WEBINAR

DATE: 15th September 2022

Trinasolar

PVTECH | TECHTalk

GREEN GENIUS

Designed for success: Bifacial PV power plants built to last and to provide lowest LCoE

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Solar Media

DESIGNED FOR SUCCESS

Bifacial PV Power Plants built to last and for Lowest LCoE

David Garmendia

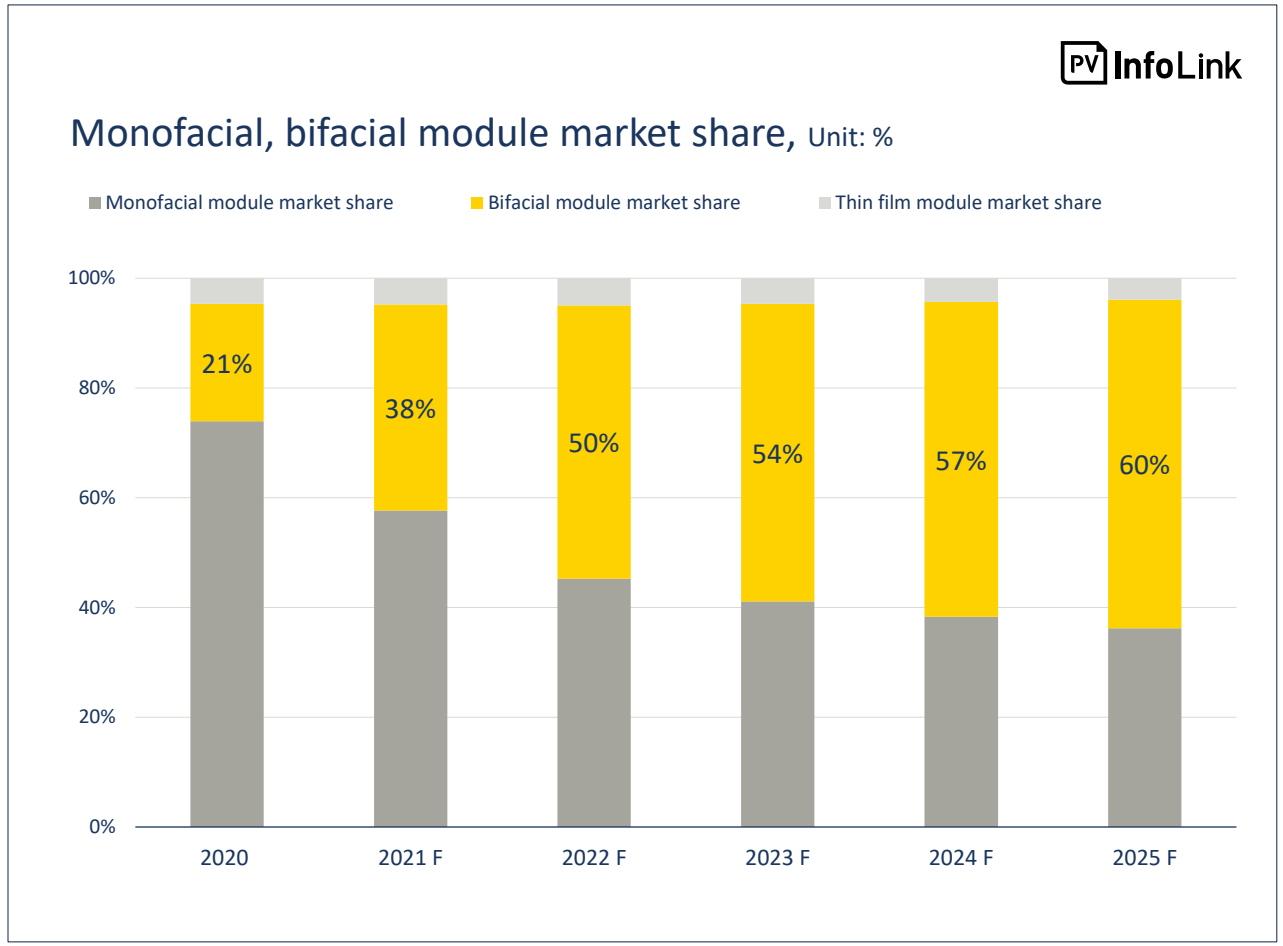
September 2022

DESIGNED FOR SUCCESS

Bifacial PV Power Plants built to last and for Lowest LCoE

- Market Trends - Bifacial Share
- Bifacial Technology - Principles
- Bifacial PV plant - Main components
- Bifacial System design - Key parameters
- Conclusions / Summary

1. Market Trends - Bifacial Share



- MS 2019 → 9%
- MS 2020 → 21%
- MS 2021 → 38%
- MS 2022 forecast → 50%
- Even higher MS if only utility-scale segment is considered

Trina Solar has 20 GW cumulative shipments of bifacial modules

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- **Bifacial Technology - Principles**
- Bifacial PV plant - Main components
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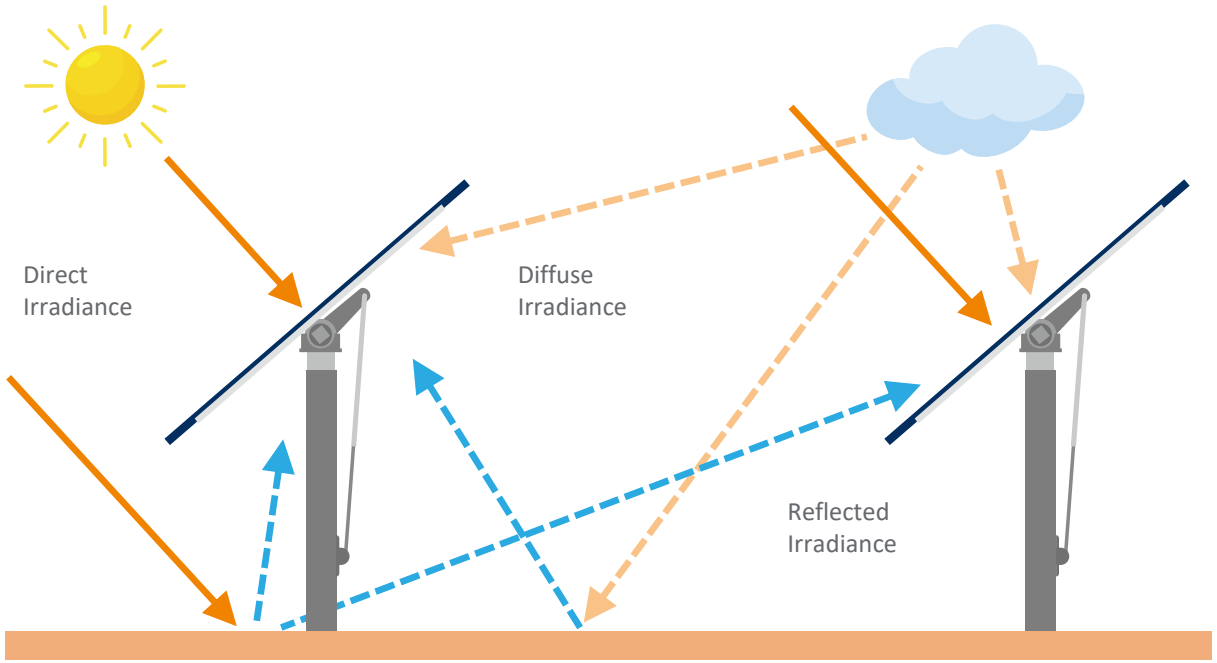
2. Bifacial Technology - Principles

