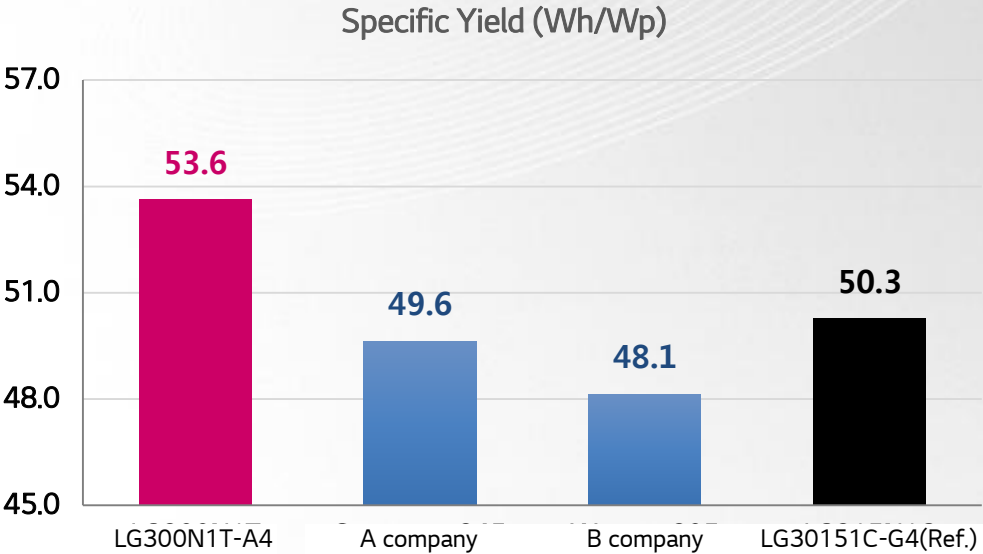
05 Field Test 6

Cardiff city, NSW, Australia



Install condition

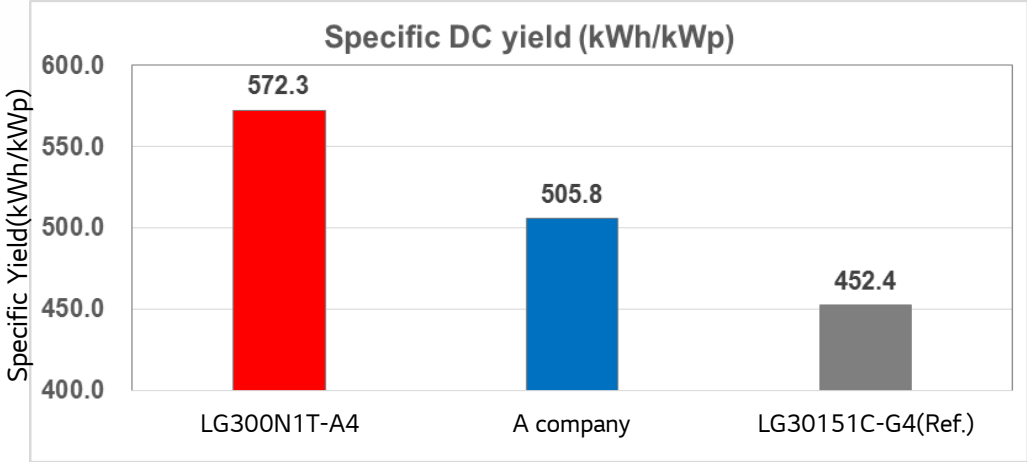
- Site: Cardiff city, NSW, Australia
- Tilt : 25deg
- Facing : North
- Ground: galvanized flat roof
- Period: 4/8~4/20, 2016



Accumulated Energy (Wh)	16088.3	17124.0	14682.3	15836.5
Specific Yield (Wh / Wp)	53.6	49.6	48.1	50.3
Bifacial Gain (%)	+6.5	-1.4	-4.4	

