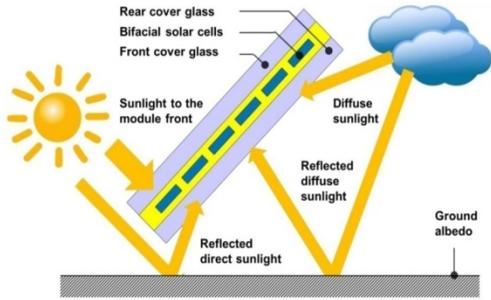


Additional Energy yield using Bifacial Solar PV Modules & dependency on Albedo

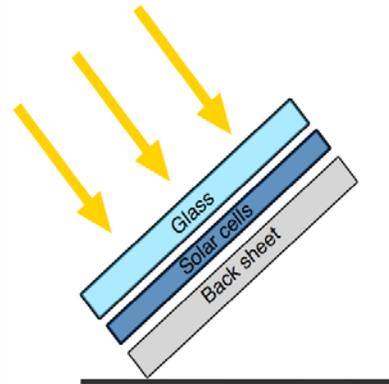
Rabindra Satpathy



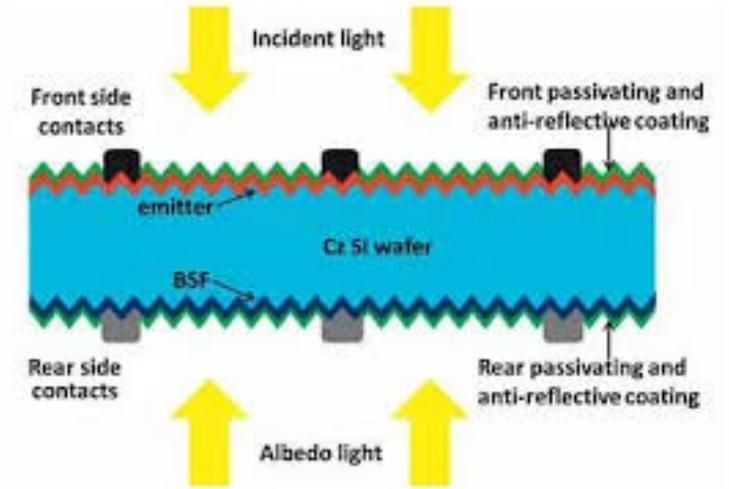
Monofacial vs Bifacial Modules



Bifacial



Monofacial



The data sheet specifies the rear side power based on albedo factor for 345W module

Electrical data – All data measured to STC *

Electrical specifications-345Wp	Only front (STC)	Irradiance percentage on backside based on ground reflectivity			
		15%	20%	25%	30%
Peak power, (0 ~+ 4.99 Wp) Pmax(Wp)	345	388	409	425	441
Maximum voltage, Vmpp (V)	41.22	41.32	41.42	41.50	41.60
Maximum current, Imp (A)	8.37	9.39	9.87	10.24	10.60
Open circuit voltage, Voc (V)	52.45	52.55	52.65	52.75	52.85
Short circuit current, Isc (A)	9.10	10.46	10.92	11.37	11.85
Module efficiency (%)	17.08	19.20	20.20	21.01	21.80

Bifacial Energy Gain Depends on

1. Type of solar cell used for the module and the Bifaciality factor

$$\text{Bifaciality factor} = \frac{\text{Power of Rear Side of Module @STC}}{\text{Power of Front Side of Module @STC}}$$

1. Bifaciality factor of different Bifacial solar modules
cell- PERC+ >70%, PERT >90%, HIT >95%, IBC >70%
If Bifacialty factor is more, the energy yield is also more
2. Location of site:
Content of diffused radiation and direct radiation affects the energy yield
Latitude decides the tilt angle of the mounting system. If diffused radiation content is more, there will be more generation.
3. Tilt angle : Tilt angle increase will cause increased reflected light and hence contributes for energy yield

Contributions of Albedo to Energy Yield

Surface Type	Albedo
Green Field grass	23%
Concrete	16%
White Painted Concrete	60-80%
White gravel	27%
White roofing metal	56%
Roofing membrane Light- grey	62%
Roofing membrane - White	>80%

