Opsun : Optimized Bifacial Racking System
PERFORMANCE OVERVIEW

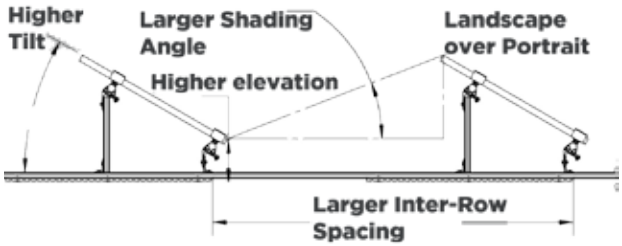
Opsun's bifacial PV racking can increase IRR by at least 10 %.

The present document aims at showing how this can be achieved using optimal bifacial design.

In order to achieve optimized bifacial performances, a solar array must be designed in a slightly different way than with standard PV modules:

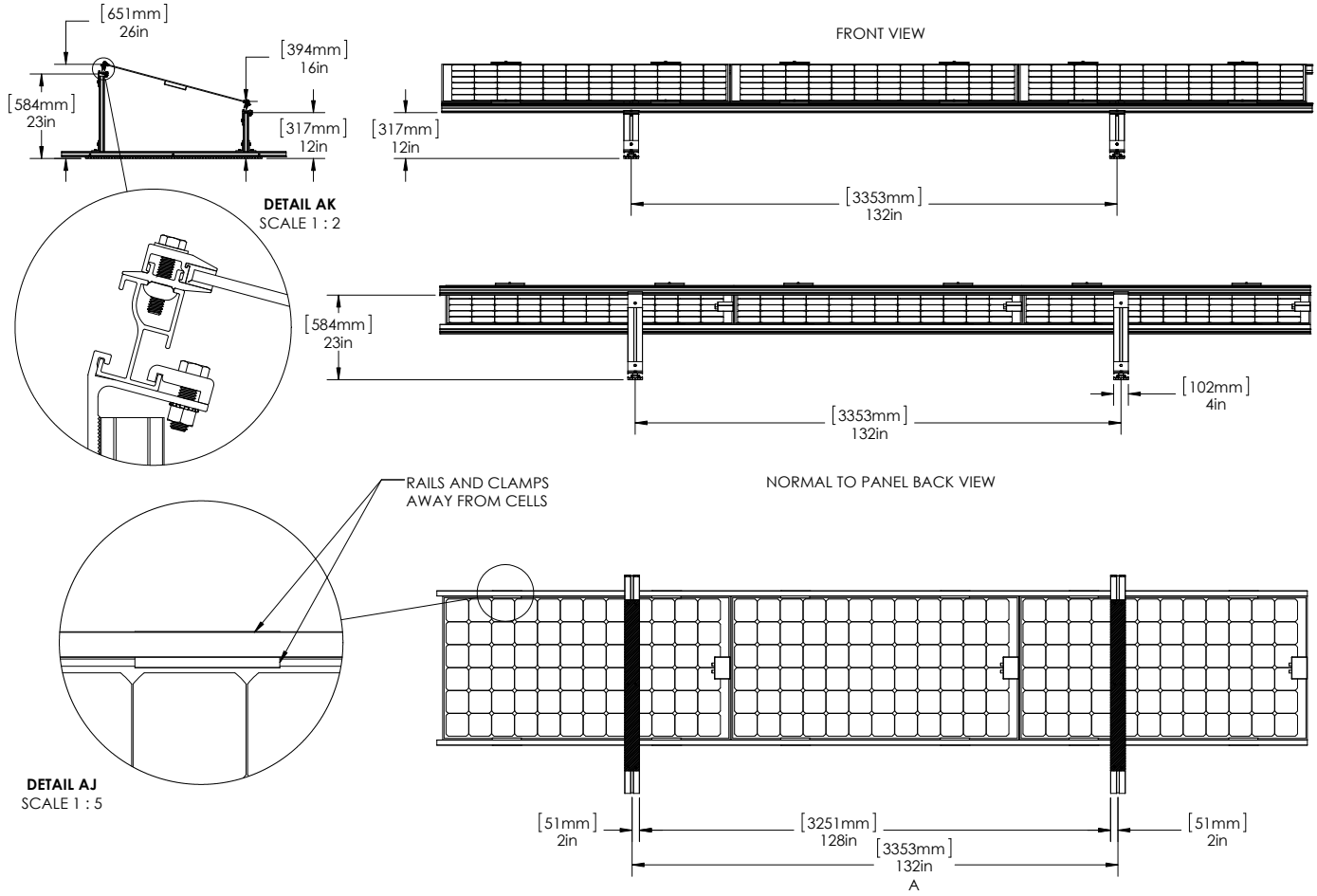
- Panels must be elevated from the roof at least 8 inches;
- Tilt should be increased up to 15 or 20 deg.;
- Shading angle should be below 19 deg.;
- Deflectors cannot be used;
- Racking must not have any component under the PVs.

