

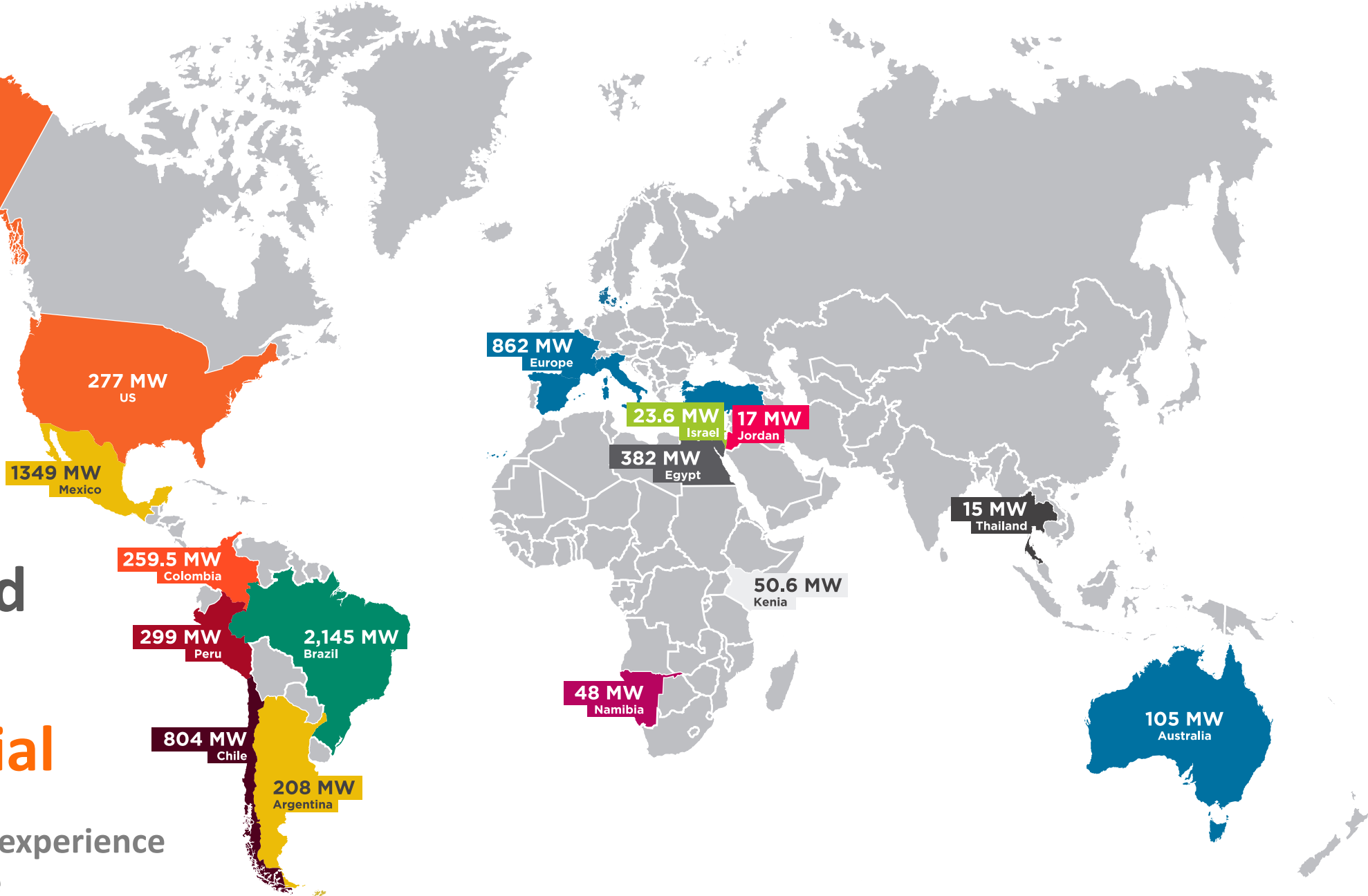


Soltec

**Making Tracks,
Building Trust**

Soltec's track-record 7.5+ GW 2 GW bifacial

15 years of industry experience
More than 1,500 people



Bifacial story



2015

'La Silla' solar plant (Chile), 2015. Soltec produced **the first solar tracker specifically designed for bifacial modules** installed in a utility scale solar plant.



2017

Soltec launches SF7 Bifacial Single-Axis Tracker.

- Higher mounting height
- Shadow-free backside
- Wide-aisle reflecting surfaces

2018

Soltec Leads with the World's First **Bifacial Tracking Evaluation Center (BiTEC)** to measure bifacial performance and its effect on yield. **10 MWp of bifacial trackers supplied in Israel, USA, Denmark, ..**

2019

2 GW SF7 Bifacial in projects worldwide

Sao Gonçalo-Brazil (475 MW), Cluster MG-Brazil (118MW), among others.



BiTEC

Bifacial Tracker Evaluation Center Livermore - California

Test Features: --- 18 Trackers

- **Albedo:** White/Seasonal/Gravel
- **GCR:** 0.4, 0.33, 0.47
- **Height** 1P, 2P

Challenges:

1. Acquiring long term bifacial tracking data
2. Obtaining real PV plant conditions
3. Characterizing variables influencing bifacial
 - *Albedo*
 - GCR
 - Height
 - Shading and interferences
4. Determining Bifacial Gain = $f(G, h, \text{Pitch}, \text{Albedo})$

Targets:

