# Bifacial PV: Performance Review

## Content



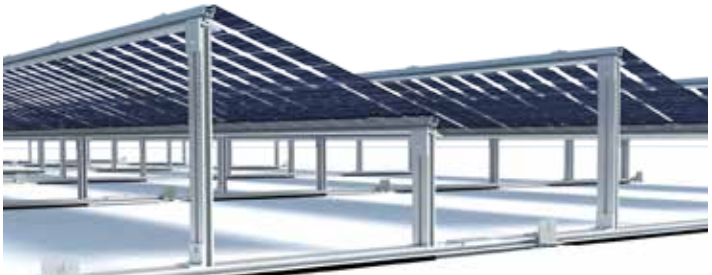
## A Shift in the World of PV

Bifacial solar panels were patented in 1966, deployed on the International Space Station in 2000, and commercialized by Sanyo in 2009. Between 2015 and 2017, most major PV modules manufacturers such as LG, Solarworld, Yingli, and specialized manufacturers such as Sunpreme and Prism, introduced their own version of bifacial PV modules, seeking to capture the commercial opportunity of the most promising trend in the PV industry.

The best designs using bifacial PV modules showed up to 25% bifacial energy gain (or “BEG” calculated as the % of additional energy produced by a bifacial PV compared to an equivalent monofacial PV). As of today, there exist no other means of capturing so much additional energy with similar cost, and the same surface, as standard solar panels.

Applications range from rooftop, to ground-mounted structures, to architectural building-integrated solar and even tracked utility-scale deployment.

Solar panels manufacturers evaluate that in volume, the additional cost of making a solar panel bifacial is between 2 to 5 cents US per Watt, meaning that using bifacial PV modules is the single most efficient mean of increasing return on investment of a solar project.



◀ Bifacial PVs show the best performance on flat roof covered with a reflective membrane.

Ground-mounted systems over grass, sand or rocks can generate much more revenue with bifacial PVs.

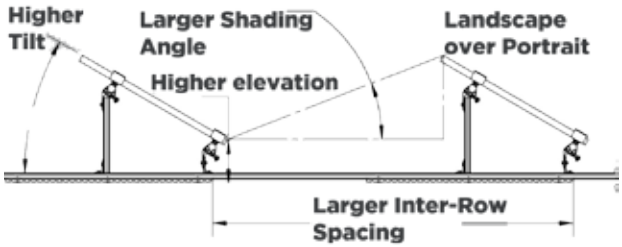
# Financial Analysis

**A good bifacial PV design can increase IRR by more than 10 %.**

**In order to achieve such a result, the solar array must be designed in a slightly different way than for standard PV modules:**

- Panels must be elevated from the roof at least 10 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.* ▶




## Assumptions:

PPA : 0.08 $/kWh,
Escalation : 3 %/year.
BEG : 20 %
Tax rate : 38 %

Debt : 80 %, 20 yrs, 5.5 %
Leasing : 0 $
Insurance, admin., O&M : 15 $/kWpeak
Modules degradation : 0.8 %

| | Standard PV | Bifacial PV |
|---|---|---|
| Power (MW) | 957 kW | 863 kW |
| Cost ($/W) | 1.80 | 2.03 |
| Energy per year (MWh) | 1220 | 1355 |
| Gross Revenues | 97.5 k$ | 108 k$ |
| IRR | 11.57% | 12.72% |

Please note that inverters are typically not oversized (1x instead of 1.2x), as with standard PVs, leading to increased inverter cost of 0.014$/W. Installation of 544 more standard PVs in the first scenario is also more expensive.

**Conclusions:**

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

Over 20 years, as the bifacial project costs only about 30 k$ more at construction, it will generate over 271 k$ more in cumulative future cashflow.

The above calculations are for estimation purposes only. They assume good quality work and design, standard degration, and limited soiling of the roof.