Bifacial Gain, Bifacial Ratio & Bifaciality



$$E_{bifacial} = E_{front} + E_{rear}$$

Bifacial Gain

$$Bifacial\ Gain = E_{rear} / E_{front}$$

Bifacial Ratio

$$Bifacial\ Ratio = G_{rear} / G_{front}$$

Bifaciality

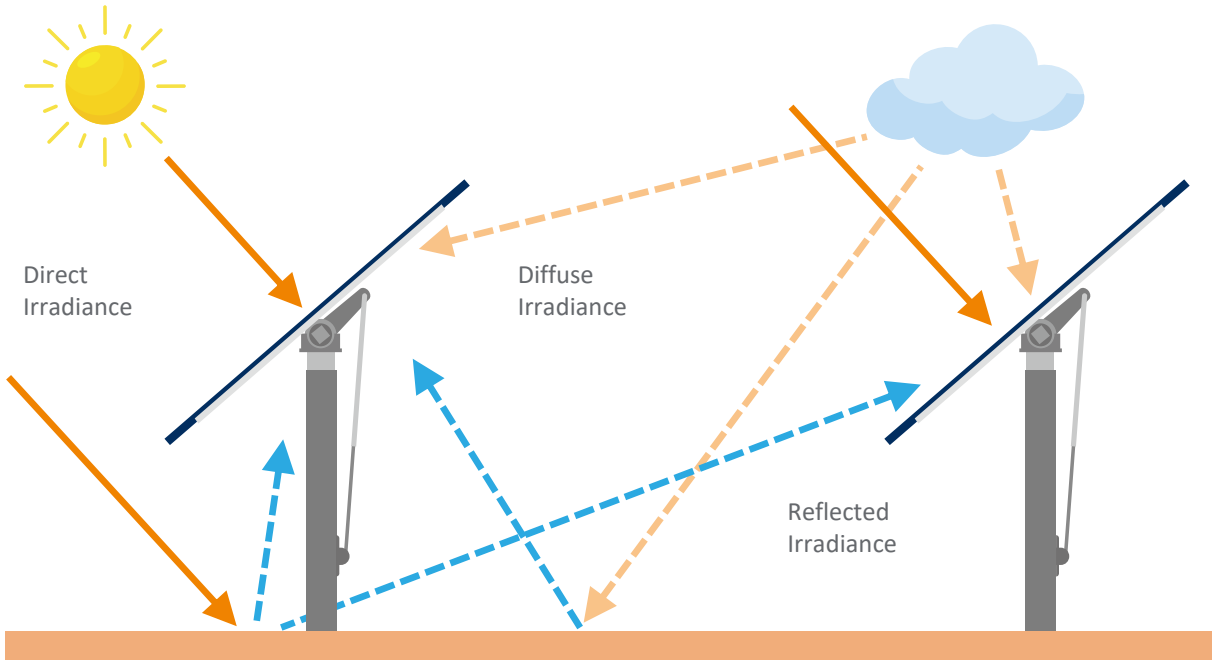
$$Bifaciality = Bifacial\ Gain / Bifacial\ Ratio$$

$$E_{bifacial} = E_{front} \times (1 + Bifacial\ Gain)$$

$$E_{bifacial} = E_{front} \times (1 + BifacialRatio \times Bifaciality)$$

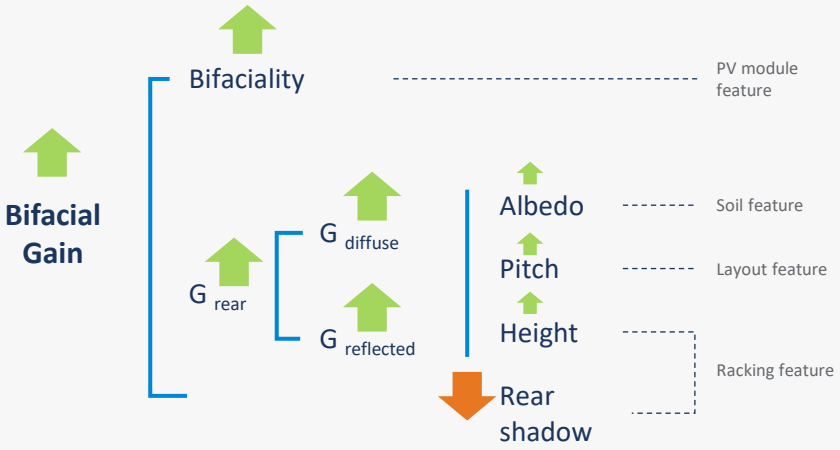
2. Bifacial Technology - Principles

Increasing Energy generated by rear side



Diffuse Irradiation vs Reflected Irradiation

$$G_{rear} = G_{diffuse} + G_{reflected}$$



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- **Bifacial PV plant - Main components**
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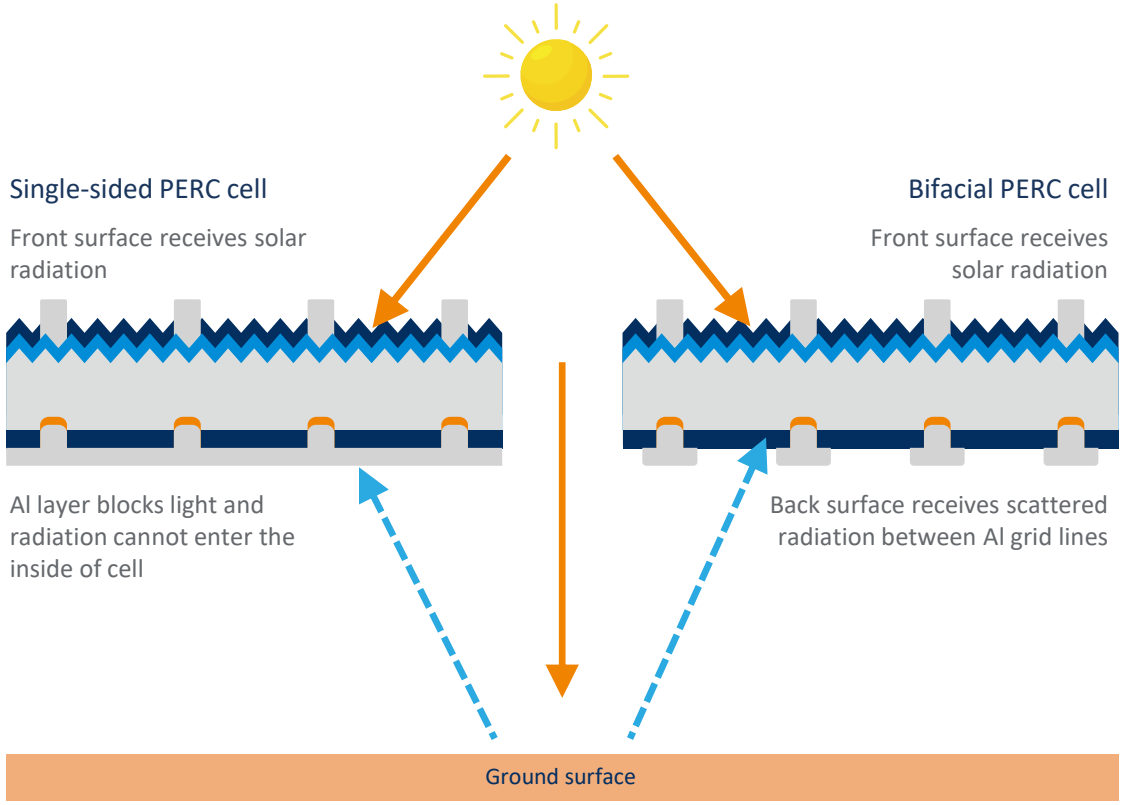
- Conclusions / Summary