- Optimizing the SF7 bifacial tracker
- Developing bifacial tracking algorithms

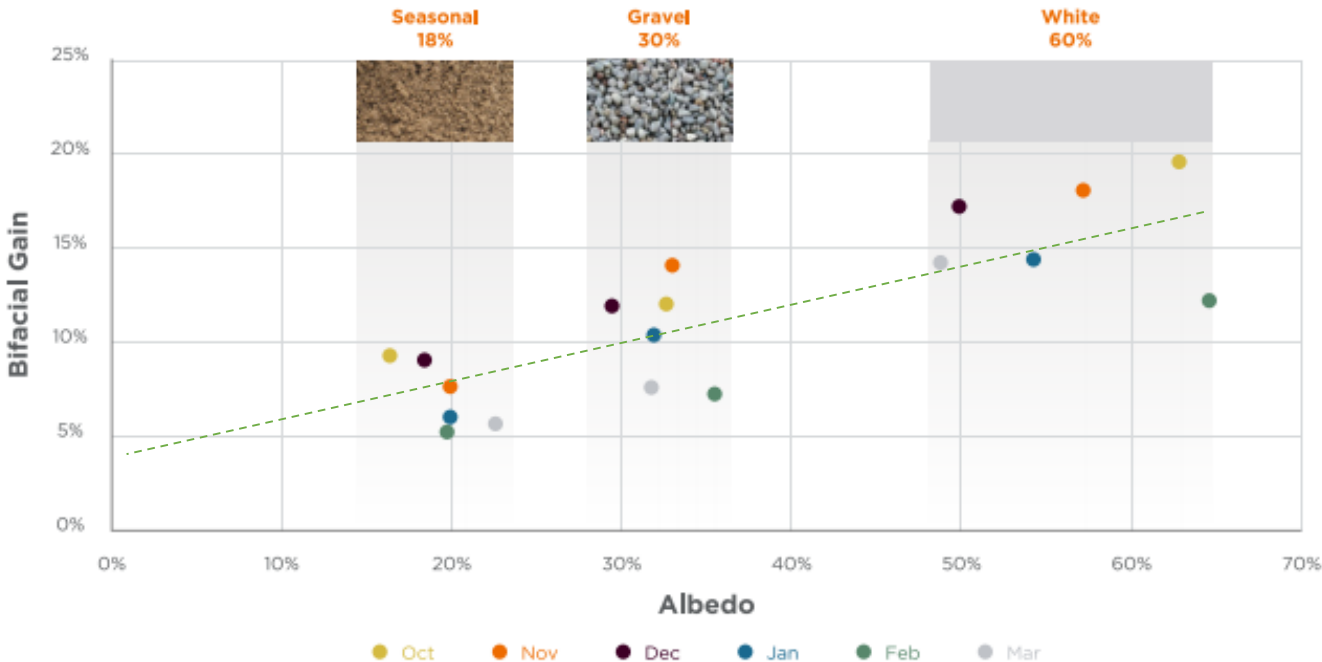


Albedo

Seasonal variation
 Linear dependence on BG
 Bifacial Gain Results



Figure 3. Evolution of grass at seasonal albedo areas from September (left) to June (right). Source: BiTEC



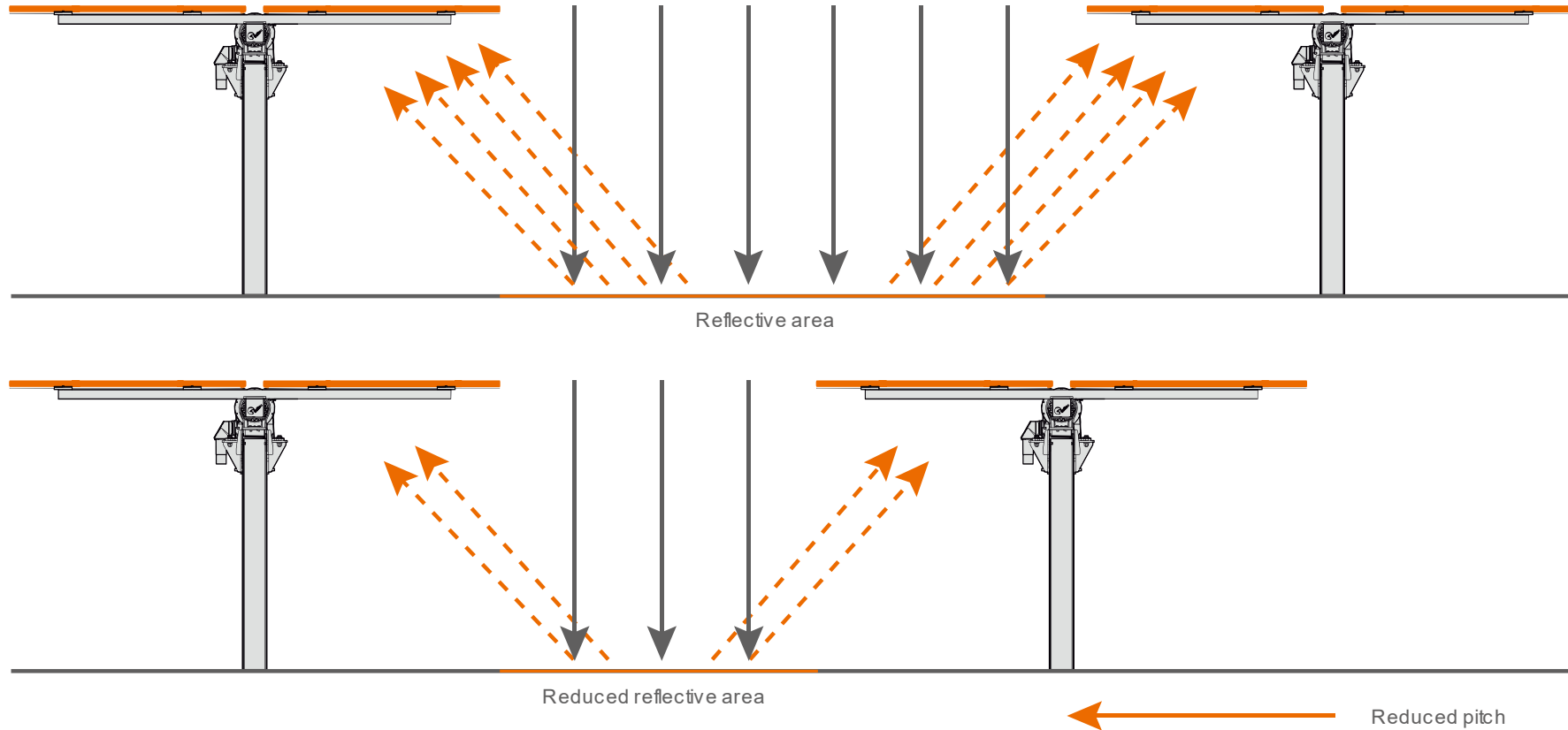
BiTEC 1-Year Results

Ground Type	Fall	Winter	Spring	Summer	1 year	BG
White	62.8%	55.50%	53.2%	55.4%	55.6%	15.7%
Gravel	32.0%	25.50%	27.2%	31.2%	29.5%	9.6%
Seasonal	19.2%	17.20%	19.6%	21.0%	19.9%	7.3%