# Financial Analysis
# Roof as Part of the Energy Generating Asset

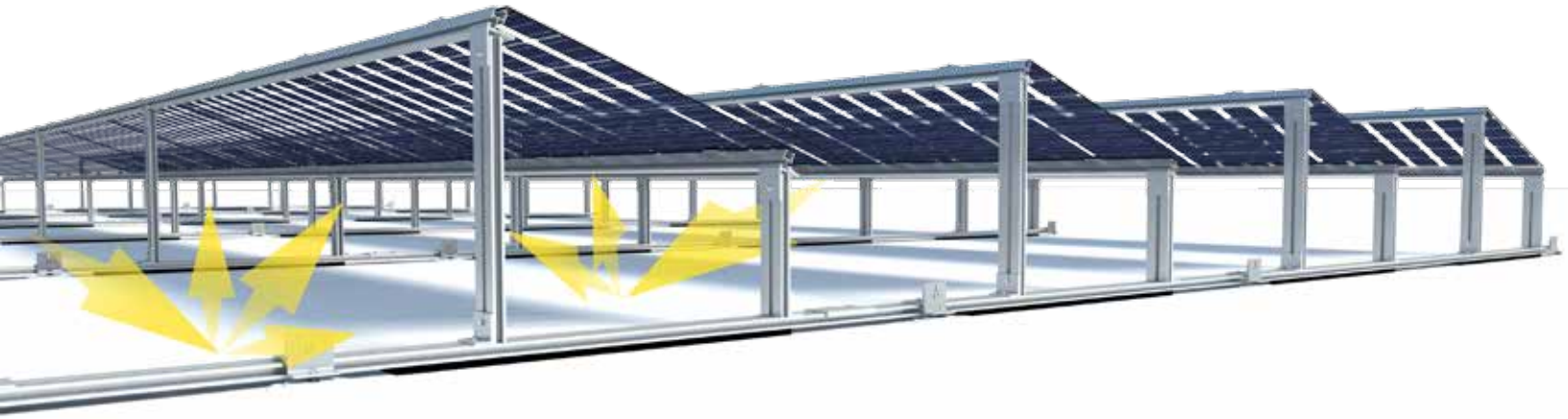
For projects in the United States, an even more interesting element is to create a financial structure where the roof is considered an active part of the "energy generating asset".

If a large proportion of the roof is covered with solar panels, chosen bifacial PV modules have a backside efficiency above 90%, and a roof with high reflectivity is installed, a significant portion of the roof has been accepted by the IRS by Private Letter Rulings to be claimed under the Investment Tax Credit (ITC) for renewable energy, in the past. Assuming a roof cost of about 1M$, claiming a portion of the roof under the ITC can raise IRR up to 45% (IRR of 17.66% in the above scenario)*.

** Opsun is not making any recommendation or representation regarding the possibility of claiming a portion of the roof under the ITC, and legal and tax advisors should be consulted in each case. The above statements are based on IRS issued Private Letter Rulings.*

## Designing with Bifacial

- Opsun has extensive knowledge on designing high performance systems with bifacial PVs;
- Using the proper racking structure will make the difference between high return on investment, and mediocre return.



Diffuse sunlight comes under the panels after being reflected in front and behind of the modules.

In the Northern hemisphere, in the morning and evening, the Sun can be behind the modules, leading to significantly increased generation in the morning and in the evening peaks.

The more diffuse light there is on a given day, the more sunlight that reaches the backside of the modules. Some studies found that bifacial can operate as much as 120% better under diffuse light conditions[1].