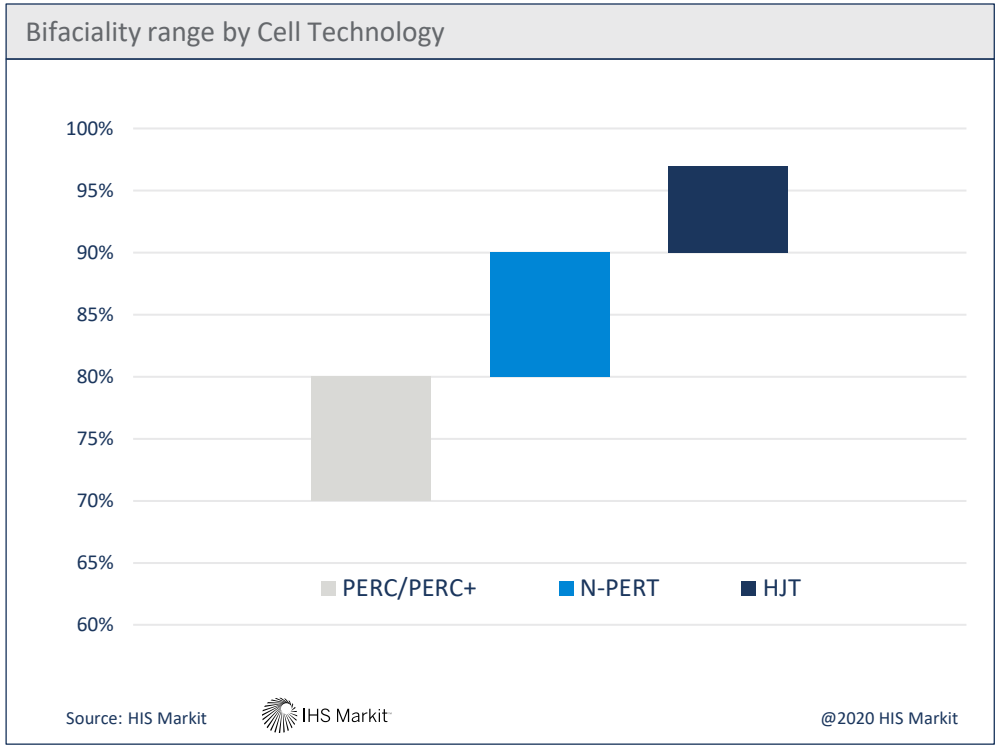
3. Bifacial PV Plant - Modules

Bifacial Cell Structure. Bifaciality vs Cell Technology

Bifacial Cell Structure



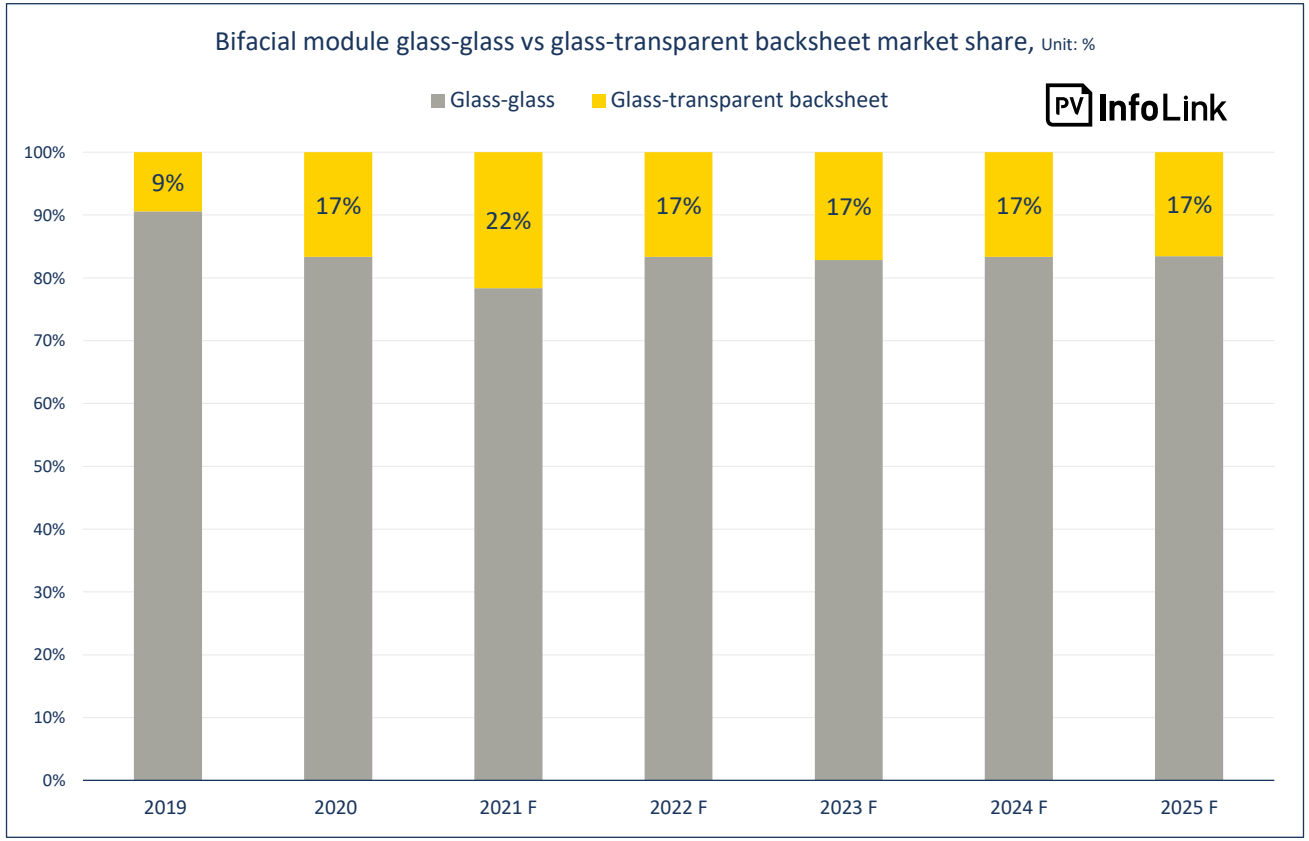
Bifaciality vs Cell Technology



3. Bifacial PV Plant - Modules

Module Materials: Glass-glass vs Transparent backsheet

Glass-glass vs Transparent Backsheet



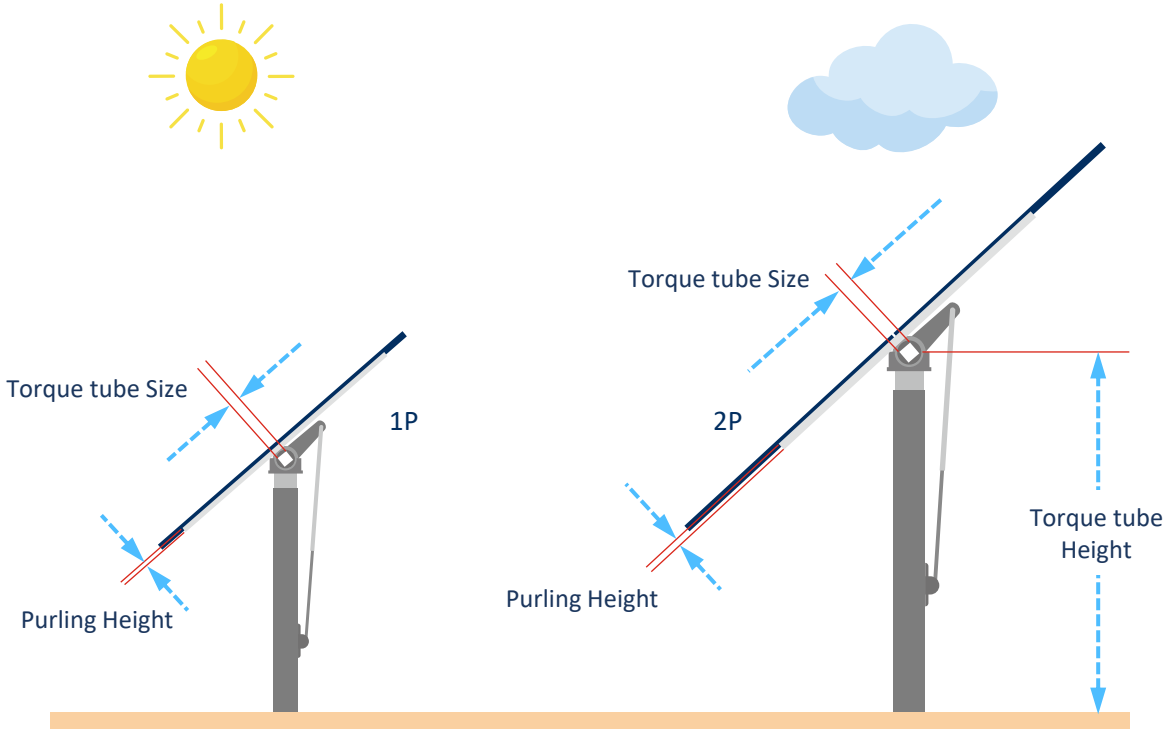
Trina Solar = Glass-Glass

BENEFITS

- Resistance to salt spay, acids & alkalis
- Zero moisture penetration
- Reduce invisible cell cracking
- More excellent mechanical load ability

3. Bifacial PV Plant - Mounting Systems

Rear side Irradiation vs Main mounting system parameters

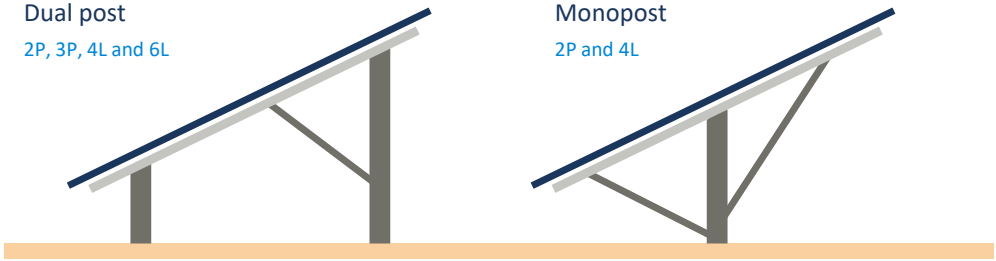


Dual post

2P, 3P, 4L and 6L

Monopost

2P and 4L

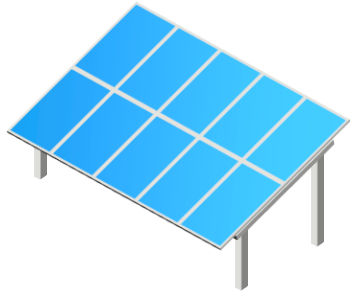


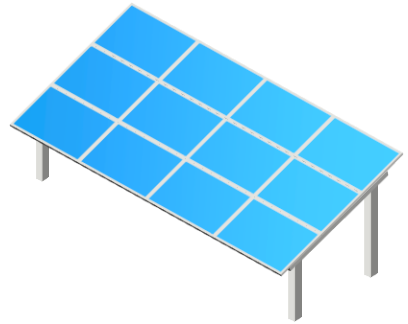
Portrait configuration

Portrait configurations are recommended for high E-W slopes terrains.