Opsun's racking design, engineering and manufacturing process can be adapted at will to find an ideal balance between cost and bifacial gains, in order to increase IRR. ▶



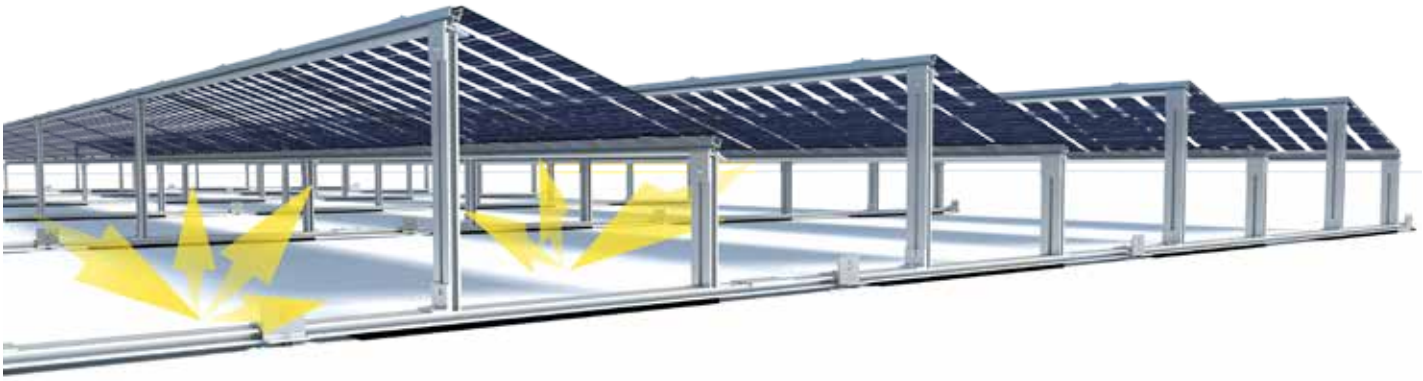
Why Opsun Racking

Opsun's racking was designed to have zero obstructions under the panels. No wind deflector, no clamps or rails under the modules, minimum amount of vertical rails. From the underside, the entire panel is visible with no shading.



Configurations : Understanding the Opsun Approach

Opsun's racking is not only a fixed product : it's an approach to make any configuration possible. Arrays can be designed at any tilt, any height (up to 24 inches) and any panels can be used. Above is one of many configurations, using a low profile and framed panels. The goal with bifacial is to allow as much light as possible to reach under the modules unobstructed, and Opsun has all the tools to do this.



Why Opsun Racking - Example Designs

Below are some examples of optimized designs for bifacial PVs.

Ulster Road, New-York

Daylight Transport, California

PVSYST 6.0 - Analysis

The first element of this performance review is to look at the effect of bifacial design for the following elements and compare simulations for "standard" PV panels and Sunpreme BxG 370W bifacial PV:

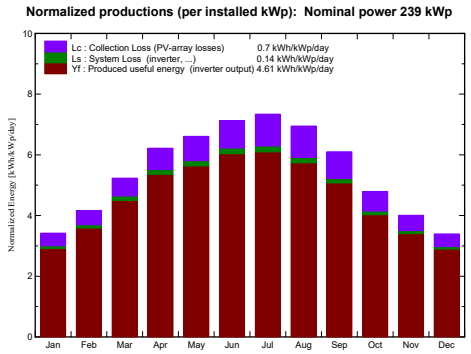
- Obstructions;
- Tilt;
- Height;

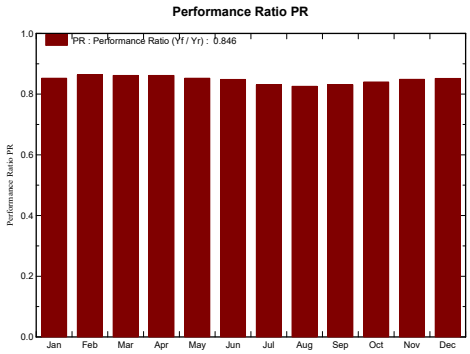
For all simulations, the software uses the same panels performance (with or without bifacial), 240 kW, 1:1 DC/AC oversizing, and Temecula, CA as location.
Base simulation gave 1600 kWh/kWpeak (10°, same panel as Sunpreme, without bifacial cells).

Obstructions : Sunpreme Bifacial (5% obstructions)

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	Sheds disposition, tilt	10°	azimuth	0°
PV modules	Model	SUNPREME-BxG-370W-BiF Pnom		370 Wp
PV Array	Nb. of modules	646	Pnom total	**239 kWp**
Inverter	Model	Symo 24.0-3 / 480	Pnom	24.00 kW ac
Inverter pack	Nb. of units	10.0	Pnom total	**240 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**402.1 MWh/year**	Specific prod.	1682 kWh/kWp/year
	Performance Ratio PR	84.56 %		





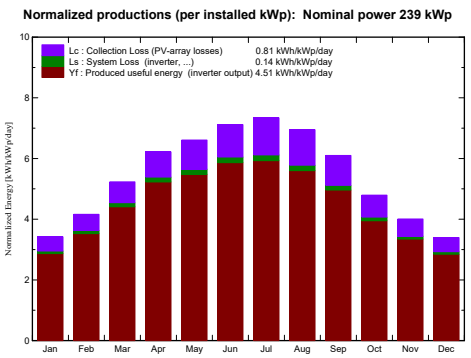
Sunpreme + Opsun with 5% obstruction: 1682 kWh/kWpeak