**Opsun offers the only racking solution that is perfectly adapted for bifacial PVs : high tilt, high elevation from the roof, large inter-row distance and no wind deflector or rails under the modules.**

# Designing with Bifacial PVs
# Basic Criteria

## Bifacial Gains Versus Height[2]

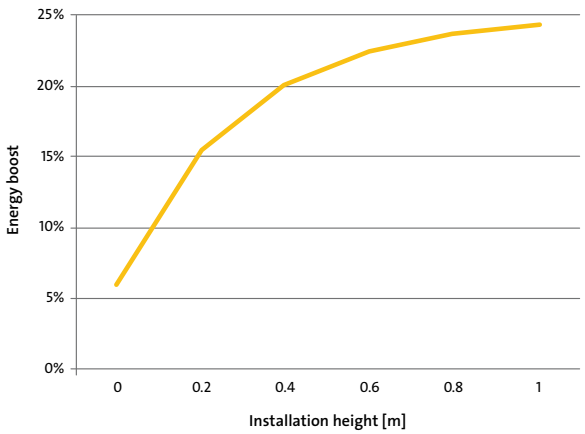



**FIGURE 6:** *Energy boost of a bifacial photovoltaic system with landscape-mounted module, south oriented, 30° pitch and a row pitch of 2.5 meters, 80 percent albedo*

Modules manufacturers tested their modules at different height from the roof or ground. All found that increasing the height increases the BEG. Opsun offers a structure which can be raised at will.

## Key Elements

- High elevation from the roof or ground;
- High tilt angle of the modules;
- Large inter-row distance;
- Absence of wind deflectors or rails blocking light under modules;
- High albedo of the roof.

We can imagine what the panel "sees" from the backside as what it can capture in terms of energy.

**Tilt:** As with standard PVs, increasing tilt angle increases energy generation per PV, while reducing power installed per surface. In northern climates, higher tilt allows for snow to slide off modules more easily. For bifacial PVs, this effect is amplified: higher tilt means more energy from the front and back sides, and snow melting even faster.

**Height:** Increasing the ratio of module elevation with the ground to its height will increase energy output. A 1m high panel is at its optimal position 1m above the ground.

**Inter-row distance:** Larger distance between rows allows for more sunlight to reach under the panels. Often, lower density of modules allow to lower solar cost, while covering the roof entirely. Lower shading will also increase energy generation from the front side.

## Reflectivity of selected surfaces[3]

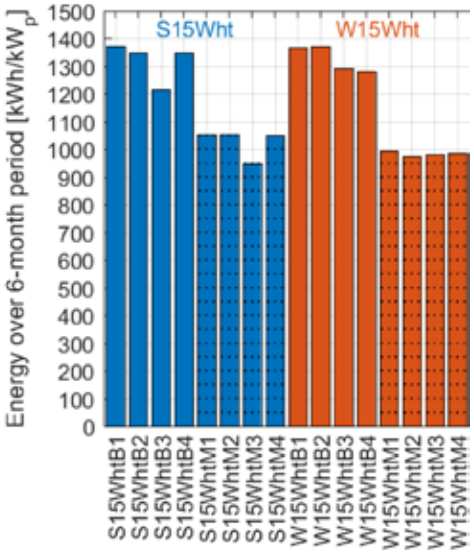
| SURFACE TYPE | ALBEDO |
|---|---|
| *Green field (Grass)* | 23 % |
| *Concrete* | 16 % |
| *White painted concrete* | 60-80 % |
| *White gravel* | 27 % |
| *White roofing metal* | 56 % |
| *Light grey roofing foil* | 62 % |
| *White roofing foil (for solar applications)* | > 80 % |

**Obstruction behind the modules:** To operate optimally, bifacial PV modules must have no rail, component or no wind deflector underneath them.

**Albedo:** EPDM and TPO roof offer high reflectivity membranes (around 70%). Scallop shells, sea shells, shite rocks and sand are viable for ground-mounted PV systems.

**Azimut:** Research shows that orienting a panel due South, East or West will generate roughly the same amount of energy at the end of the year. Azimuth can be ignored.

## Bifacial Gain Vs Orientation[4]




S15WhtB1 means "South-facing, on white membrane, bifacial PV, numbered 1 through 4.

W15WhtB1 means "West-facing on white membrane bifacial PV, numbered 1 through 4.