Landscape configuration

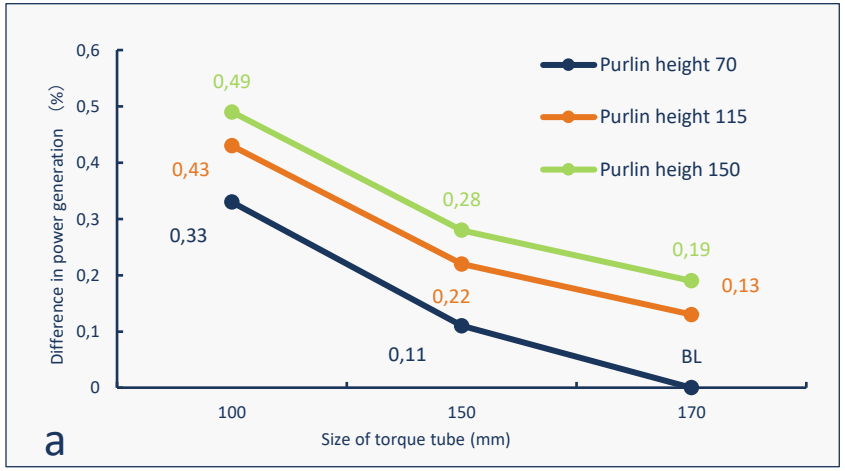
Landscape configurations are recommended for bifacial modules to minimize shading on the rear part of the solar panels.

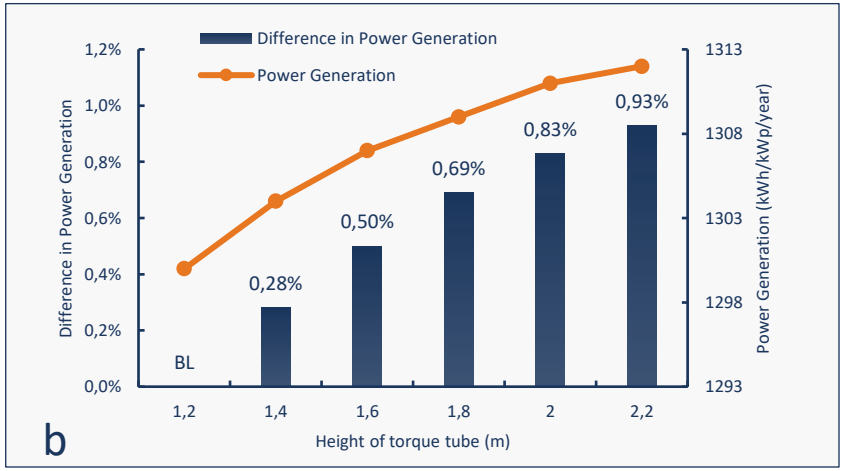


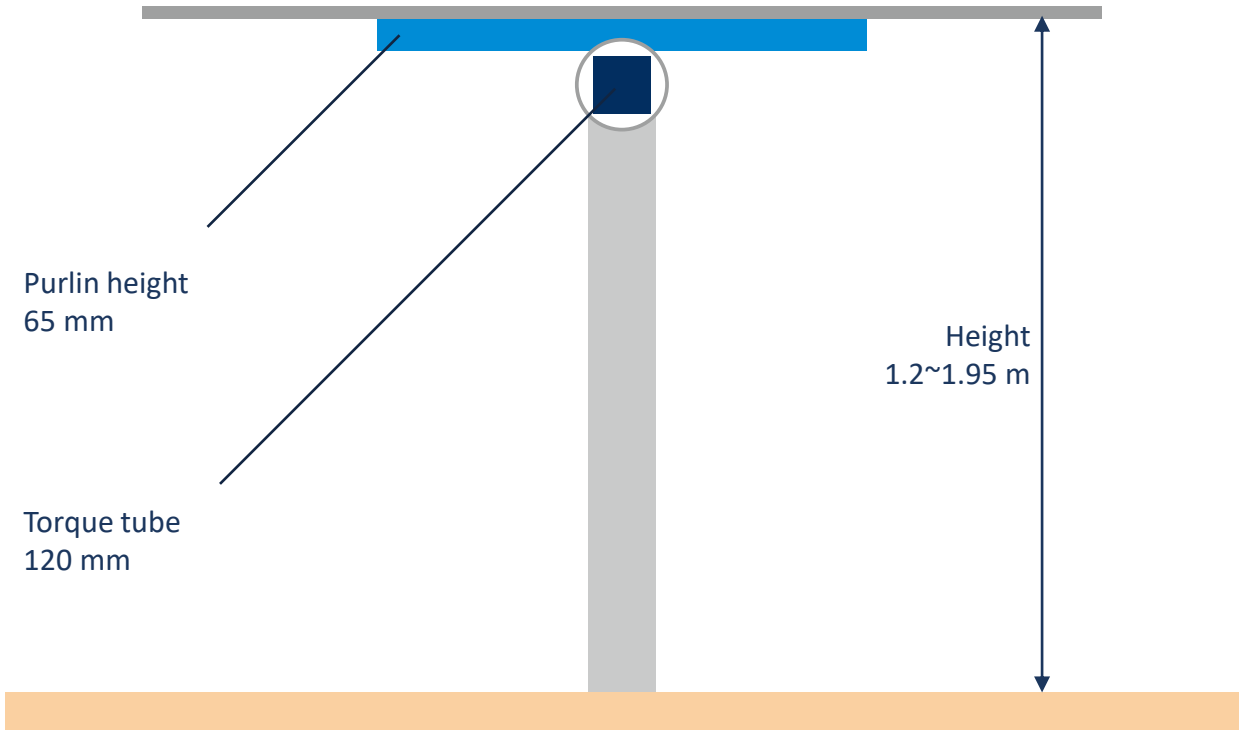


3. Bifacial PV Plant - Mounting Systems. 1P trackers

Power generation vs Main 1P tracker parameters

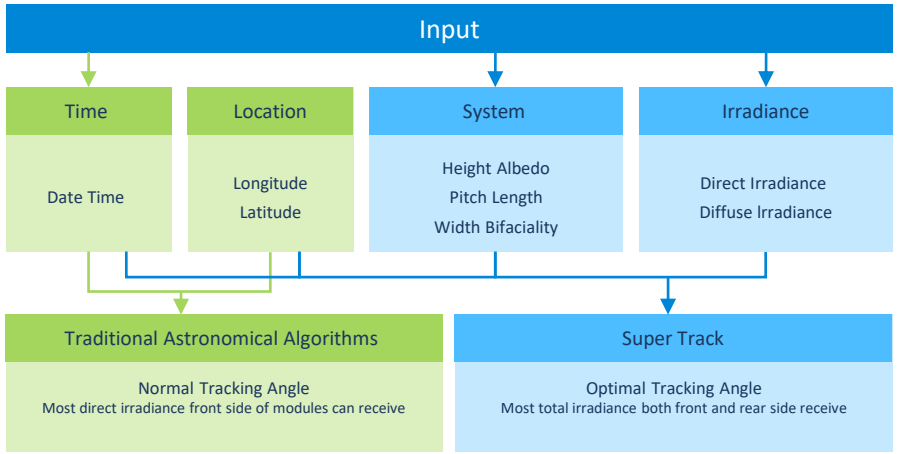


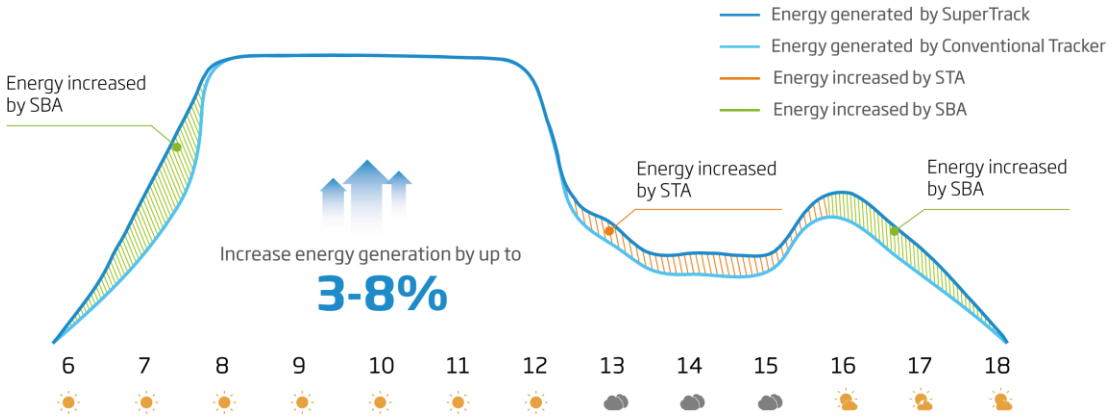




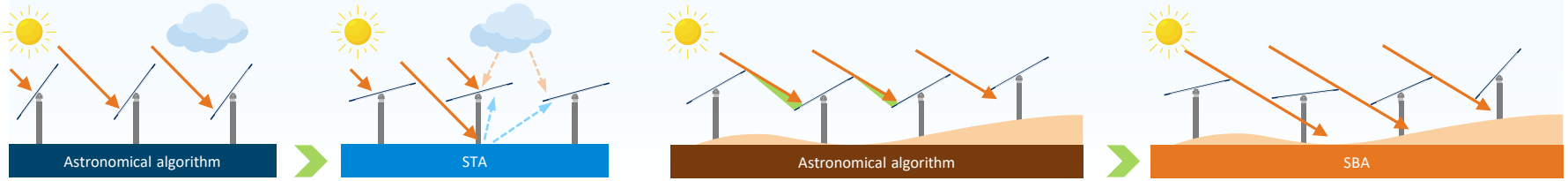
3. Bifacial PV Plant - Mounting Systems. Smart Tracking