05 Field Test 7

Fraunhofer ISE, Freiburg, Germany



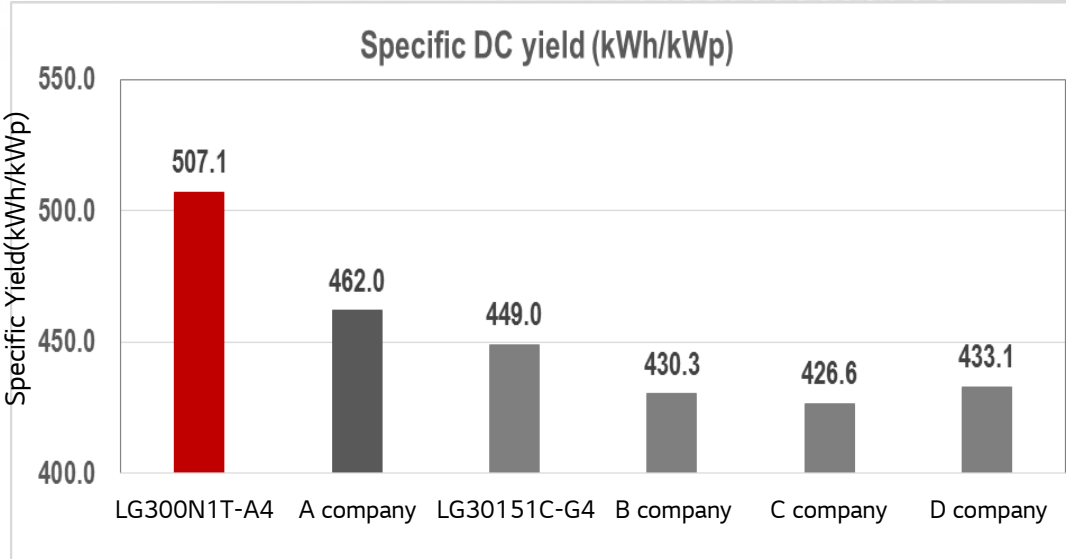
Install condition

- Site: Freiburg, Germany
- Tilt : 35deg
- Facing : South
- Ground: Bright white roofing membrane
Albedo 80%
- Period: 2016.11.08~2017.05.08

Accumulated Energy (kWh)	174.6	136.6	142.5
Specific Yield (kWh / kWp)	572.3	505.8	452.4
Bifacial Gain (%)	+26.5	+11.8	-

05 Field Test 8

Fraunhofer ISE, Freiburg, Germany



Install condition

- Site: Freiburg, Germany
- Tilt : 35deg
- Facing : South
- Ground: Concrete tiles
Albedo 25%
- Period: 2016.11.08~2017.05.08

Accumulated Energy (kWh)	152.14	125.75	141.43	118.34	123.7	112.6
Specific Yield (kWh / kWp)	507.1	462.0	449.0	430.3	426.6	433.1
Bifacial Gain (%)	+13.0	+2.9	-	-4.2	-5.0	-3.5