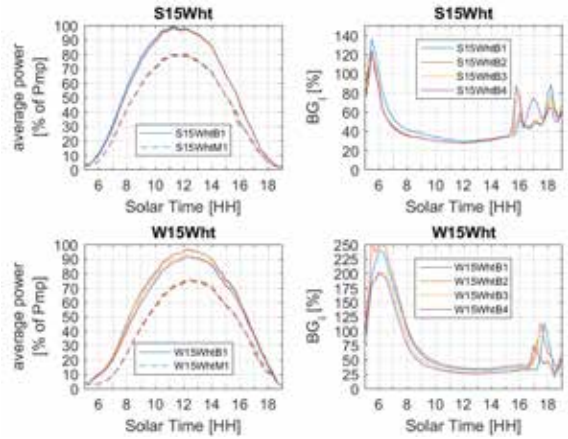
The same names with M1 to M4 at the end means monofacial modules.

## 6-month Study by Sandia National Labs

- 15 degree tilt, on 50%+ albedo white surface;
- South and West oriented systems;
- Bifacial Energy Gains over 30%;
- Same energy output overall for South-facing and West-Facing systems.

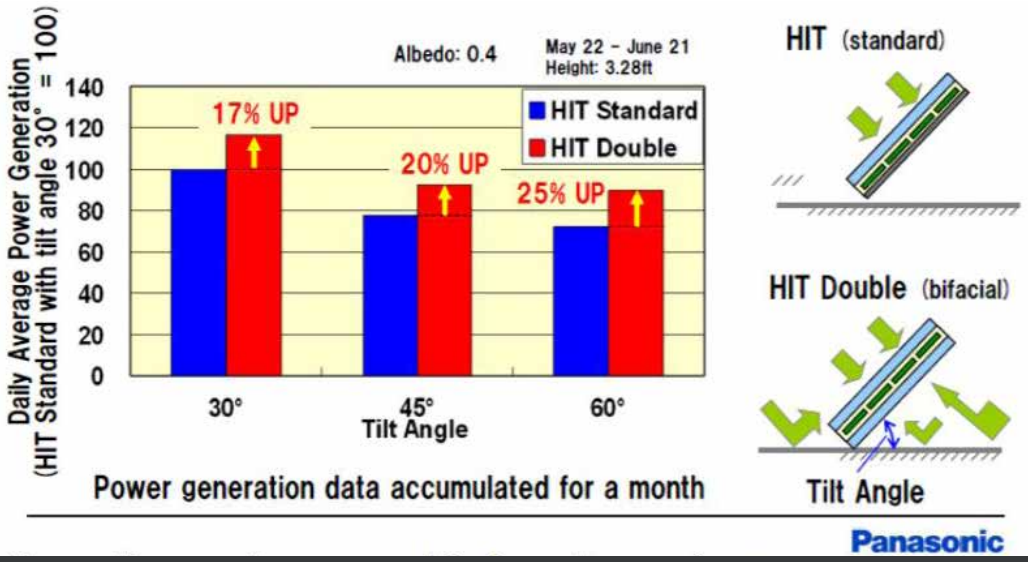
It is important to note that light reaching the backside of the modules increases the current (A) but not the tension (V) of each individual solar cells. As with the front side, if a cell is shaded, it will impair (act as a resistance) each other cell stringed in series with it. Since the cells are stringed horizontally on a panel in landscape, having a rail or racking component underneath it that shades every cell in a column will prevent the entire module to work efficiently to generate energy from the backside.

Obviously, modules tilted west will gather more energy from their backside, since they are facing sunrise with their back. Tests conducted outside, for 6 months found an average of 32% bifacial energy gains from measured bifacial PV vs standard monofacial systems, using calibrated equipment (p.30). Since these were single panels, and not arrays in strings, we should expect commercial full-scale applications to be a few percents lower. Nevertheless, results are clear : bifacial PVs start producing more power earlier in the day, and produce mode power all day long[5]:




S15Wht means South facing bifacial PVs on white membrane. They generate 120% more energy on their backside than on their front side in the morning, and over 25% additional energy from their backside at noon. Overall, they generate about 32% more energy.