SuperTrack smart tracking technology





SuperTrack = Smart Tracking Algorithm + Smart Backtracking Algorithm



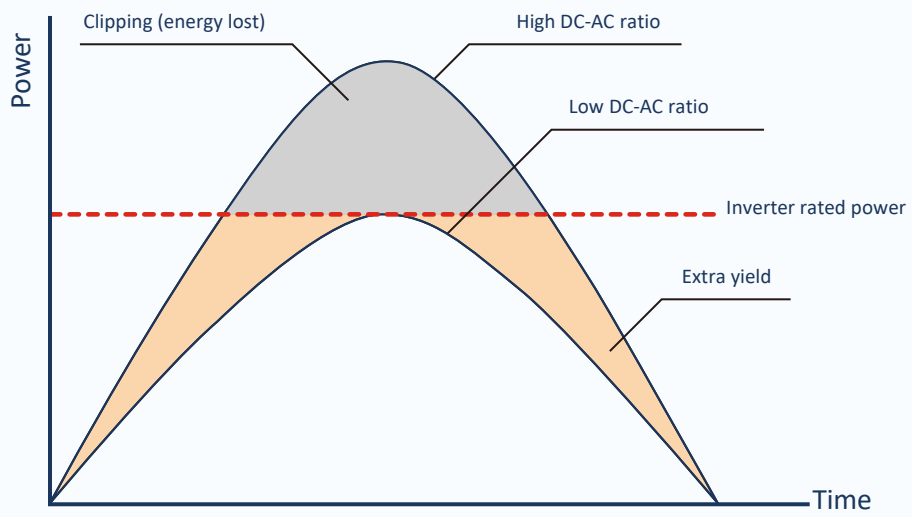
SuperTrack is developed to increase yield gain:

- Sunrise and Sunset
- Cloudy
- Overcast Weather
- Uneven Terrain

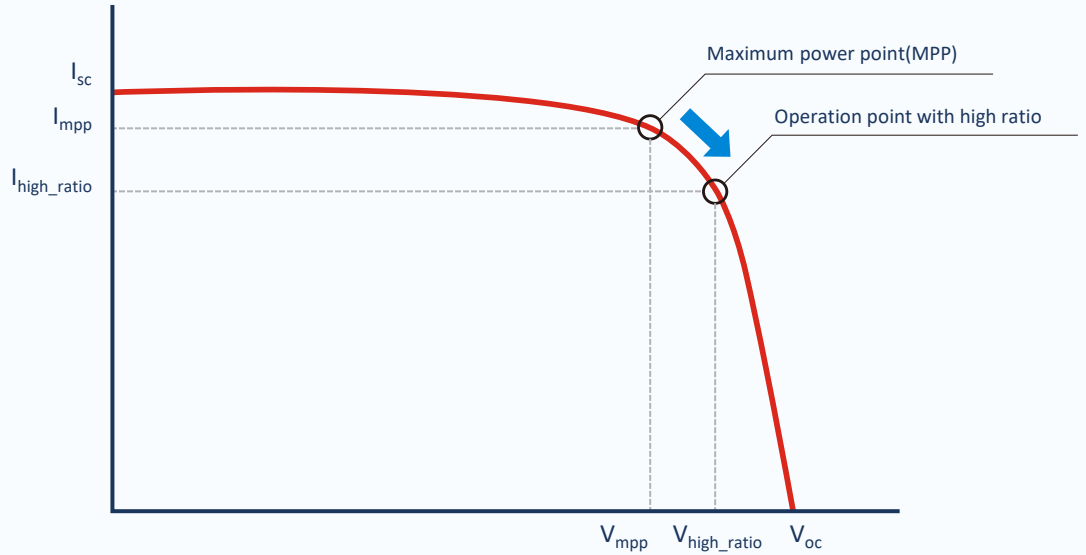
3. Bifacial PV Plant - Inverters

Bifacial PV plant means bigger DC/AC ratio

Bifacial modules → Higher DC/AC ratios



Bifacial modules vs DC/AC ration & Clipping Losses Phenomena



DC-AC ratios between **1.2 and 1.4** used to be the most common choice for designers

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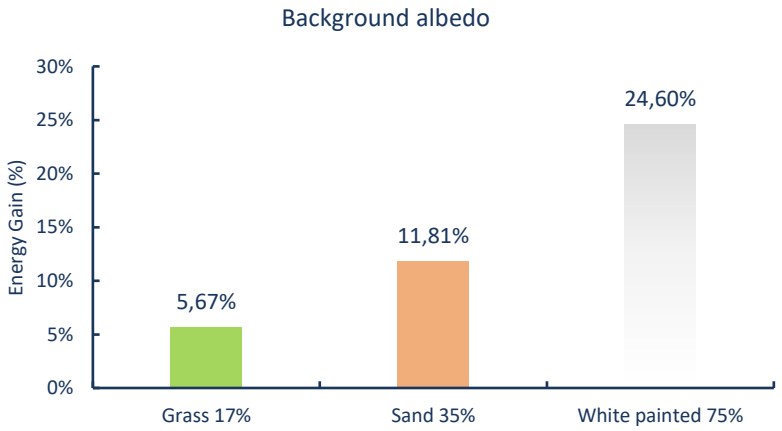
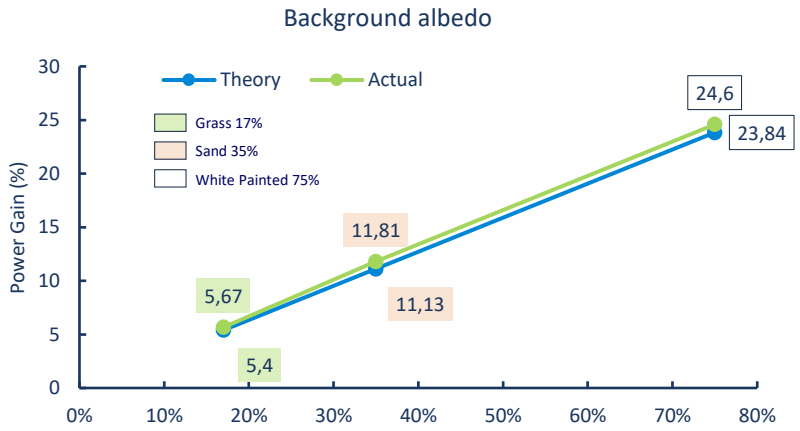
4. Bifacial System Design - Albedo

Albedo is the ratio between Reflected Irradiance (RI) and the Global Horizontal Irradiance (GHI) received by a ground surface



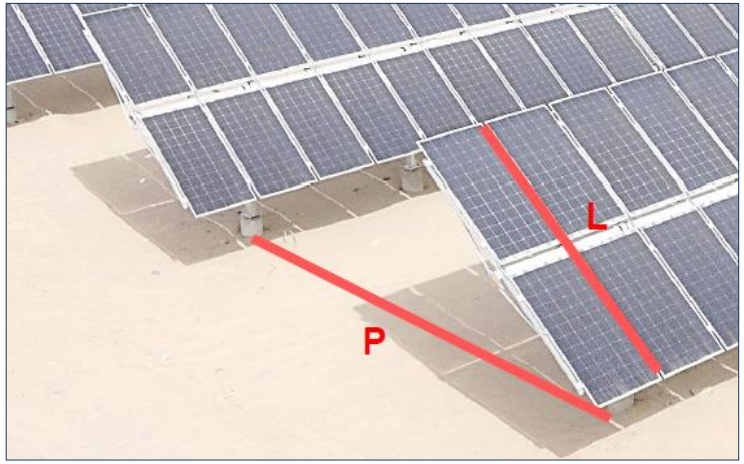


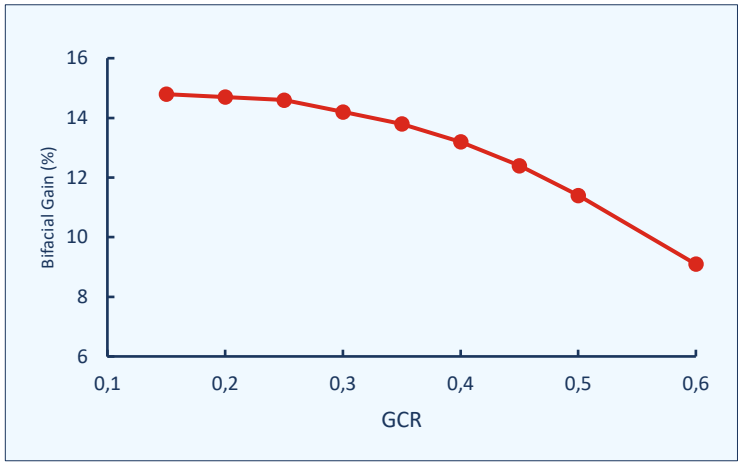
- Fixed-tilt configuration
- Tilt angle: 27º
- Module height: 0.4 m