Albedo Measured with pyranometers at 1,5m
 BG of Jolywood Module assess respect
 monofacial polycrystalline module

Pitch

- Wider Pitch = Longer Tracking + Better Bifacial Gain

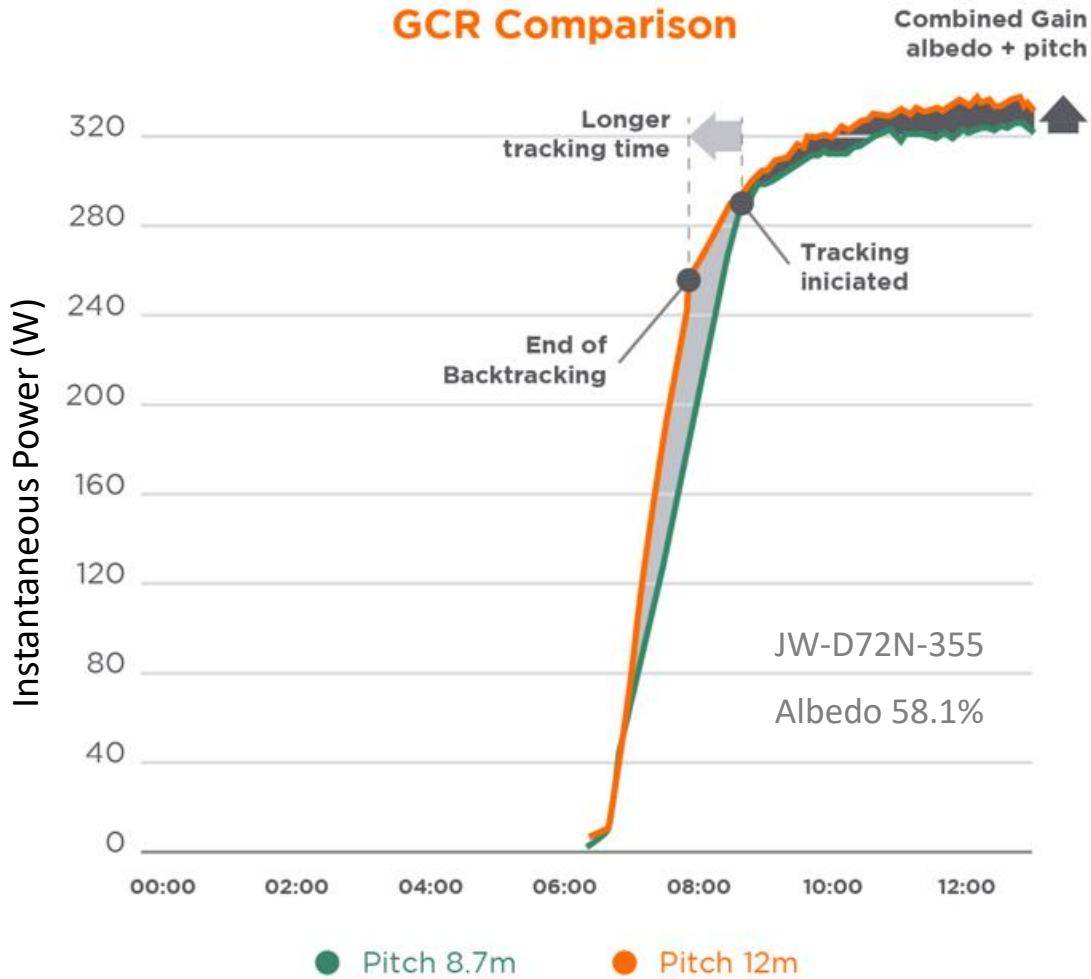


Pitch

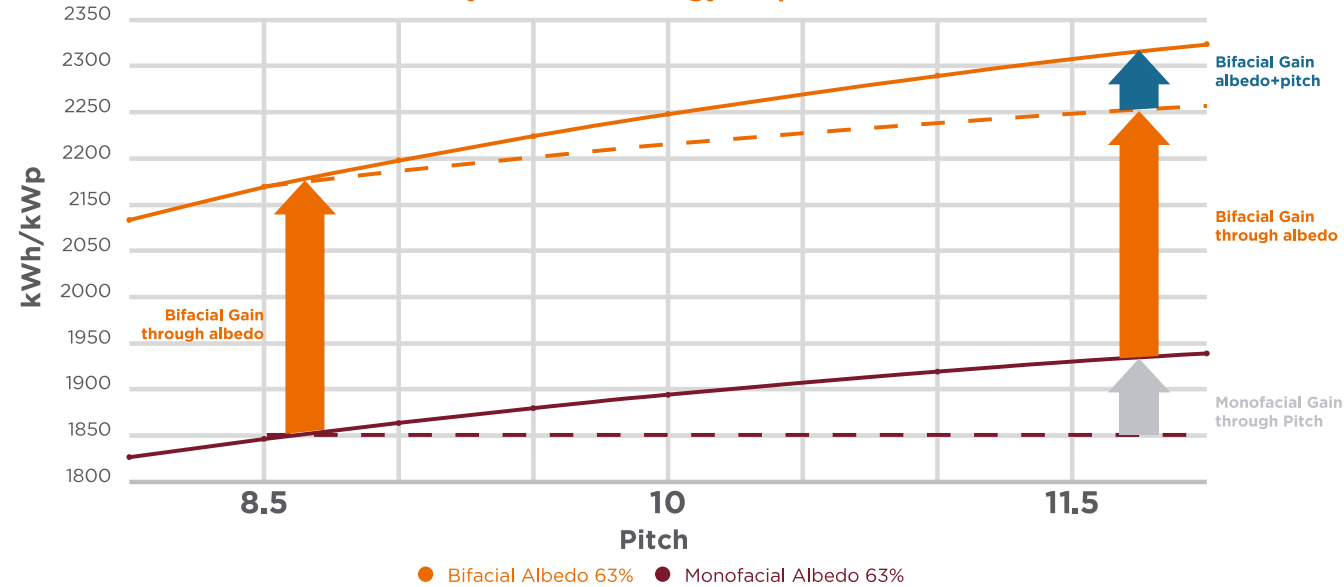
Longer Tracking + Better Bifacial Gain

BiTEC Measurements

GCR Comparison



Sensibility of Bifacial Energy Output with Pitch



BiTEC Measurements

Pitch	8.7 meters	10 meters	12 meters
<u>Bifacial Gain</u>	9.49%	12.11%	14.58%
<u>Δ</u>	- 2.62%	<u>Baseline</u>	2.47%

Bifacial Gain Comparison during comon tracking hours in March. Albedo 58.1%

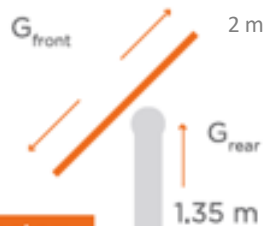
Interferences & Shading