## Bifacial Gain Vs tilt[6]




Panasonic came to the conclusion that increasing the tilt up to 30° increases both the front and the backside energy.
Above 30°, more bi-facial gains are found, but less energy reaches the panel's front side.

## SUMMARY OF FIELD TEST WITH DIFFERENT MODULES AND DESIGNS

- Bifacial gains between 10 and 20% are easily achievable;
- Best designs (30° tilt, 1m above ground, high albedo) have achieved over 25% BEG;
- Even low tilts and low abedo can create high BEG (10-15%), as long as there is no obstruction behind the modules.
- Importance of height of modules in regards to the roof.

| **Design** | **BEG** | **Gains over Standard PVs @ 10D** (including snow & soiling gains) |
|---|---|---|
| Standard racking, 10° tilt, low profile | < 5% | < 5% |
| 10° tilt, 10" elevation | 15% | 15% |
| 20° tilt, 16" elevation | 19% | 26.2% |
| 30 ° tilt, 24" elevation | 25% | 36.5% |
| Ground-mounted | 18% | - |

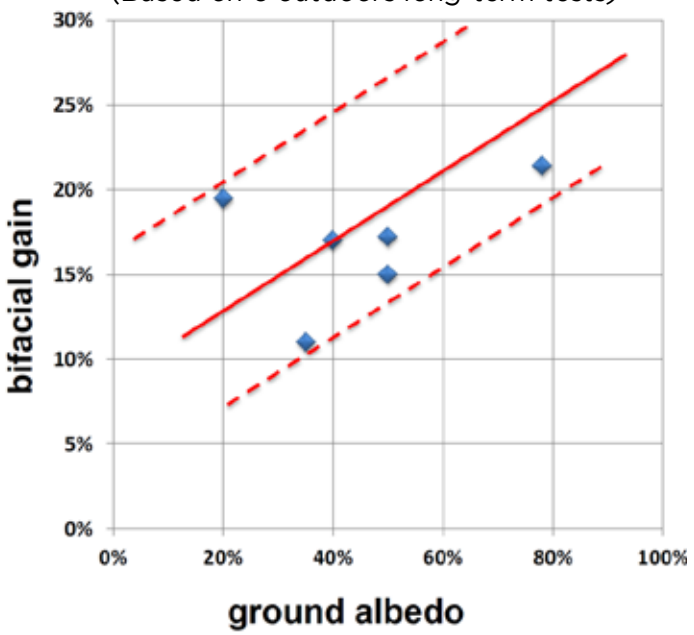
Above are evaluations of bifacial energy gains, based on PVSyst simulations, for New-York, at different tilt angles and elevations, for monocrystalline high quality glass-on-glass modules, compared with the same module, but monofacial.

Note how a standard racking with ballast blocks, low profile, with rails under the modules will only generate small bifacial energy gains.

In comparison, high tilt and high elevation quickly increase the performance and revenue of a PV system.

## Bifacial Gain Vs Albedo[7]

*(Based on 6 outdoors long-term tests)*



# Case Studies

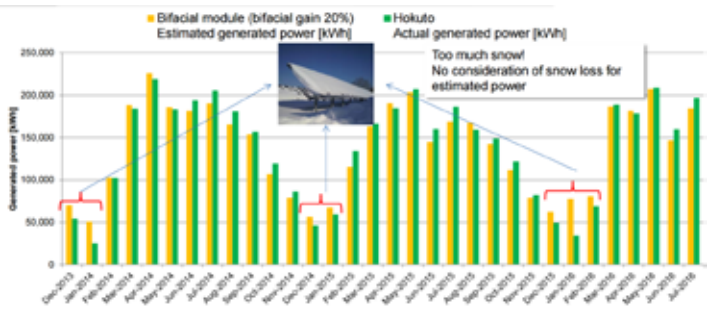
## Bifacial The Future of Utility Scale

> Opsun's ground-mounted structure is specifically designed for frameless modules, in landscape position;
> Only two rows maximizes irradiation on all panels;
> No obstruction behind modules allow for maximum BEG;
> Tilt can be set as desired.