Types of ground	Albedo (%)	Estimated Bifacial Gain (%)
Grass	17	5.67
Sand	35	11.81
White Painted	75	24.6

4. Bifacial System Design – Pitch / GCR

Lower GCR means higher Bifacial Gain but higher CAPEX too



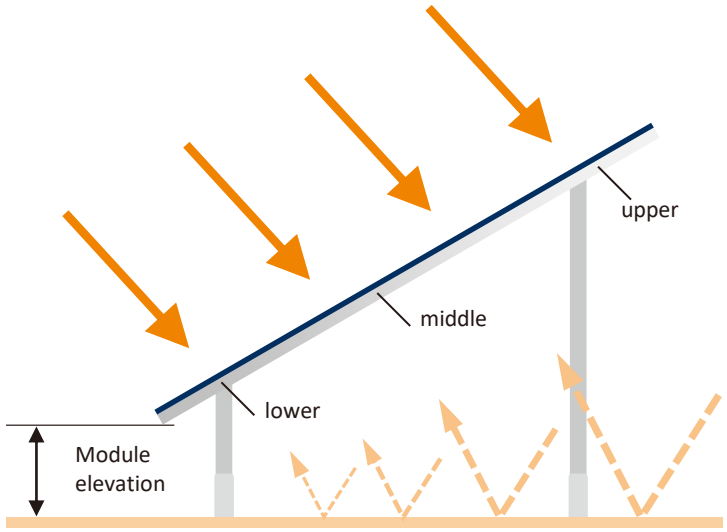


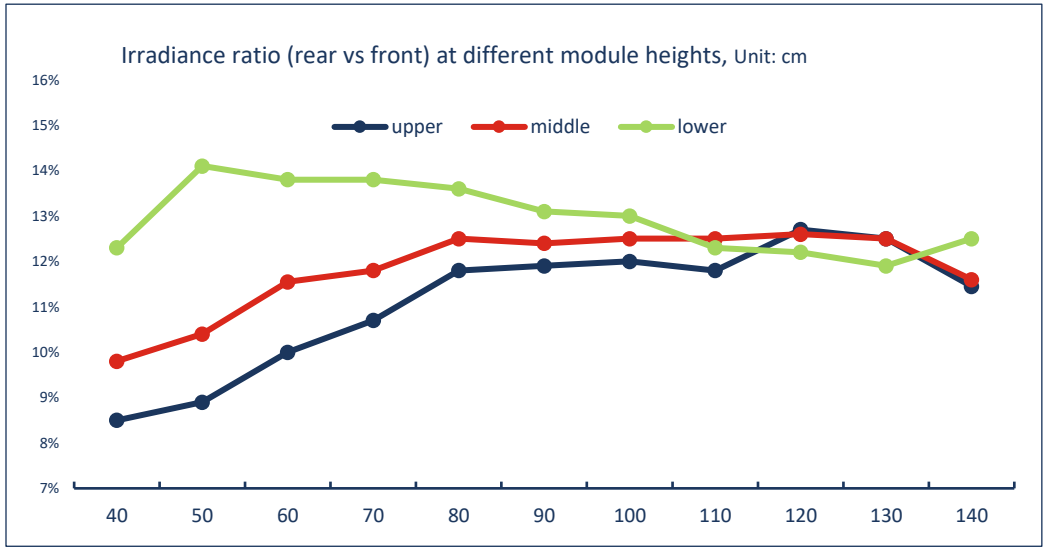
$$GCR = \frac{module\ area}{ground\ area} = \frac{L}{P}$$

Bigger Pitch (Lower GCR) means Higher Bifacial Gain

4. Bifacial System Design - Module Height

Higher module elevation increases radiation on rear side

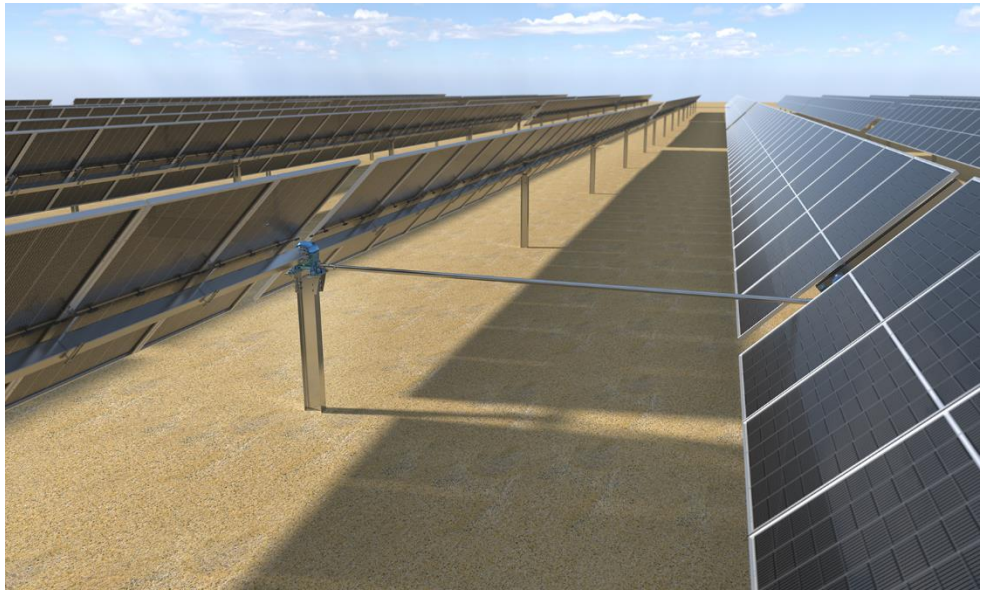


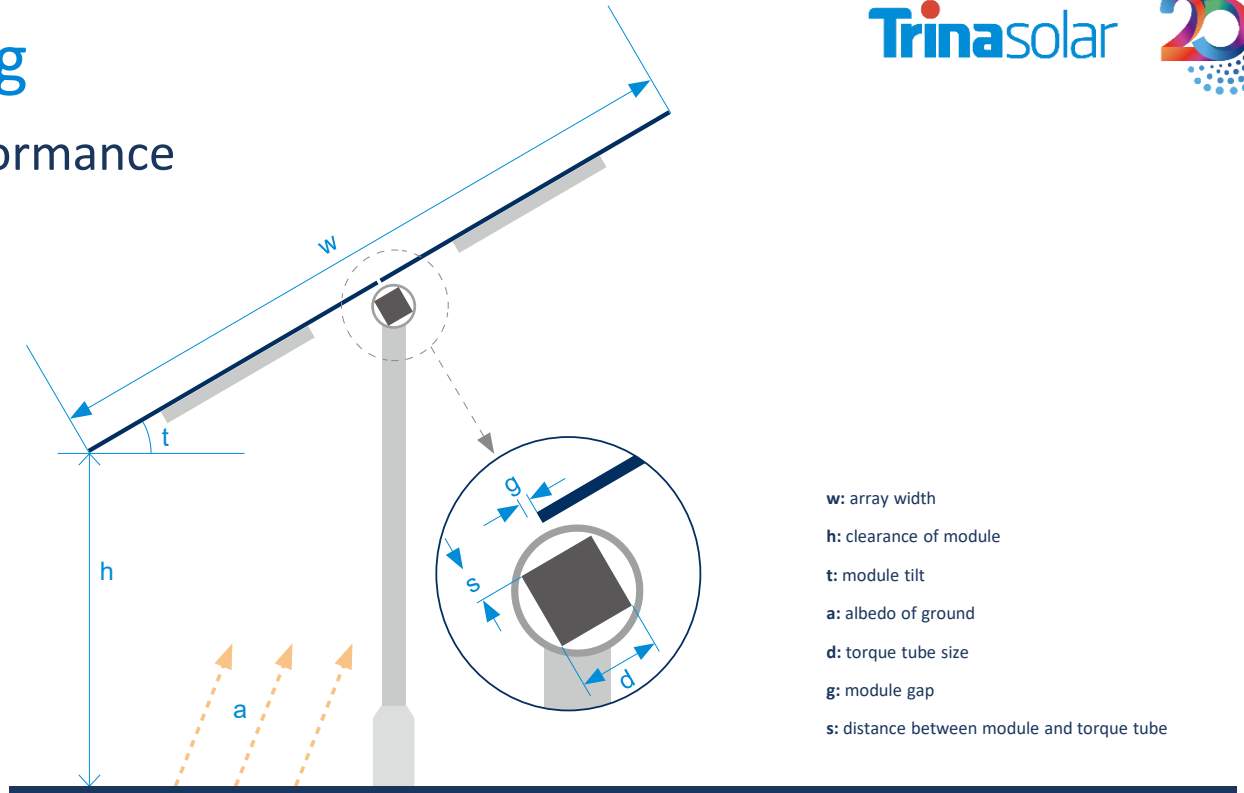


Modules higher off the ground see more diffuse radiation	Modules higher off the ground receive more reflected radiation	Modules higher off the ground normally work at lower temperature
Higher Bifacial Gain	Higher Bifacial Gain	Better Performance