05 Field Test 6

Gumi city, KOREA _ vertical installation

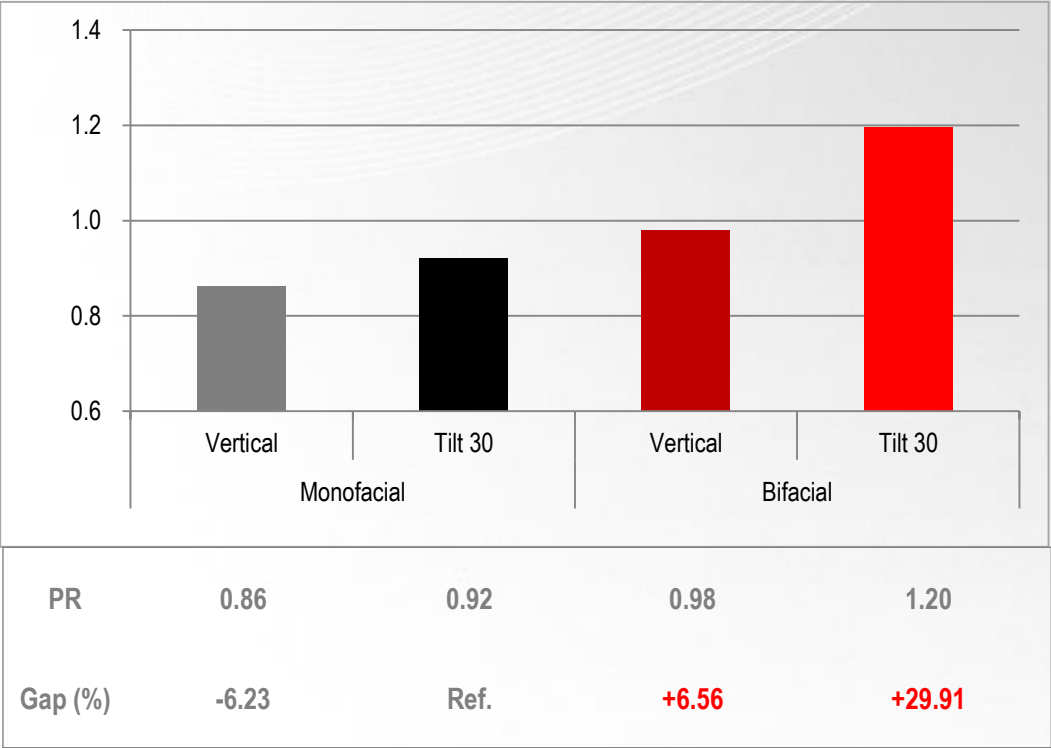


1. Testbed information

- Location : Gumi city, Korea
- Test duration : 2016.10

2. Installation information

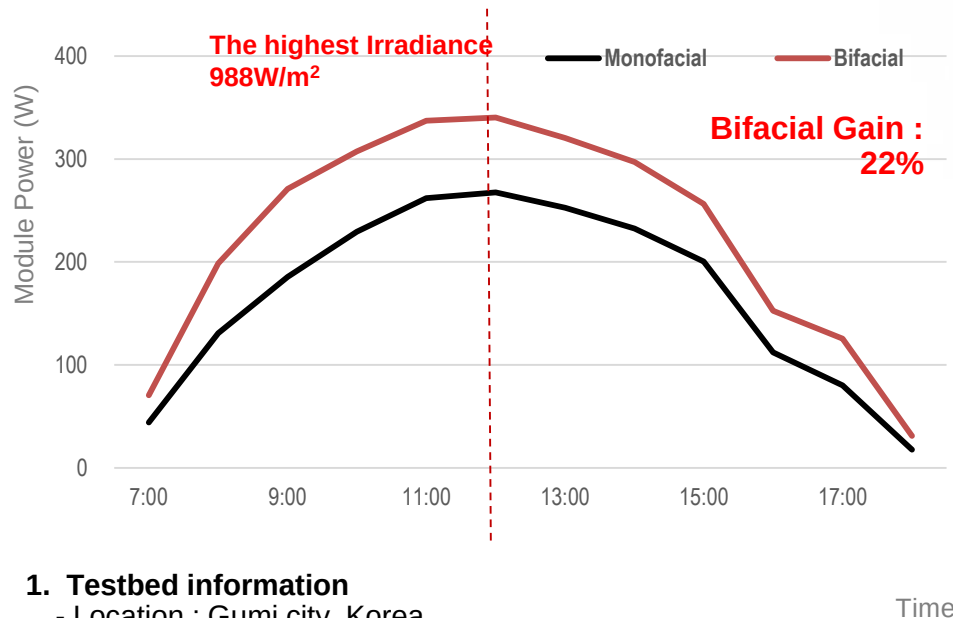
- Module : LG LG NeON® 2 BiFacial 370W 2ea(Old ver),
LG NeON®2 370W 2ea
- Albedo ≒ 79% (White membrane)



05 Field Test 7

To choose inverter size, consider the bifacial gain estimation at the highest irradiance time.