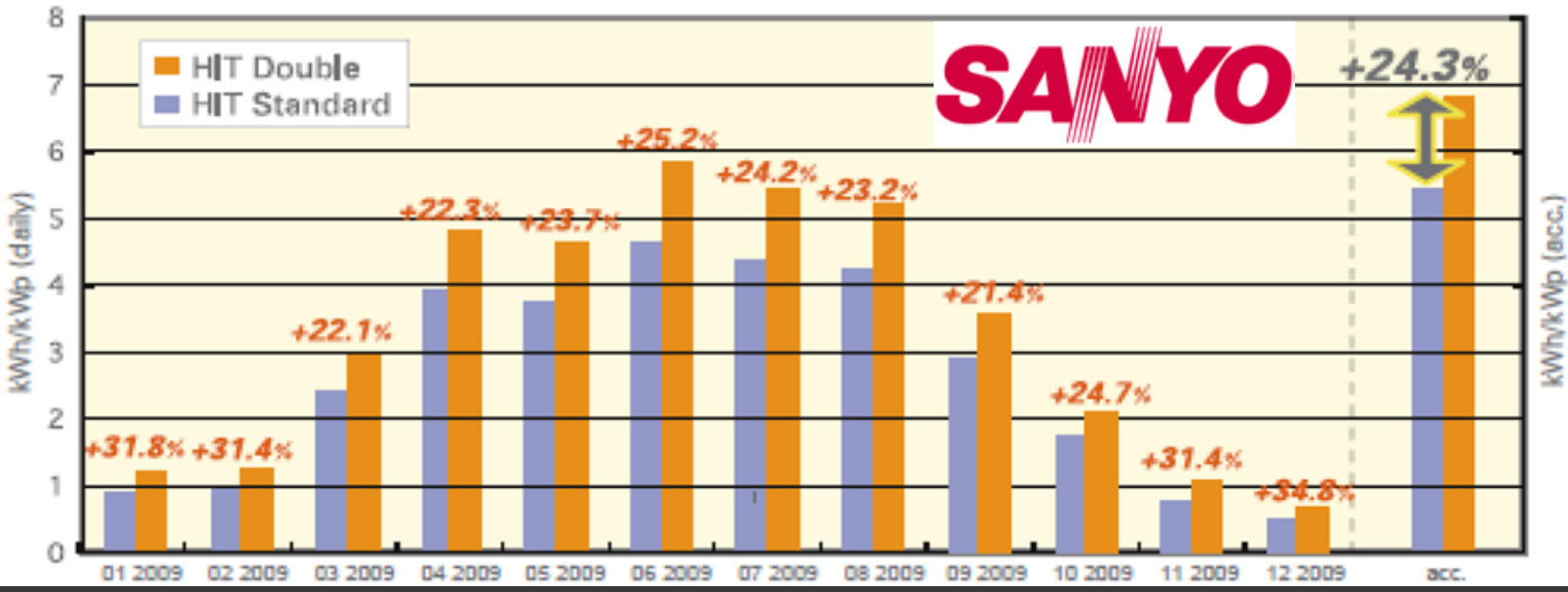
**Hokuto Solar Plant[8]**

- Japan, built in 2013
- 1.25 MW
- 1.5m height above ground
- 40 degrees tilt
- 20% albedo in the summer + snow