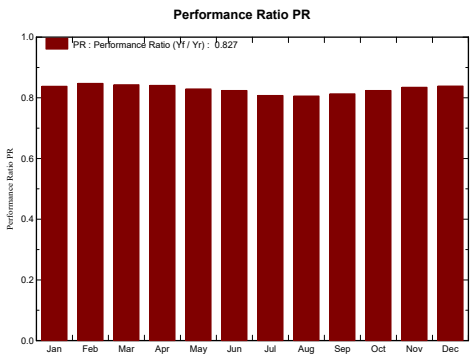
BIFACIAL GAINS : 5%

Obstructions : Sunpreme Bifacial (30% obstructions)

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	Sheds disposition, tilt	10°	azimuth	0°
PV modules	Model	SUNPREME-BxG-370W-BiF Pnom		370 Wp
PV Array	Nb. of modules	646	Pnom total	**239 kWp**
Inverter	Model	Symo 24.0-3 / 480	Pnom	24.00 kW ac
Inverter pack	Nb. of units	10.0	Pnom total	**240 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**393.0 MWh/year**	Specific prod.	1644 kWh/kWp/year
	Performance Ratio PR	82.65 %		





Sunpreme + standard racking with 30% obstruction: 1644 kWh/kWpeak

BIFACIAL GAINS : 2.75%

CONCLUSION :

Even a set of small rails behind the panel only covering 30% of the cells can reduce bifacial gains a lot.

HEIGHT

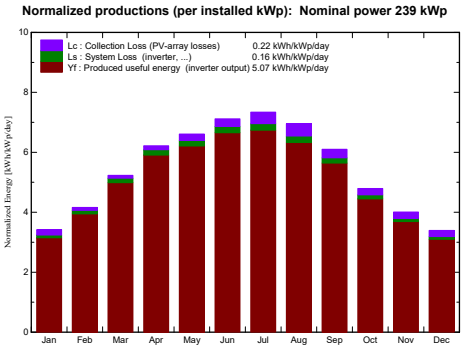
Height is the easiest element to adjust with Opsun's bifacial PV racking. Increasing height does not affect module density on roof. Standard rackings have panels 3 inches above roof, Opsun's standard "High Profile" racking has panels 16'' from the roof, which can be further increased to 24''.

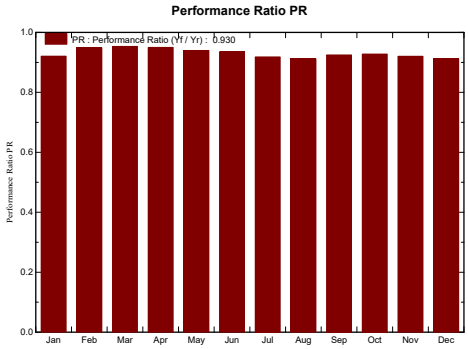
Height : Sunpreme Bifacial (24 inches height)

PV Field Orientation	Sheds disposition, tilt	10°	azimuth	0°
PV modules	Model	SUNPREME-BxG-370W-BiF Pnom		370 Wp
PV Array	Nb. of modules	646	Pnom total	**239 kWp**
Inverter	Model	Symo 24.0-3 / 480	Pnom	24.00 kW ac
Inverter pack	Nb. of units	10.0	Pnom total	**240 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results

System Production	**Produced Energy**	**442.5 MWh/year**	Specific prod.	1851 kWh/kWp/year
	Performance Ratio PR	93.04 %		





Sunpreme + Opsun with 24 inches elevation: 1851 kWh/kWpeak

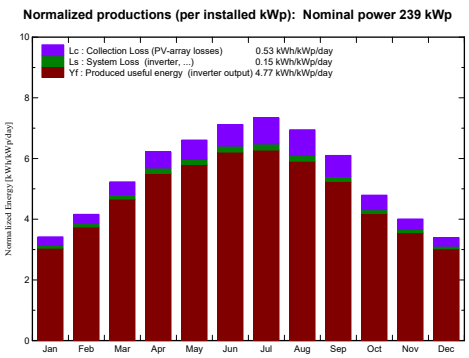
BIFACIAL GAINS : 15.7%

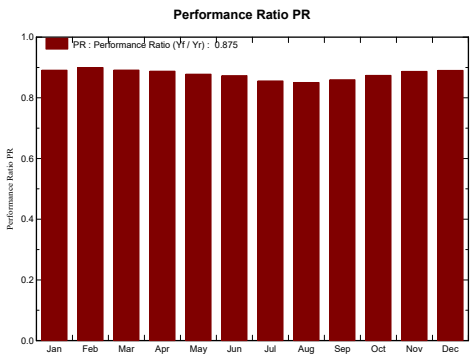
Height : Sunpreme Bifacial (3 inches height)

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	Sheds disposition, tilt	10°	azimuth	0°
PV modules	Model	SUNPREME-BxG-370W-BiF Pnom		370 Wp
PV Array	Nb. of modules	646	Pnom total	**239 kWp**
Inverter	Model	Symo 24.0-3 / 480	Pnom	24.00 kW ac
Inverter pack	Nb. of units	10.0	Pnom total	**240 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results

System Production	**Produced Energy**	**416.2 MWh/year**	Specific prod.	1741 kWh/kWp/year
	Performance Ratio PR	87.52 %		





Sunpreme + standard racking with 3'' height: 1741 kWh/kWpeak

BIFACIAL GAINS : 8.8%

CONCLUSION :

Opsun's racking capacity to reach 24inches can double bifacial gains.