SF7 Bifacial PVsyst simulation
Structure Shading Factor = 0%

Simplified Modeling
PV syst / SAM / bifacial radiance

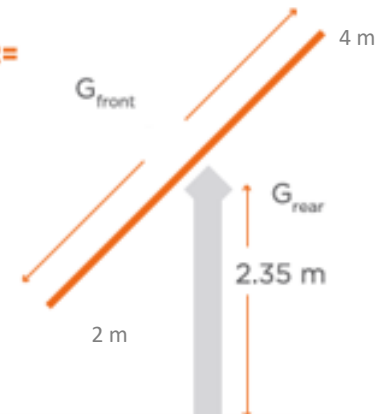
No shading

Module 1 = continuous plane
No torque tube



Shading factor:
-5.6%

Module 1 + Module 2 = continuous plane
No torque tube



Shading factor:
0%

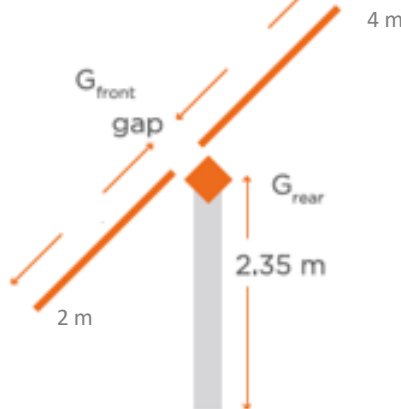
Comprehensive Modeling
bifacial radiance

Real module location
torque tube shading

Module 1 = continuous plane
With torque tube



Module 1 + Gap + Module 2
With torque tube



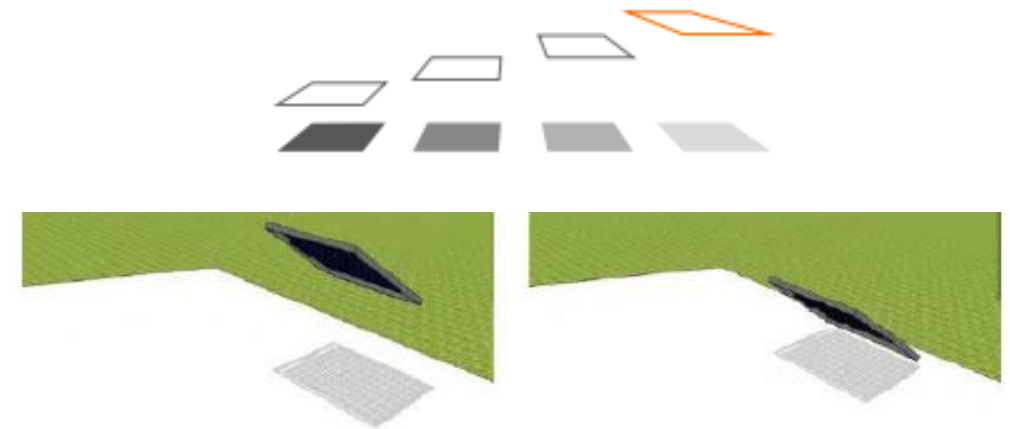
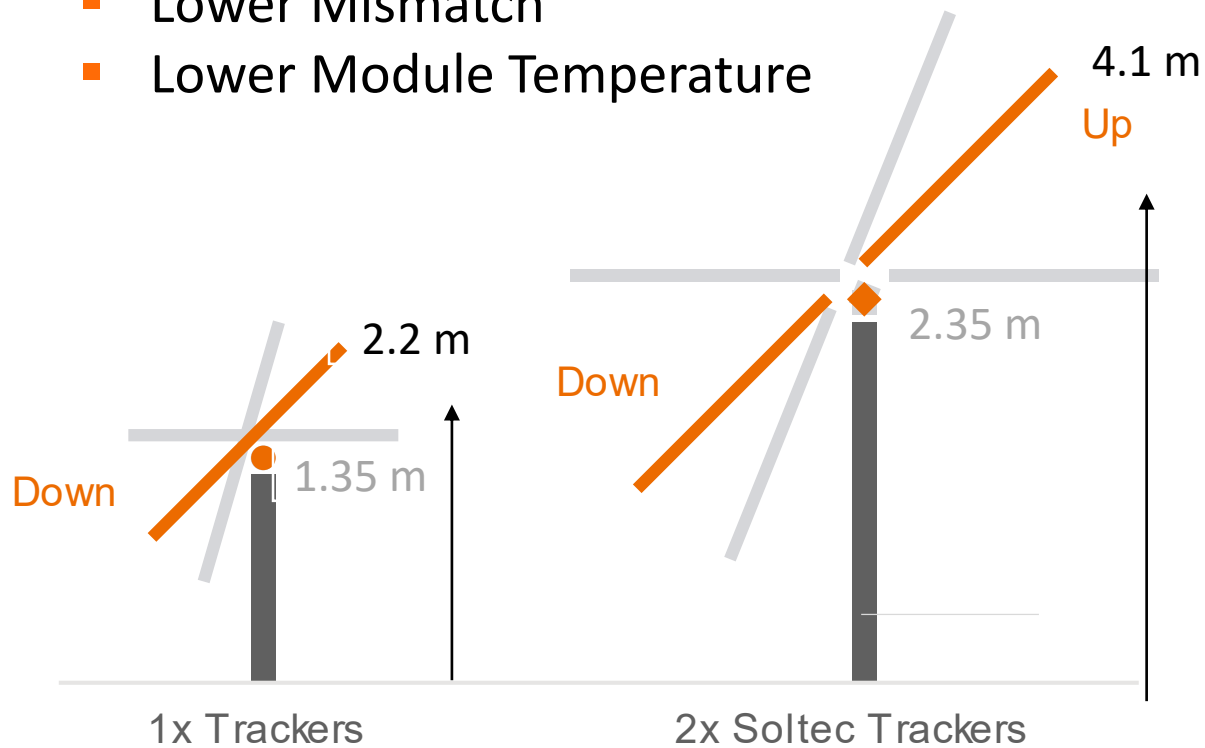
Racking shading could reach
↓6% rear irradiation loss