4. Type of horizontal surface , from which the reflection is coming and its reflectivity (Albedo factor)

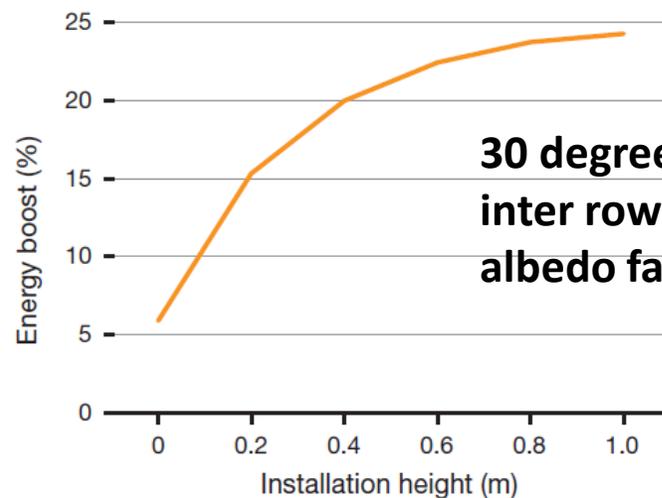
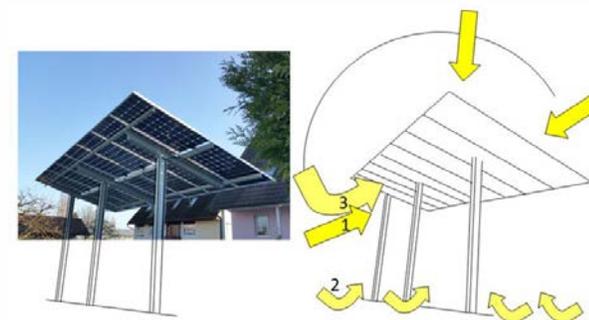
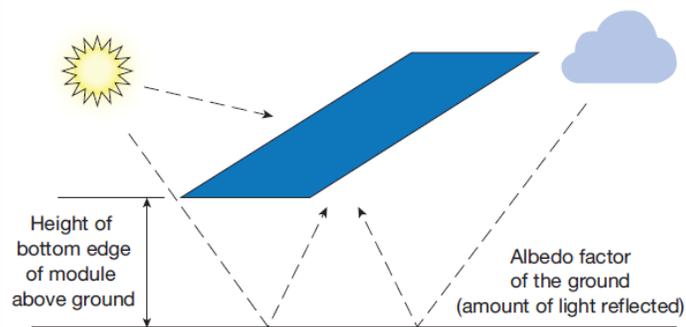
5. Row to Row distance: If inter row space is increased reflected light will increase on rear side and hence contributes for energy yield



Data Source:

<https://solarkingmi.com/assets/How-to-Maximize-Energy-Yield-with-Bifacial-Solar-Technology-SW9001US.pdf>