TILT

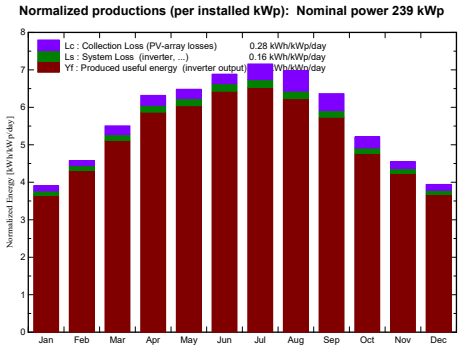
Increasing tilt has the disadvantage to reduce the module density (how many panels, or kWpeak, fir on the roof). On the other hand, installing fewer panels at a higher tilt will significantly increase the electricity generated by each panel, leading to better return on investment. In this comparisson we will show a 5° tilt Vs an ideal 20° tilt.
Base simulation for 5° without bifacial cells was 1557 kWh/kWpeak.

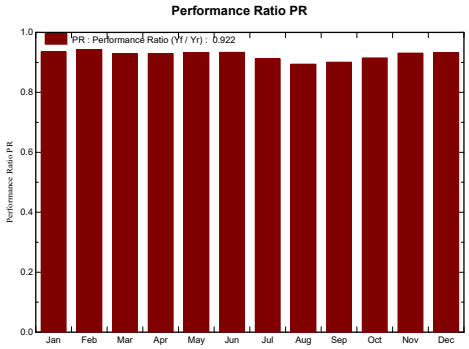
Tilt : Sunpreme Bifacial (20° tilt)

PV Field Orientation	Sheds disposition, tilt	20°	azimuth	0°
PV modules	Model	SUNPREME-BxG-370W-BiF	Pnom	370 Wp
PV Array	Nb. of modules	646	Pnom total	**239 kWp**
Inverter	Model	Symo 24.0-3 / 480	Pnom	24.00 kW ac
Inverter pack	Nb. of units	10.0	Pnom total	**240 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results

System Production	**Produced Energy**	**455.5 MWh/year**	Specific prod.	1906 kWh/kWp/year
	Performance Ratio PR	92.22 %		





Sunpreme + Opsun at 8'' height and 20° tilt: 1906 kWh/kWpeak

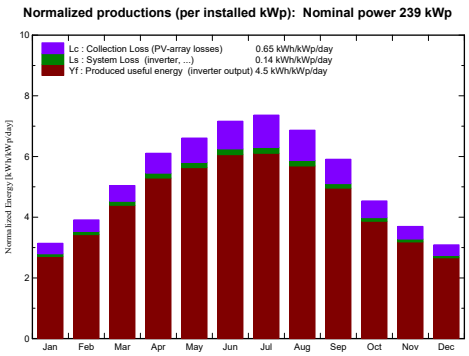
BIFACIAL GAINS : 22.4% (Vs 5° STD PVs)

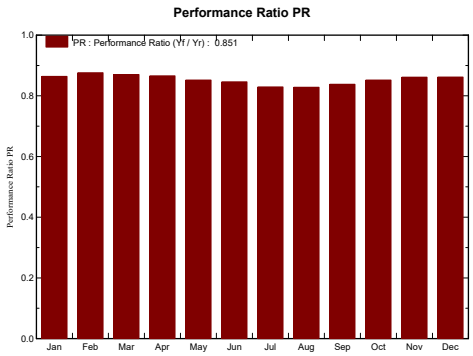
Tilt : Sunpreme Bifacial (5° tilt)

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	Sheds disposition, tilt	5°	azimuth	0°
PV modules	Model	SUNPREME-BxG-370W-BiF	Pnom	370 Wp
PV Array	Nb. of modules	646	Pnom total	**239 kWp**
Inverter	Model	Symo 24.0-3 / 480	Pnom	24.00 kW ac
Inverter pack	Nb. of units	10.0	Pnom total	**240 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results

System Production	**Produced Energy**	**392.9 MWh/year**	Specific prod.	1644 kWh/kWp/year
	Performance Ratio PR	85.05 %		





Sunpreme with standard racking at 3'' height and 5° tilt: 1644 kWh/kWpeak

BIFACIAL GAINS : 5.6%

CONCLUSION :

When space is not constrained, raising tilt produces better performances on front and back side, leading to huge gains.

OPTIMAL DESIGN

Below, two simulations compare a sub-optimal racking design at 5°, with 3'' height, and 30% of the cells obstructed (rails under the modules, wind deflector), and an optimal design that maintains high panels density : 15° tilt, 16 inches from the roof and no obstruction behind the modules.

Optimization : Sunpreme Bifacial & Optimal Opsun Racking (15° tilt, 16'' H)

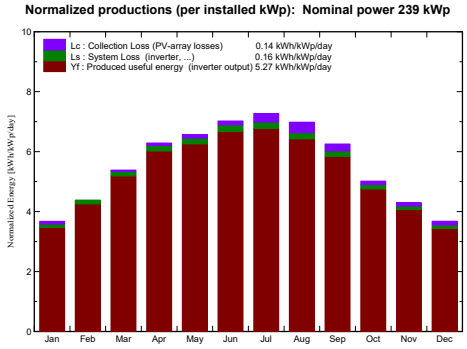
PV Field Orientation	Sheds disposition, tilt	15°	azimuth	0°
PV modules	Model	SUNPREME-BxG-370W-BiF	Pnom	370 Wp
PV Array	Nb. of modules	646	Pnom total	**239 kWp**
Inverter	Model	Symo 24.0-3 / 480	Pnom	24.00 kW ac
Inverter pack	Nb. of units	10.0	Pnom total	**240 kW ac**
User's needs	Unlimited load (grid)			