4. Bifacial System Design - Shading

Shading needs to be avoided to maximize performance





w: array width

h: clearance of module

t: module tilt

a: albedo of ground

d: torque tube size

g: module gap

s: distance between module and torque tube

- Shading always impact negatively module performance
- Torque tube is the major source of module shading
- Shading modelling is relevant to estimate accurate Bifacial Gain

View Factor Model

Structure Shading Factor (SSF)

Mismatch Loss Factor (MLF)

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7. Summary / Conclusions

Dominant Technology

Above 50% Market Share

Basic principles:

- Bifacial Ratio
- Bifaciality
- Diffuse Irradiation
- Reflected Irradiation

Bifacial Gain

Lower LCOE

- Case studies
- Tracker + Bifacial module
- Sensitivity Analysis

System parameters:

- Albedo
- GCR
- Module Height
- Shading

System Energy Yield

Main components

- Modules - Glass-glass configuration
- Mounting systems - Torque tube size & height, purling & central gap
- Inverters - DC/AC ratio & string configuration

DISCOVER THE ULTIMATE **GUIDEBOOK** FOR **BIFACIAL SYSTEM** DESIGN

https://bit.ly/BifacialSolutions-TrinaSolar

Trinasolar 25TH

THANKS !

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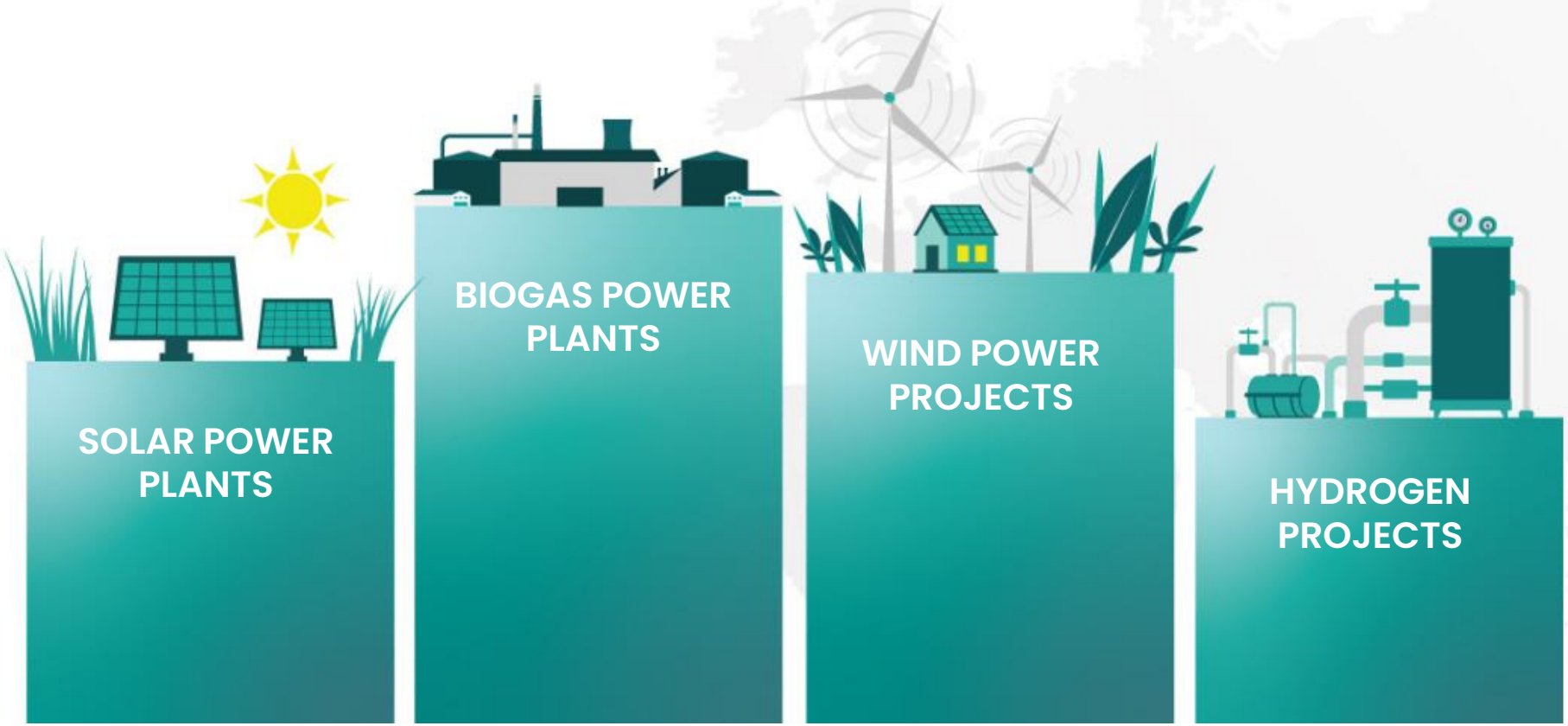
David Garmendia September 2022

Green Genius

“Bifacial vs Monofacial” - proof of concept

Launched by
MODUS GROUP

We develop, build and operate



Overview

GREEN GENIUS

Biogas projects - more than
20 MW
in all markets

1.5 GW
Pipeline of projects

Solar power projects - more than
210 MW
in all markets

7
countries

More than
250 people

€ 445 M
invested over past 5 years

Solar portfolio (MW)

Implemented projects	
Poland	129
Lithuania	28
Ukraine	47
Belarus	6
Latvia	1

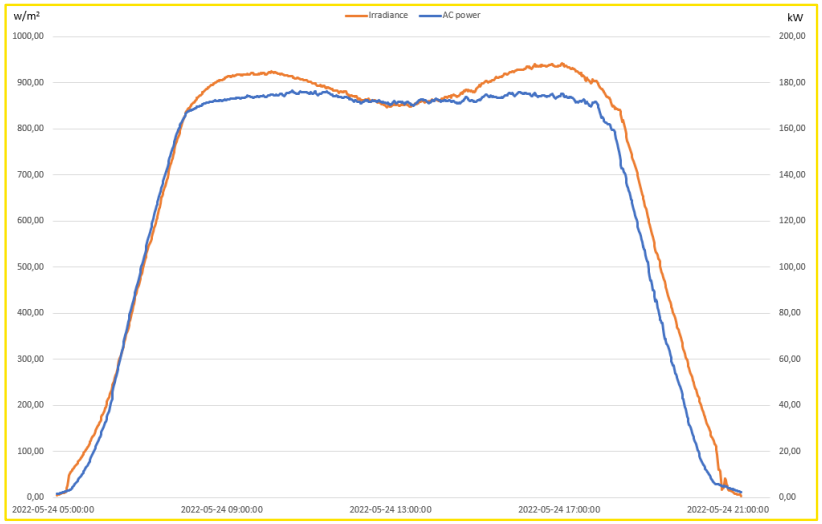
In late development (including contruction)	
Italy	685
Spain	143
Poland	152
Lithuania	48

In early development (planned)	
Lithuania	453
Romania	100
Poland	195
Italy	72
Spain	55

Proof of concept – „SUBACIUS“ PV plant

- Global horizontal irradiation - 1042.1 kWh/m²
- Energy output – 1267 kWh/kWp/year
- Installed DC power – 1.784 MWp
- DC/AC overload ratio – 1.13
- Tilt/Azimuth – 1P tracker / E-W
- Modules – bifacial Trina TSM-DEG19C.20 530 and **2 strings - monofacial Trina TSM-DE19 535**
- Inverters – string type 9 x 175kWac
- Pitch – 6m