Contributions of Height to Energy Yield



**30 degree tilt, 2.5 mtr
inter row space, 80%
albedo factor**

6. Elevation and Height of Structure

Flush mounting blocks the light on rear side

Less height cause self shading on rear side of module

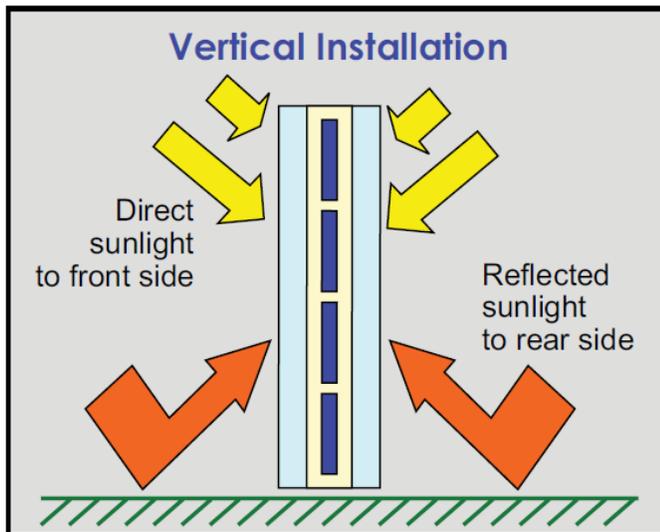
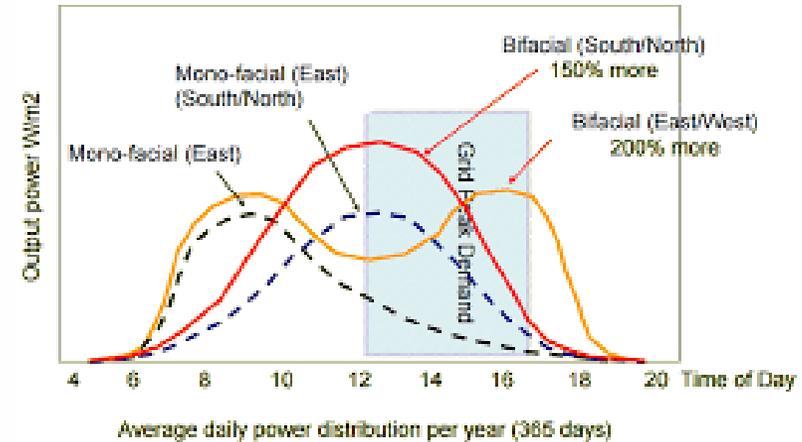
Increasing the height up to 1 mtr will increase the reflected light and boosts the energy yield

Contribution of Tracker/ mounting to Energy gain



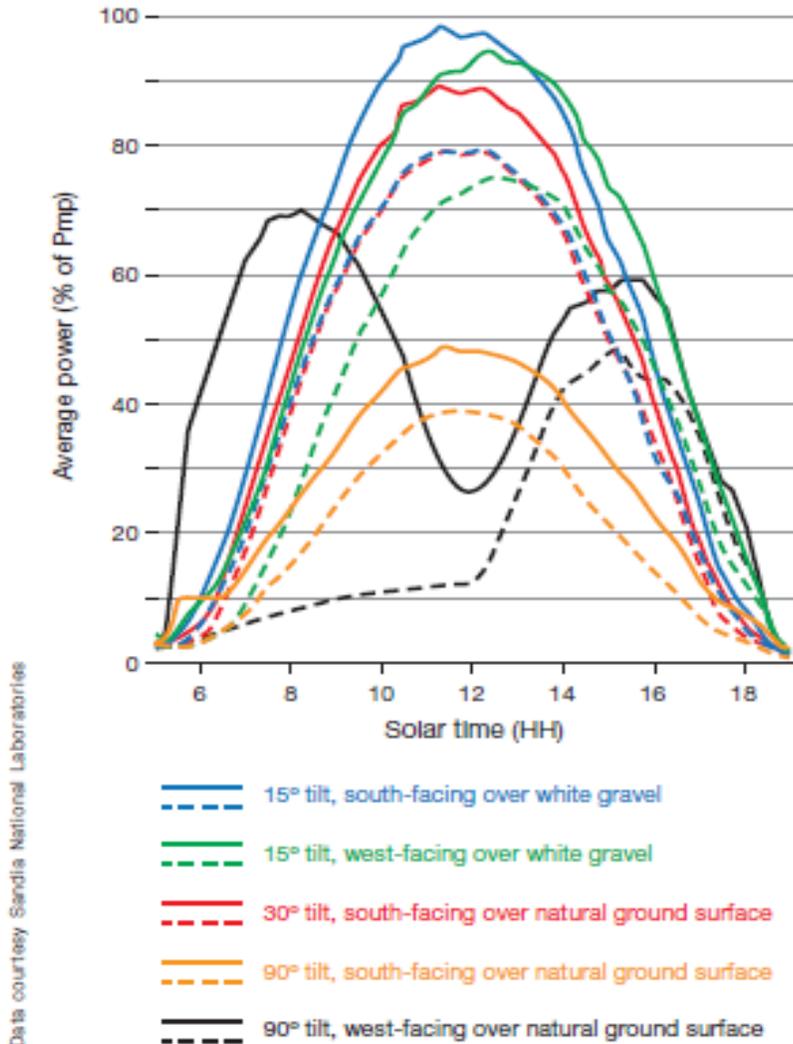
7. Usage of Single axis tracker , enhances the reflected radiation on rear side and boosts the energy up to 15%