Example of central row. Simulations count with my rows.

Diffuse Irradiation due to Height

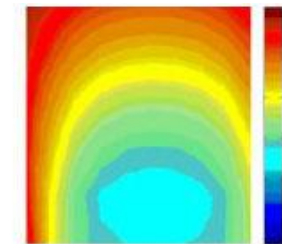
Module's Height increases the Rear Irradiance due to:

- Diffuse Irradiation
- View Factor (more reflective surface)
- Lower Mismatch
- Lower Module Temperature



Module elevation: 2 m | $\alpha = 0.5$

Module elevation: 1 m | $\alpha = 0.5$



Irradiance at the module rear side [W/m^2] on an exemplary summer day in Cairo

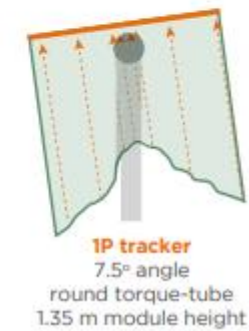
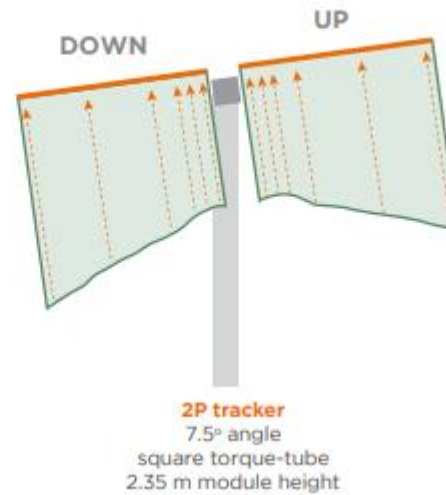
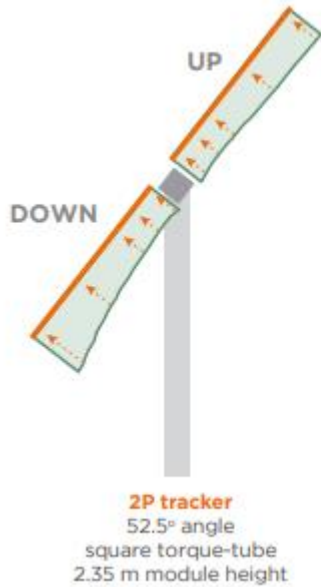
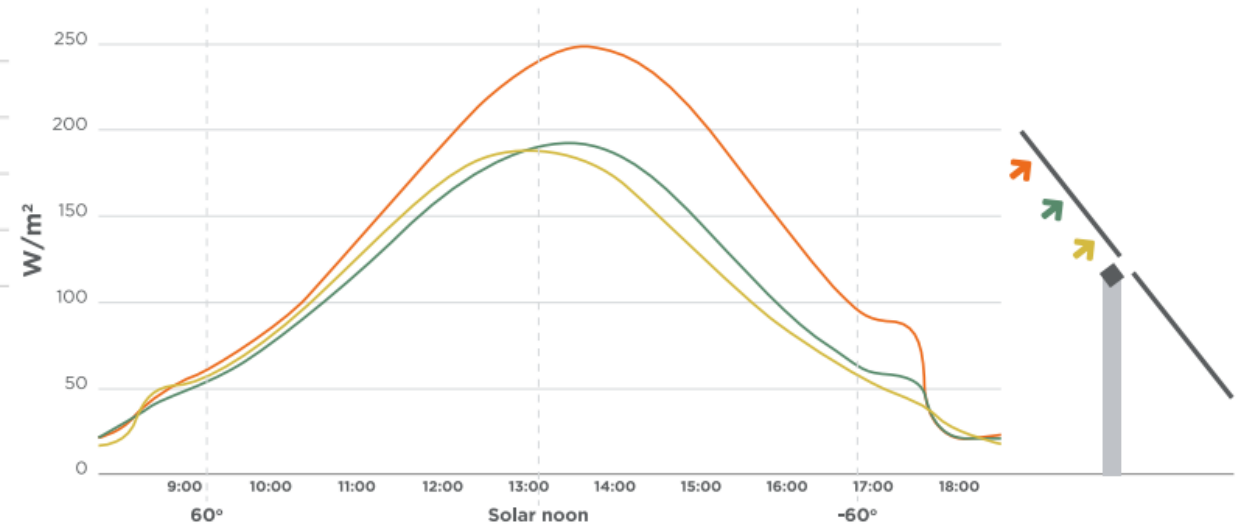
Source: RWTH Aachen University - ISC