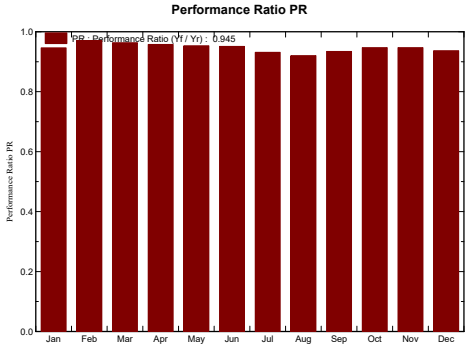
Main simulation results

System Production	**Produced Energy**	**459.7 MWh/year**	Specific prod.	1923 kWh/kWp/year
	Performance Ratio PR	94.54 %		

Sunpreme + Opsun at 16'' height and 15° tilt: 1923 kWh/kWpeak

BIFACIAL GAINS : 23.5% (Vs 5° STD PVs)





Optimization : Sunpreme Bifacial (5° tilt, 30% obstructed cells, 3'' height)

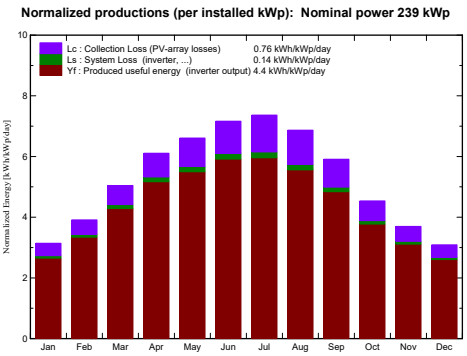
Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	Sheds disposition, tilt	5°	azimuth	0°
PV modules	Model	SUNPREME-BxG-370W-BiF	Pnom	370 Wp
PV Array	Nb. of modules	646	Pnom total	**239 kWp**
Inverter	Model	Symo 24.0-3 / 480	Pnom	24.00 kW ac
Inverter pack	Nb. of units	10.0	Pnom total	**240 kW ac**
User's needs	Unlimited load (grid)			

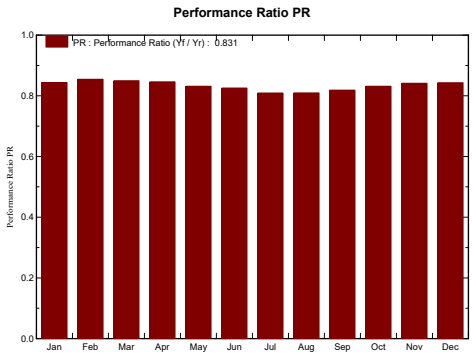
Main simulation results

System Production	**Produced Energy**	**383.7 MWh/year**	Specific prod.	1605 kWh/kWp/year
	Performance Ratio PR	83.06 %		

Sunpreme with standard racking at 3'' height and 5° tilt: 1605 kWh/kWpeak

BIFACIAL GAINS : 3.1%





CONCLUSION : Opsun's Optimized racking at 16'' (High Profile) and 15° tilt makes bifacial PV much more profitable than standard PVs.

Financial Analysis

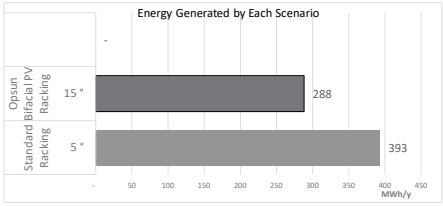
Based on the simulations before, it is possible to make a full discounted cash flow (DCF) analysis, in order to see how this improvement on performance increases the return on investment (IRR).

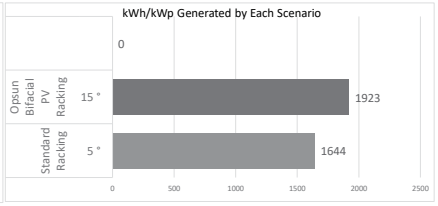
Notes:

- The "Optimized" scenario uses Sunpreme Bifacial PVs, 15° tilt, 16 inches height, 70% albedo roof, and has 37.3% fewer modules (1923 kWh/kWpeak, based on simulation).
- The reference scenario uses 5° tilt Sunpreme panels, unoptimized, obstructed and low tilt design (1605 kWh/kWpeak, based on simulations).
- Optimized bifacial design can cost up to 10 cents/W more, it is still 10% more profitable.