Yearly average of daily power distribution (365 days)



8. Vertical mounting with E-W direction generates more energy yield for higher latitudes (NREL study)

Study by Sandia National Laboratory-USA



The average daily power curve for bifacial modules (solid lines) vs mono-facial modules (dashed lines) in 5 different test conditions, which Sandia measured over a 6-month period at its New Mexico Regional Test Center

- Bifacial gain vary throughout the day
- The bifacial contribution is more in morning , evening and during cloudy conditions
- Bifacial modules out performing from 18% to 136% compared to monofacial modules

Study by Trina Solar

Module Mounting	Bifacial gain
On grass	5.20%
On grass with a tracker	10.57%
On sand	10.79%
On sand with a tracker	24.42%
On white-painted surface	21.90%
On white-painted surface with a tracker	33.20%

- Trina Solar set up a test in Changzhou, China, to find out how much more energy bifacial modules generate compared to Mono-facial modules.
- Combined with a tracker and placed on a white-painted surface, bifacial modules outperform the standard mono-facial panels by more than a third.

		SURFACE TYPE					
		concrete	green field	white gravel	sand	white roofing metal sheet	bright white roofing foil
		ALBEDO					
		16% albedo	23% albedo	27% albedo	40% albedo	56% albedo	80% albedo
INSTALLATION HEIGHT (m)	0.0	1.20 %	1.70 %	2.00 %	3.00 %	4.20 %	6.00 %
	0.1	2.30 %	3.30 %	3.90 %	5.80 %	8.10 %	11.60 %
	0.2	3.10 %	4.40 %	5.20 %	7.70 %	10.80 %	15.50 %
	0.3	3.60 %	5.20 %	6.10 %	9.10 %	12.80 %	18.20 %
	0.4	4.00 %	5.80 %	6.80 %	10.10 %	14.10 %	20.20 %
	0.5	4.30 %	6.20 %	7.30 %	10.80 %	15.10 %	21.50 %

Bifacial gain in energy (BGE) increases with θ : tilt angle of modules

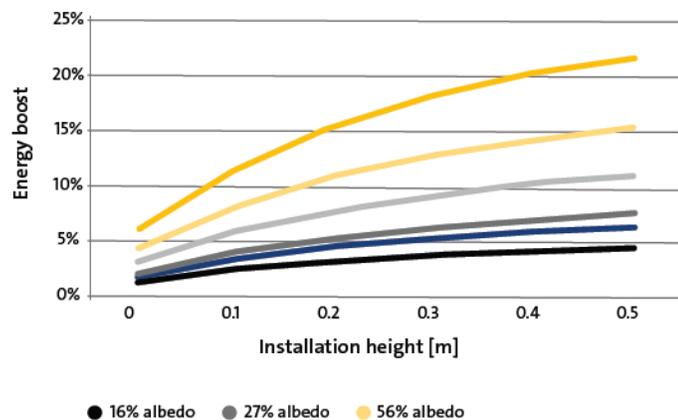
h: height above the ground

α : albedo of the ground

$$BGE(\%) = A * (\theta) + B * (h) + C * (\alpha)$$

Where A,B,C are Numerical coefficients

TABLE 3: Additional energy yield of a bifacial module for different surface types and installation heights (landscape-mounted module, 65 percent bifaciality, south oriented, 30° pitch and a row pitch of 2.5 meters) (source: own calculation)