Irradiation Mismatch due to Height

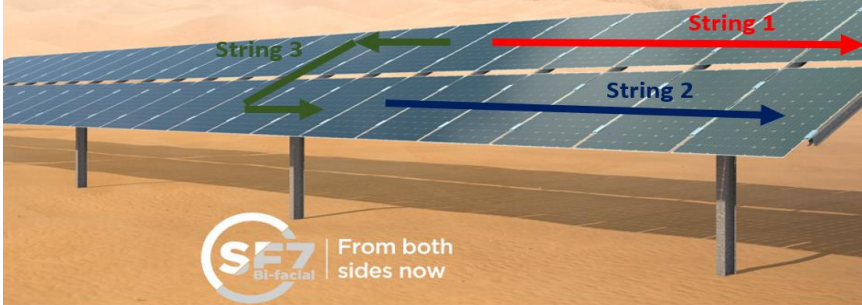
	2P SF7 Bifacial	Standard 1P
UP module standard deviation	6.3%	--
DOWN module standard deviation	17.8%	18.5%
Average	12.0%	18.5%
Irradiation Mismatch*	2.4%	3.7%

Table 6. Rear irradiation mismatch and rear standard deviation comparison at a 52.5° angle
*Relative to total irradiation

Measured Irradiation Distribution



Electrical Mismatch due to Height



BiTEC Measurements

Worst Case Instantaneous

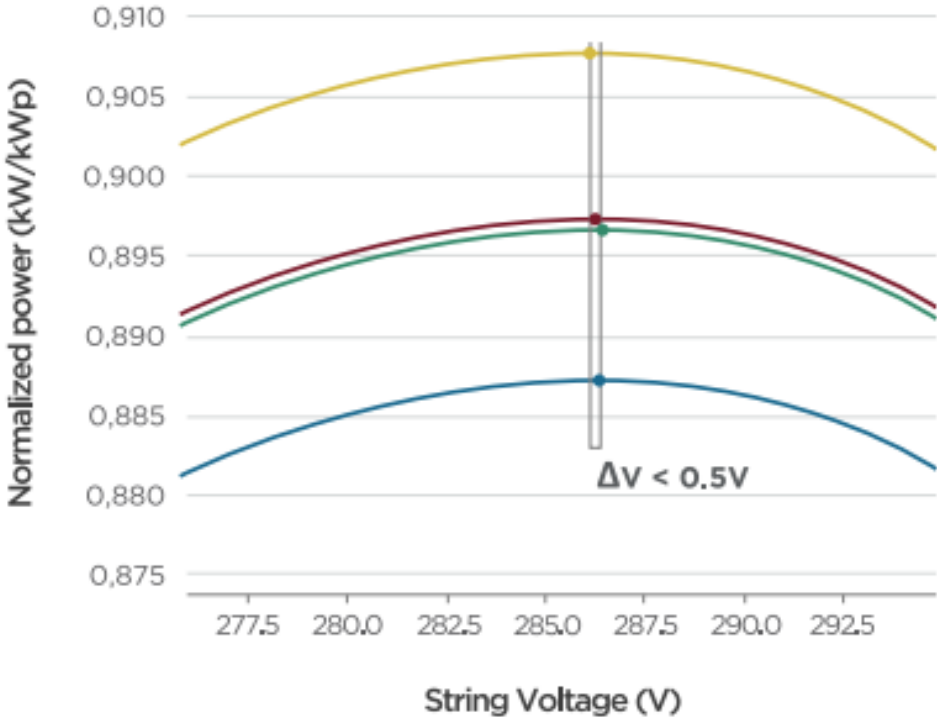


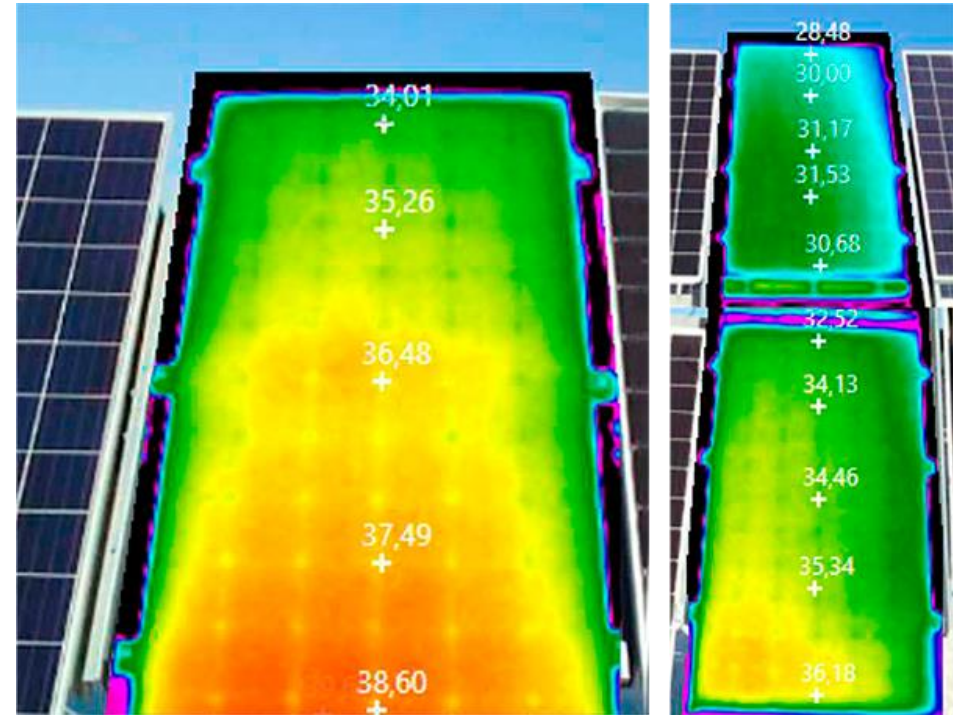
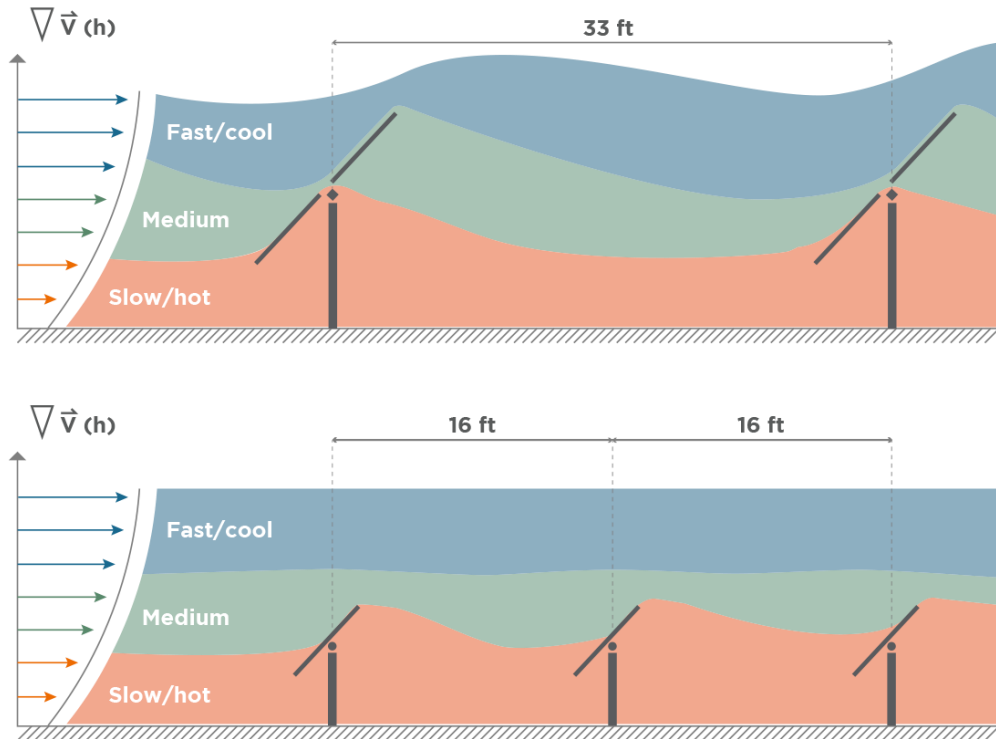
Figure 9. P-V curve in the MPP range per string at 17:00 h August 7th. Source: BiTEC