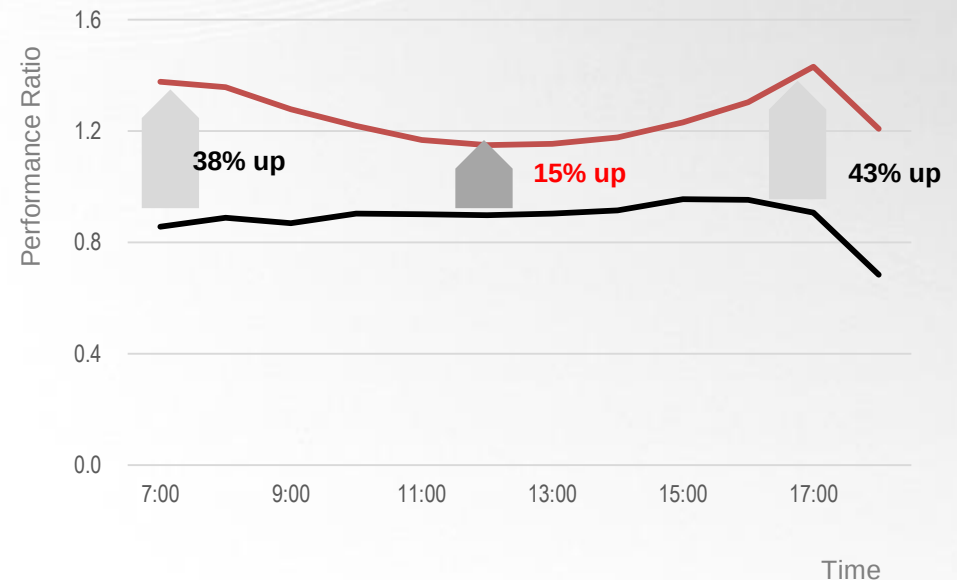
Comparison Module Power per day



1. Testbed information

- Location : Gumi city, Korea
- Test duration : 2016.07.23
- Module : LG LG NeON® 2 BiFacial 370W 3ea(Old ver),
LG NeON®2 370W 3ea
- Albedo = 79% (White membrane)

Comparison Performance Ratio per day



- 2. Total accumulated Irradiance per day : 6.06 kWh/m²
- 3. The highest Irradiance during day : 988W/m²
- 4. Bifacial Gain per day : 22%

Bifacial Performance Modeling



06 Bifacial Performance Modeling

LGE Software gives estimation for bifacial gain in various installation condition.

Bifacial Gain in normal condition

Expected Energy Yield by install condition

Albedo ²⁾ (%)	Surface in practical	Module height from ground [m]				
		0.2	0.3	0.5	0.7	1.0
15	Soil, meadows	4.9%	5.2%	5.8%	6.2%	6.7%
30	Dirt, Gravel, Concrete	8.4%	9.0%	10.0%	10.9%	12.0%
50	Sand	12.9%	13.9%	15.7%	16.9%	18.9%
70	Snow	17.5%	18.8%	21.2%	23.2%	25.5%
85	White membrane	20.8%	22.5%	25.4%	27.7%	30.7%

1) Base on LG internal Simulation Program (Module level)

Consideration : region_Gumi city, Korea / azimuth_south

2) Albedo : Reflecting light energy of a surface, It changes according to aging, wetness, measurement of surface

*Value of reference material

※ Isolated single array condition

Tilt angle correction factor

reflection rate[%]	Module Tilt Angle (degrees)					
	$\theta = 10^\circ$	$\theta = 20^\circ$	$\theta = 25^\circ$	$\theta = 30^\circ$	$\theta = 60^\circ$	$\theta = 90^\circ$
30	94%	98%	99%	100%	95%	76%
85	91%	96%	98%	100%	102%	93%

Thank You