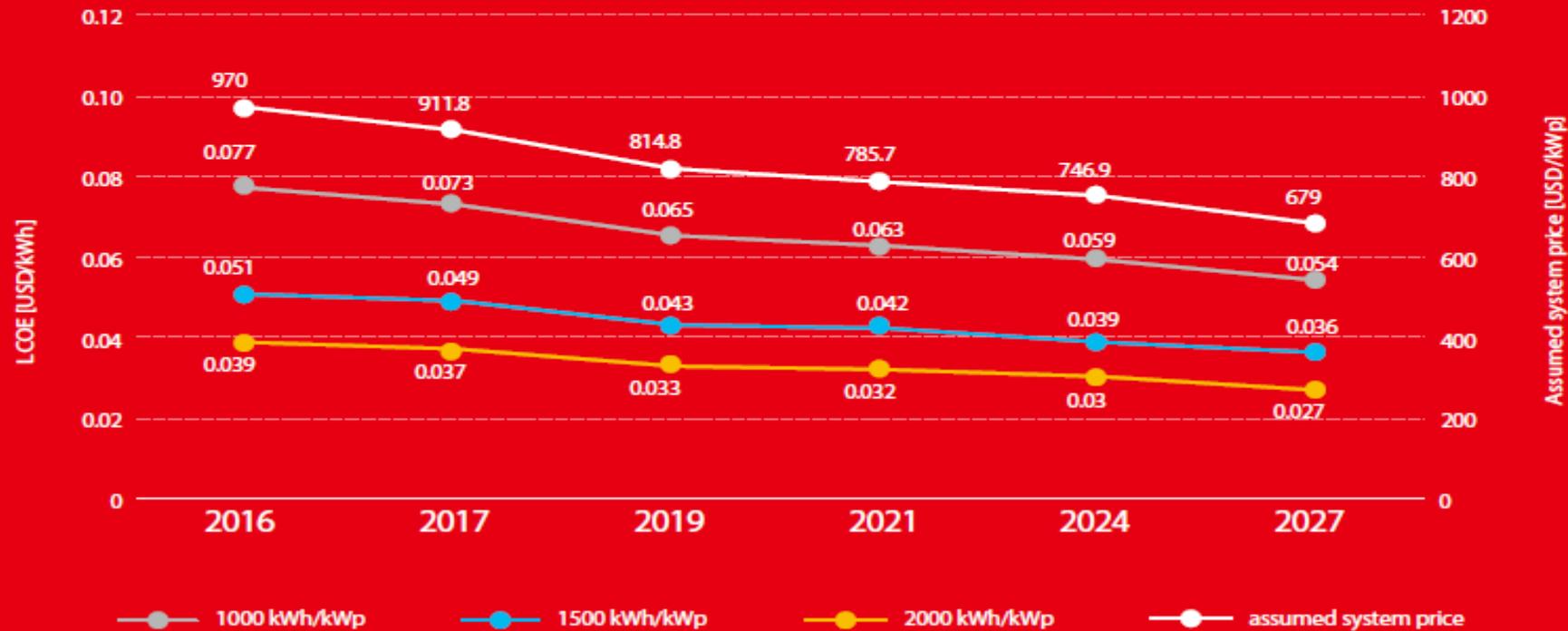


- High albedo gives higher energy yield
- Higher the installation height of the module, higher the energy yield
- Bifacial boost is greater on days with lower insolation
- Bifacial modules provide a considerable performance boost even in less than ideal circumstances

FIGURE 8: Additional energy yield of a bifacial photovoltaic system with landscape-mounted module, 65 percent bifaciality, south orientation, 30° pitch and a row pitch of 2.5 meters for various albedo values (source: own calculation)

BIFACIAL TECHNOLOGY

Will enable PV LCOE to drop below \$0.05/kWh for most regions sooner



CONCLUSION

- The Bifacial solar PV modules gain in energy, depends on Module Bifaciality Factor, Albedo factor & the Height of the module
- Bifacial performance is quite sensitive to enhanced albedo of the ground surface.
- E-W bifacial vertical modules, which can outperform optimally oriented mono-facial modules, especially with enhanced albedo.
- Vertical E-W bifacial modules produce energy in the morning and evening of the day than S-facing arrays.
- Bifacial modules significantly outperform mono-facial modules in conventional designed systems. Additional performance benefits from bifacial modules are possible with optimized system designs that enhance albedo, avoid backside obstructions and minimize ground shading beneath the array.
- Careful design and Parameters choice of both modules and field installation will insure Bifaciality gain of 30-40%
- LCOE will drop below 5 US cents/kWh

THANK YOU