String	Instantaneous		Month Agregated	
	V (V)	I (A)	E(kWh/kWp)	Mismatch
String 1	285.81	8.89	216.27	0.03%
String 2	286.11	8.68	215.55	0.03%
String 3	286.31	8.76	215.71	0.09%
Single addition	-	-	215.91	-
Group (3)	286.03	26.24	215.79	0.06%

Table 7. Electrical measurement per string. Worst Case Instantaneous/Agregated. Source: BiTEC.



Module temperature due to Height



BiTEC Measurements

+3.5 °C

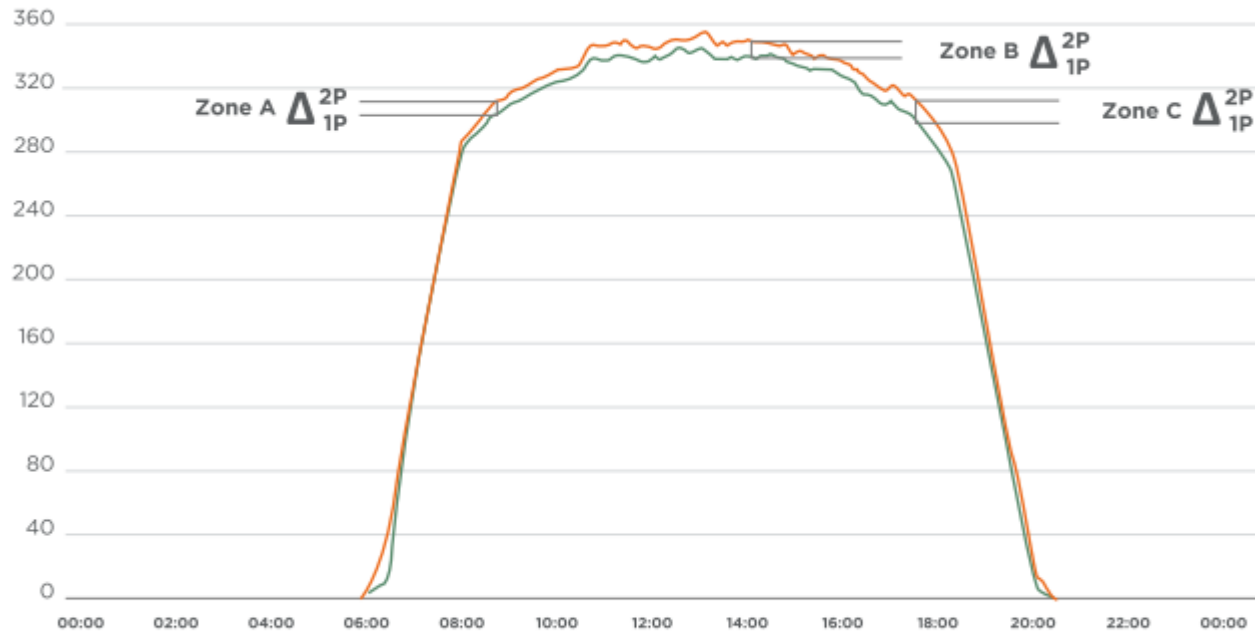
Date (2018)	Time	1P Tracker	2P SF7 Bifacial		1P Vs. 2P		
		Single Module T(°C)	Module down T (°C)	Module up T (°C)	2P \bar{T}	ΔT (°C)	ΔP %
oct 18	11:01	33.0	30.8	22.0	26.4	6.6	2.4
oct 22	15:23	36.3	34.6	30.3	32.5	3.8	1.4
oct 23	10:23	27.3	29.4	24.4	26.9	0.4	0.1
oct 24	10:53	33.0	30.5	23.7	27.1	5.9	2.2
oct 25	15:23	40.2	41.3	37.4	39.4	0.9	0.3
Average		33.96	33.32	27.56	30.44	3.5	1.3