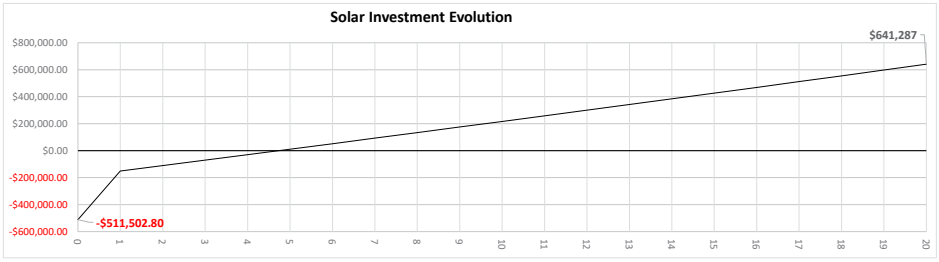
Scenarios	Standard Racking	Opsun Bifacial PV Racking
PV tilt angle	**5 °**	**15 °**
Module Power (W)	370 W	370 W
Project size (W, DC nominal)	239	150
PV Orientation / Type	Landsc. w/ standard PV	Landsc. w/ bifacial PV
Total Cost ($/W)	**$2.14**	**$2.24**

Energy generation



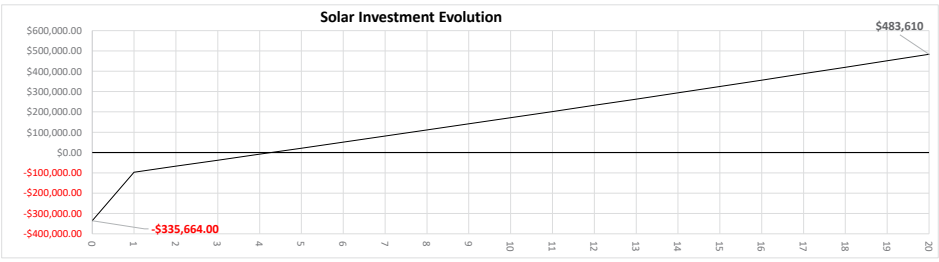


Standard Racking



Year	Annual cash flow
0	-$511,502.80
1	$359,933.47
2	$40,464.73
3	$40,558.48
4	$40,659.99
5	$40,769.38
6	$40,886.78
7	$41,012.30
8	$41,146.05
9	$41,288.18
10	$41,438.79
11	$41,598.02
12	$41,765.99
13	$41,942.83
14	$42,128.69
15	$42,323.68
16	$42,527.95
17	$42,741.64
18	$42,964.88
19	$43,197.81
20	$43,440.60

Opsun Bifacial PV Racking



Year	Annual cash flow
0	-$335,664.00
1	$238,991.29
2	$29,317.10
3	$29,418.81
4	$29,526.22
5	$29,639.42
6	$29,758.47
7	$29,883.49
8	$30,014.55
9	$30,151.74
10	$30,295.16
11	$30,444.89
12	$30,601.04
13	$30,763.70
14	$30,932.96
15	$31,108.92
16	$31,291.69
17	$31,481.36
18	$31,678.04
19	$31,881.83
20	$32,092.84

IRR (Discounted Cash Flow Internal Rate of Return)	**16.47%**	**18.17%**
VARIATION		**+ 10.35%**

Assumptions:

PPA : 0.10 $/kWh,
Escalation : 3 %/year.
Tax rate : 38 %
Debt : 80 %, 20 yrs, 5.5 %
Leasing : 0 $
Insurance, admin., O&M : 15 $/kWpeak
Modules degradation : 0.5 %

Conclusions:

Using a bifacial PV design that generates about 20% BEG (considering some designs can reach over 30%) will increase return on investment by 10%, for minimal additional costs/W.

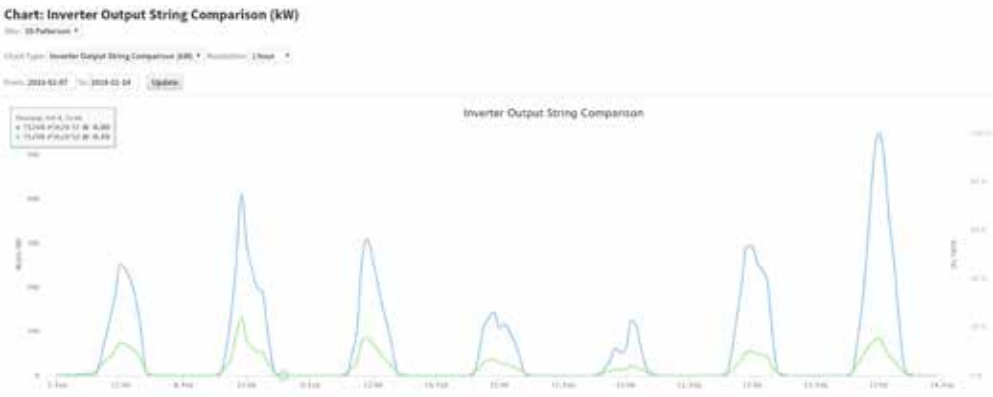
CASE STUDY

REAL RESULTS - Barry, ON

Opsun installed a system in Barry, Ontario, Canada, where two sets of modules were compared:

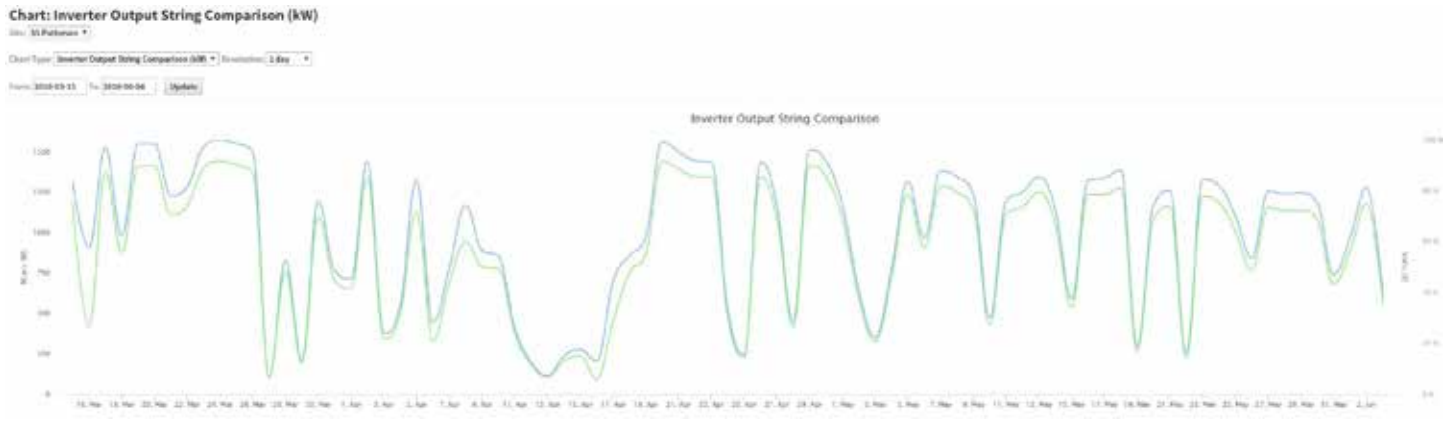
- First, an array of 7 standard, high quality, mono panels at 370W (green);
- then 7 bifacial panels at 360W (normalized for this comparison) (blue).

High Snow



Opsun Racking under heavy snow :
200%-500%
performances under heavy snow due to bifacial PVs melting snow faster.

Normal Conditions (Mid March 2018 - June 2018)



Opsun Optimized Bifacial PV Racking:

Overall 13.3% gains, with higher peaks, earlier peaks in the day, lasting later in the day.

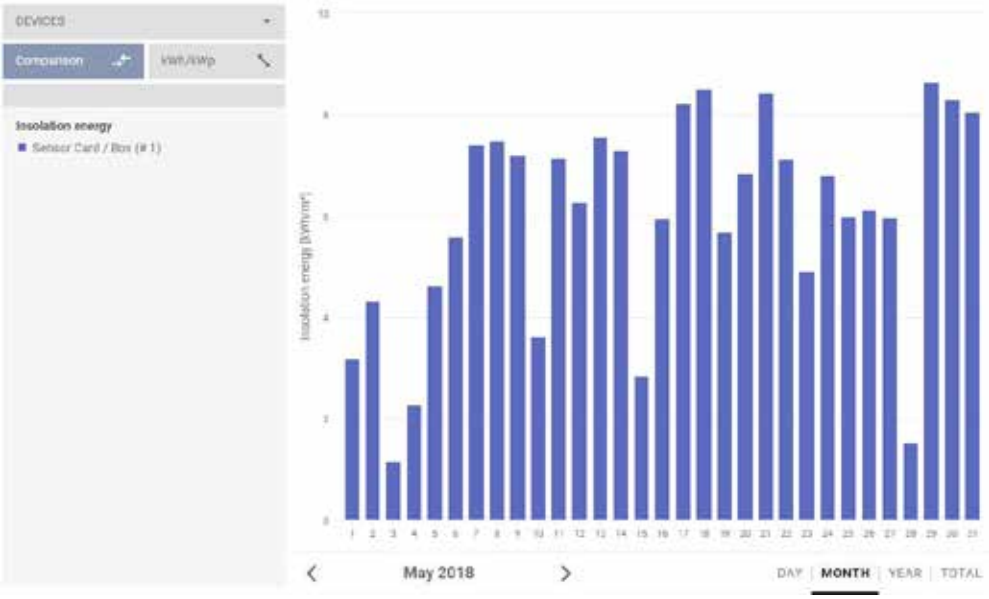
Note : this project did **not** have a white roof.

CASE STUDY

REAL RESULTS - QUEBEC CITY, QC.

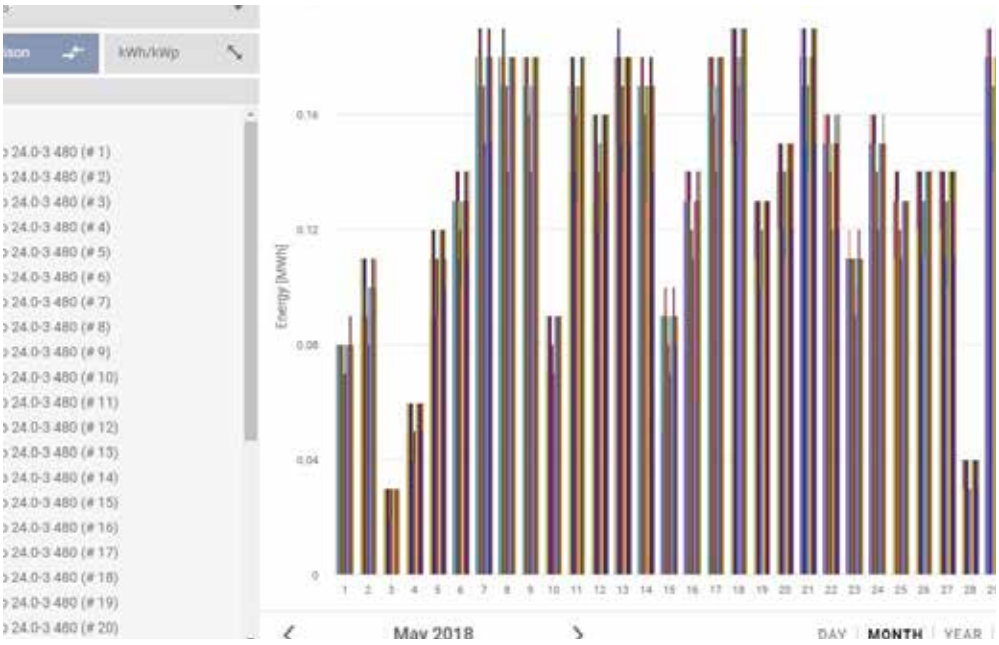
Opsun installed a system Quebec City, Quebec, Canada, which has 2309, 300W bifacial PV panels. For the month of May 2018, the following results were obtained:
The sensor registered **185 MWh/m².**
The inverters registered **133 MWh being produced** in May (at inverter output, after DC and conversion losses).