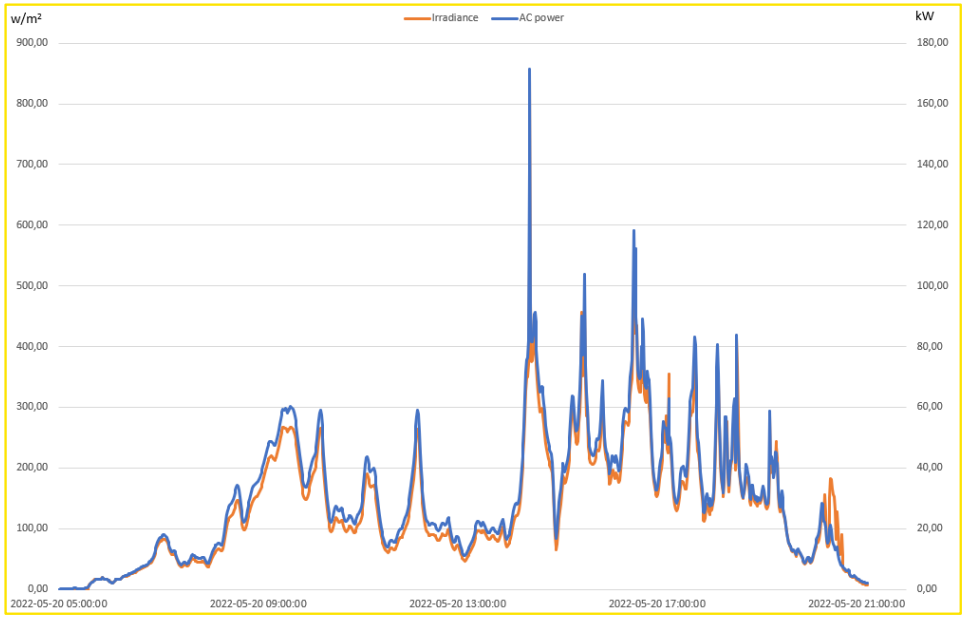
Proof of concept - inverter power with high irradiance



String performance with high irradiance

String No.	Total daily energy, kWh	Module power, kW	Total daily energy, kWh/kWp	Difference, %
MPPT2	197,61	18,02	10,97	+4,1
MPPT5	200,83	18,02	11,14	+5,8
MPPT9 (MONO)	191,61	18,19	10,53	

Proof of concept - inverter power with low irradiance



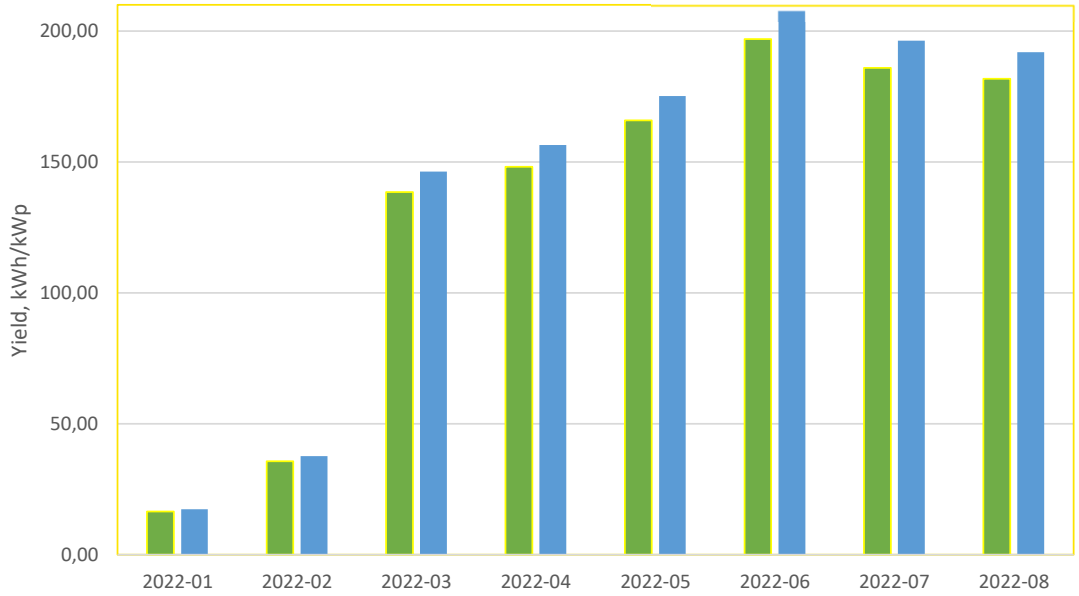
String performance with low irradiance

String No.	Total daily energy, kWh	Module power, kW	Total daily energy, kWh/kWp	Difference, %
MPPT2	43,3	18,02	2,40	+7
MPPT5	44,56	18,02	2,47	+10,1
MPPT9 mono	40,84	18,19	2,25	

Proof of concept - current year energy string comparison and Yield

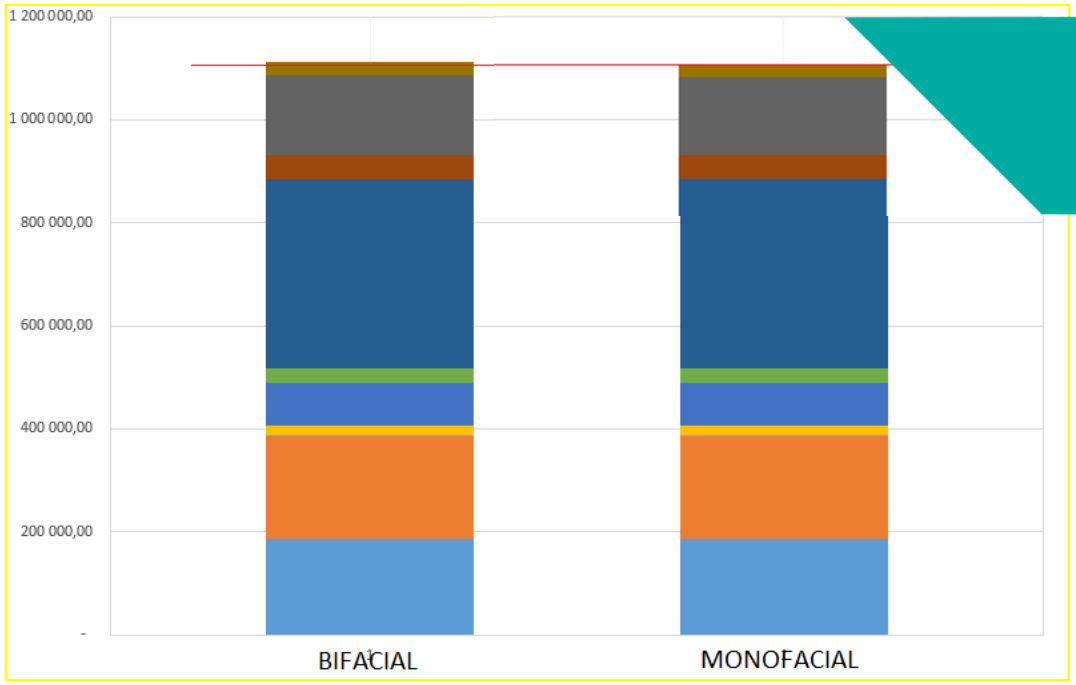
String No.	Total energy, kWh	Module power, kW	Total energy, kWh/kWp	Difference, %
MPPT2	37226,68	18,02	2065,85	+5,4
MPPT5	37961,02	18,02	2106,60	+7,5
MPPT9 mono	35650,01	18,19	1959,87	

Month	Yield, kWh/kWp	
	MONO	BIFACIAL
2022-01	16,49	17,41
2022-02	35,67	37,67
2022-03	138,57	146,33
2022-04	148,22	156,51
2022-05	165,96	175,24
2022-06	197,01	208,04
2022-07	185,99	196,40
2022-08	181,82	192,00
Total	1069,73	1129,60
Average +59,87 (or +5,3%)		



Proof of concept – CAPEX

No.	CAPEX	Bifacial	Monofacial
1	Installtion	185 901,00 €	185 901,00 €
2	MV station, line and connection	200 026,00 €	200 026,00 €
3	Scada	3 518,00 €	3 518,00 €
4	Fencing	16 672,00 €	16 672,00 €
5	RTB status	82 680,00 €	82 680,00 €
6	Security	28 700,00 €	28 700,00 €
7	Modules	**375 881,90 €**	**366 881,90 €**
8	Inverters	45 750,00 €	45 750,00 €
9	Trackers	**156 047,41 €**	**150 047,41 €**
10	Other	26 760,00 €	26 760,00 €
	TOTAL	**1 121 936,31 €**	**1 106 936,31 €**



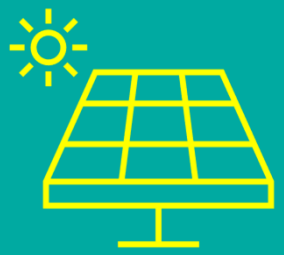
Proof of concept – OPEX

Proof of concept – LCoE

CASE	MONO	BIFACIAL
Year - 0 Energy production (MWh)	1925,51	2033,28
CAPEX (MEUR)	1,106936	1,121936
OPEX (EUR/MWp/year)	12000	12000
LCoE (EUR/MWh)	574,88	551,79
		-4,02%

Proof of concept – module handling

- Same number of modules per packing unit – expenditures are equal, for different yield.



- TSM-DE19 weight is 28,6 kg vs TSM-DEG19C.20 weight is 32,6 kg.

- Identical assembly method - no difference, which could increase CAPEX.

Proof of concept – Conclusions

- Slightly higher initial investment
- Proven lower LCoE
- Using bifacial modules gives no additional risk

THANK YOU

GREEN GENIUS Launched by MODUS GROUP