+1.3% BG

Module temperature due to Height

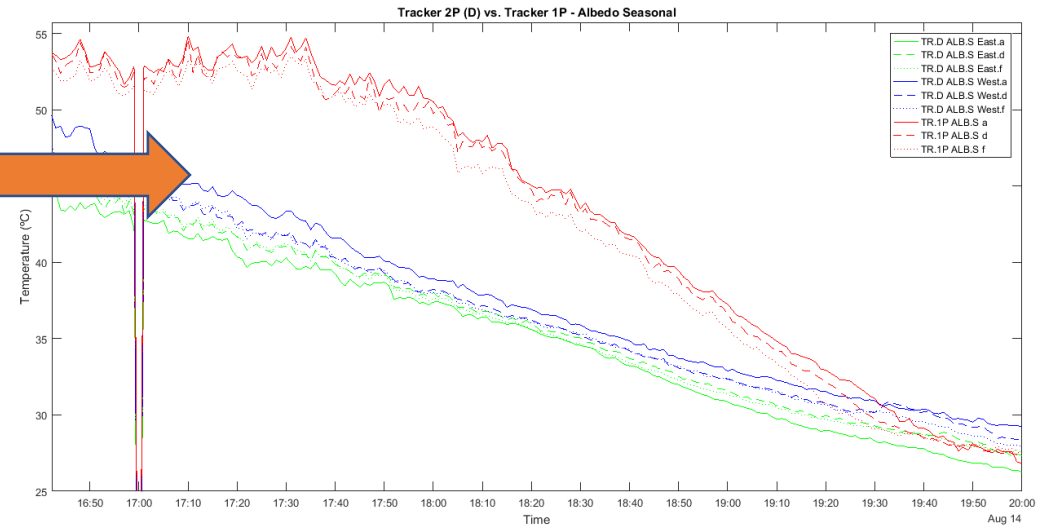
	Ambient Temp.	2P-UPPER	2P-LOWER	1P	ΔT (2P-UPPER vs. 1P)	ΔT (2P-LOWER vs. 1P)
15/08/2019 - 16:00 a 20:00						
MAX	30,55	51,80	55,41	58,12	-6,32	-2,70
MIN	12,21	27,20	24,62	26,90	0,30	-2,28
MEAN	17,48	38,65	40,58	45,89	-7,24	-5,31

Comparison graphs for 1P Vs. 2P

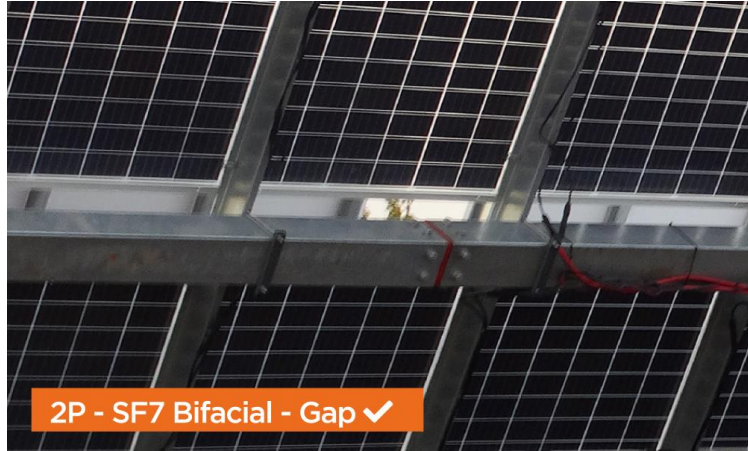


● Module: Jolywood 355 W,
1P configuration, white albedo, GCR 0.4

● Module: Jolywood 355 W,
2P configuration, white albedo, GCR 0.4



1P vs. 2P Solar Trackers



Tracker	Height	Albedo	GCR 0.4 Pitch
2P (SF7 Bifacial)	2.35 m	55.6%	10 m
1P	1.35 m	55.6%	5 m

Measured Bifacial Gain				
Fall	Winter	Spring	Summer	Yearly
19.2%	14.3%	13.4%	15.8%	15.7%
16.8%	12.6%	11.4%	13.7%	13.6%
Δ +2.4%	+1.7%	+2.0%	+2.1%	+2.1%

Yearly Yield 2P vs 1P Single Axis Tracker	Delta Bifacial Gain
Lower average module temperature (better air cooling)	+1.3%
No torque tube shading	+0.7
Higher module height and other design features	+0.1
Total	+2.1%

Parameters adjustments in PVsyst® for the SF7 Bifacial tracker

Parameters	Standard 1P trackers	SF7 Bifacial
Angle	–	-60° +60°
Height	1.35 meters	2.35 meters
Structure Shading Factor	5.6%	0%
Shed Transparent Fraction	MT%	$(MT^* + 3.75) \times 1'017$ (%)
Thermal Loss factor Thermal factor (Uc)	29 W/m2 k	31 W/m2 k
Thermal Loss Factor (Uv)	0 W/m2 k/m/s	1.6 W/m2 k/m/s
Mismatch Loss Factor	10 %	3.1 %

*MT: Module Transparency from module manufacturer

Conclusions

- Field data from BiTEC obtained from September 2018 and August 2019 show a Bifacial Gain of **15.7%** for individual bifacial tracker modules with an albedo of about 55%.
- Under seasonal albedo conditions, in which ground albedo changes throughout the year, Bifacial Gain was **7.3%**.
- Bifacial Gain for 2P SF7 Bifacial tracker is **2.1% higher** than a solar tracker with 1P configuration.
- This difference is mainly caused by the **lack of shading in the rear side** of the module, by the **higher position of the solar panels**, and by a **lower operating temperature**.
- The specific performance and advantages of bifacial modules can be simulated using available software, such as PVsyst®, provided bifacial parameters are properly entered. To do that, it is necessary to adjust the values for **Structure Shading factor, Shed Transparent fraction, Field Thermal Loss factors and Mismatch Loss factor**.