SENSOR DATA



IN ORDER TO FIND THE BIFACIAL ENERGY GAIN, WE MUST FIND THE EXPECTED GENERATED ENERGY, BY FINDING THE EXPECTED PANELS EFFICIENCY (AFTER MISMATCH, TEMPERATURE, AND OHMIC LOSSES).

NORMAL CONDITIONS (MID MARCH 2018 - JUNE 2018)



FOUND EFFICIENCY WAS 18.96% VS EXPECTED PV PANELS EFFICIENCY OF 15.19% (AFTER LOSSES).

BIFACIAL GAIN: 24.8%

Case Studies

Conclusion

> **Bifacial can increase return on investment over 10%;**
> Bifacial gains can reach 13-25.8% depending on roof reflectivity;
> Opsun has experience designing and optimizing a bifacial PV project and rackings;
> High tilt, elevation from the roof, inter-row distance and albedo will increase BEG.

Highest Commercial Rooftop Bifacial Energy Gain Achieved by Opsun

In 2016, Opsun helped design and supplied racking for a community-owned commercial rooftop project in the New-York region.

- 61cm height above ground
- 30 degrees tilt
- 125 kW system
- 70% albedo

Six months BEG (including winter) : 25%

(See https://www.prismsolar.com/white-roof-case-study/

With proper design and engineering, bifacial PV projects can generate very high return on investment. The trends are clear : the market is moving toward bifacial cells. With price of bifacial cells dropping every month, it will soon become the norm to build bifacial solar systems, leading to lower LCOE and more cost-competitive solar.

Bifacial design process is different than with standard solar panels : instead of adding as many panels as possible at a low tilt, bifacials require fewer modules at high tilt, large spacing and elevated from the roof, each PV generating much more energy than a standard monofacial one.

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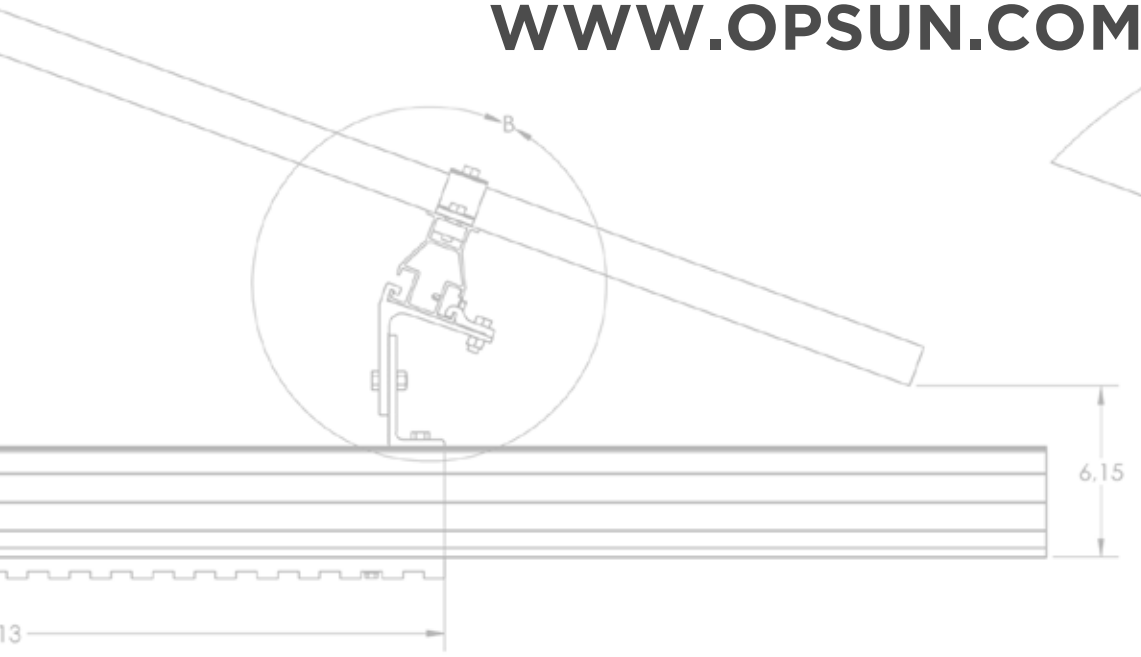

DETAIL A
SCALE 1 : 5

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DETAIL B
SCALE 1 : 2

SRL-RL5 : ALUMINUM RAIL LINK