**3 years BEG : 19.5%**



# Case Studies




## Sanyo's Results[9]

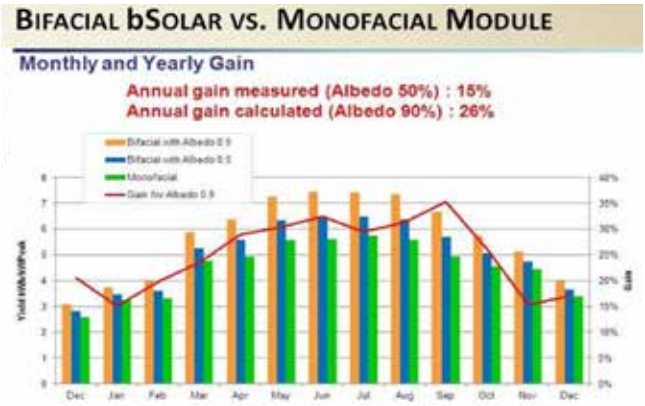
- Germany, built in 2009
- 30 cm height above ground
- 20 degrees tilt
- 64% albedo

**Achieved BEG : 24.3%**

**bSolar Solar Plant[10]**

- Jerusalem
- 70cm height above ground
- 30 degrees tilt
- 50% albedo

**3 years BEG : 15%**



# Case Studies

## Conclusion

> **Bifacial can increase return on investment over 10%;**
> Several reknown sources validated between 10 to 30% BEG;
> 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%**

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.

**Designed with Opsun, a 20 degrees tilted bifacial system on reflective roof can generate as much energy as the same roof covered with standard monofacial panels at 10 degrees, for a lower cost.**

# References

The following sources are available online for free, in integrity. All elements cited in this document are derived directly from scientific data provided by others. Opsun waves any responsibility on incorect information transmitted in the following documents.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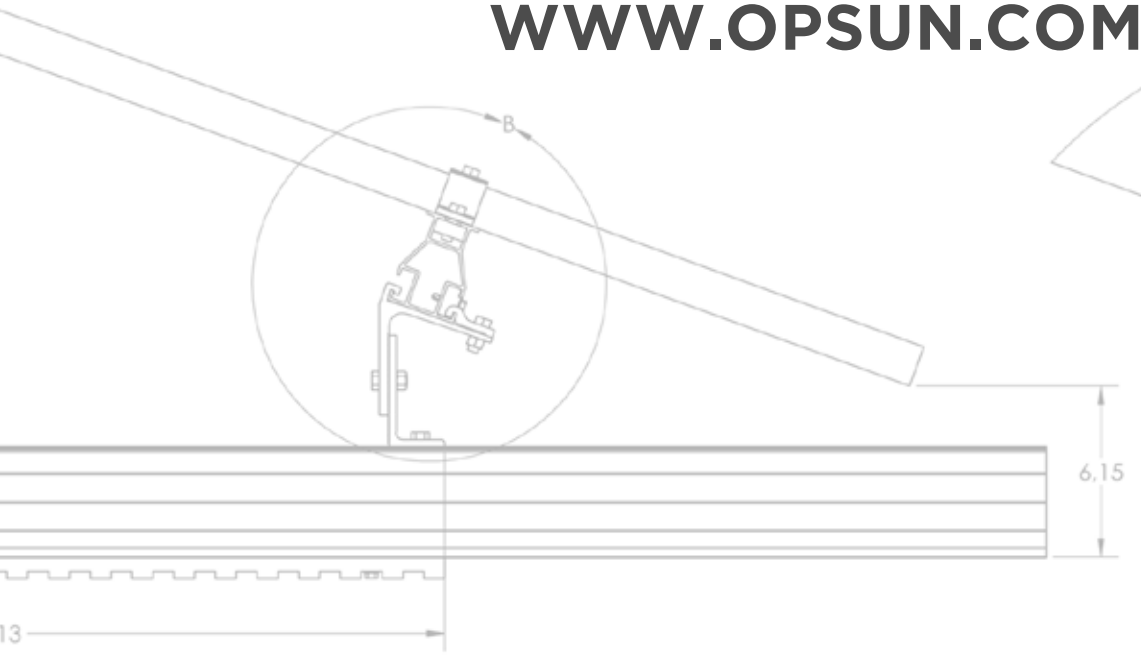


DETAIL A
SCALE 1 : 5


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DETAIL B
SCALE 1 : 2



SRL-RL5 : ALUMINUM RAIL LINK