



CENER

NATIONAL RENEWABLE
ENERGY CENTRE

ADitech

OPTIMIZE YOUR BIFACIAL PV TRACKER PROJECT TO DELIVER EXTRA ENERGY GAINS

FACTORS AFFECTING ENERGY GENERATION

Webinar
July 8th, 2020
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MINISTERIO
PARA LA TRANSICIÓN ECOLÓGICA
Y EL RETO DEMOGRÁFICO

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DE CIENCIA
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Ciemat

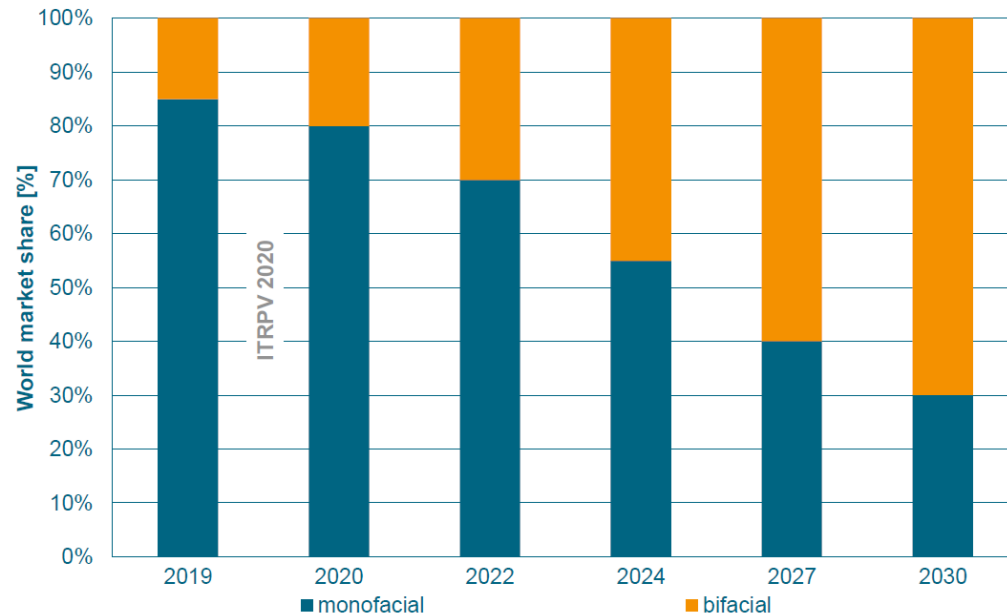


Gobierno de Navarra
Nafarroako Gobernua

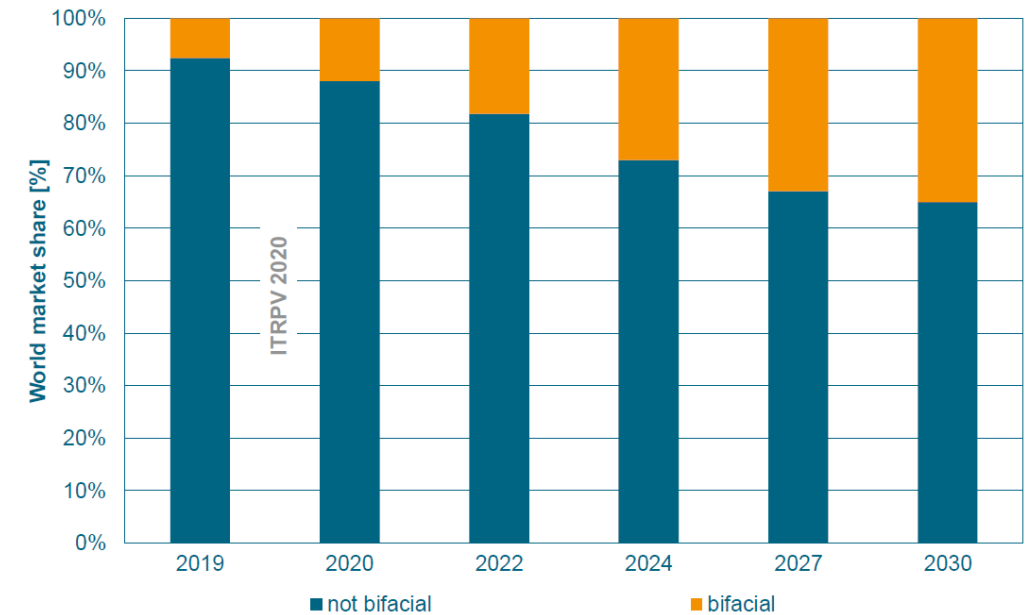
Introduction

- Bifacial PV Installations – Present & Future
- Hot topic in PV industry

Bifacial cell in world market



Bifacial Module Technology



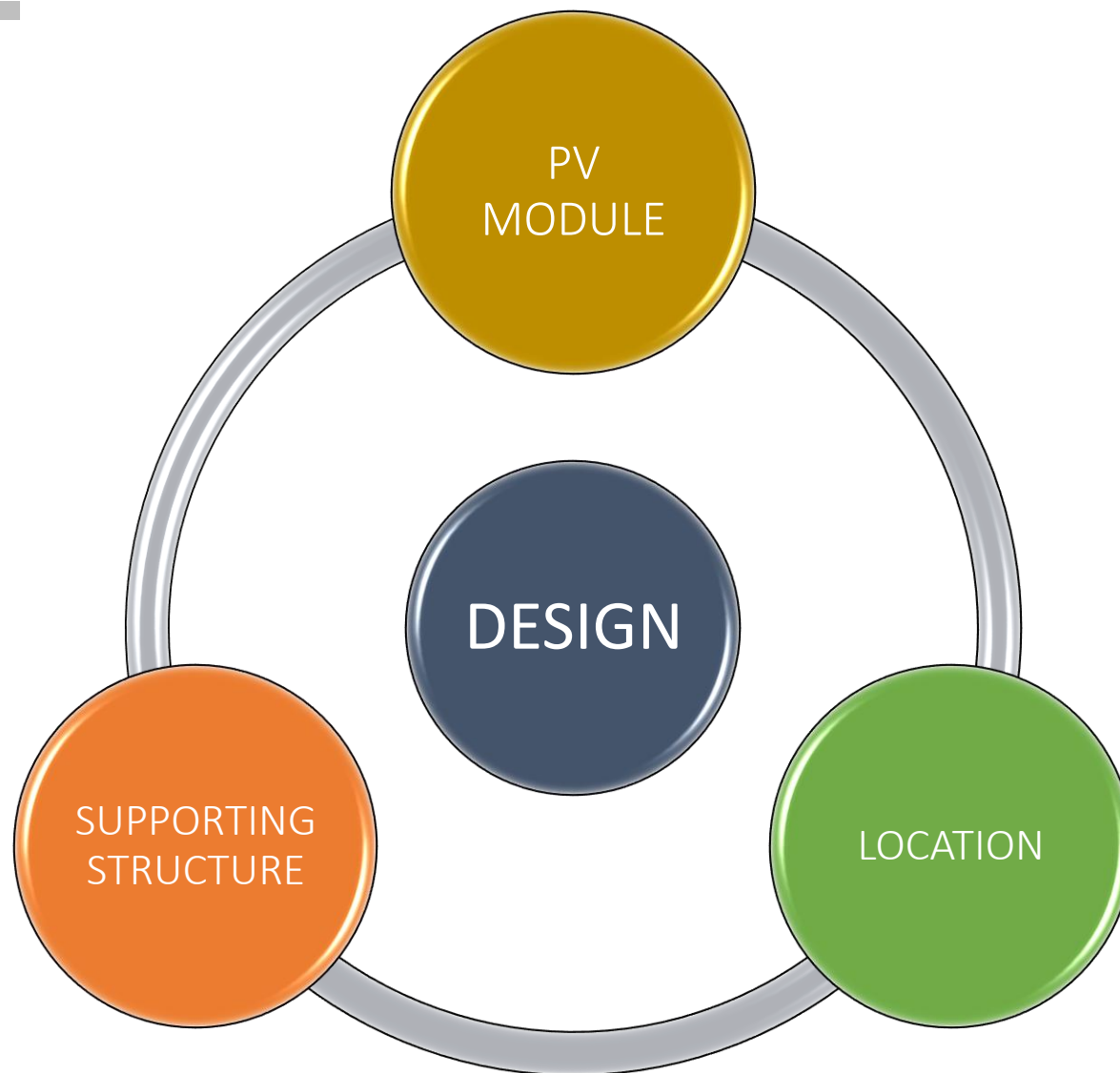
CENER experimental PV plant



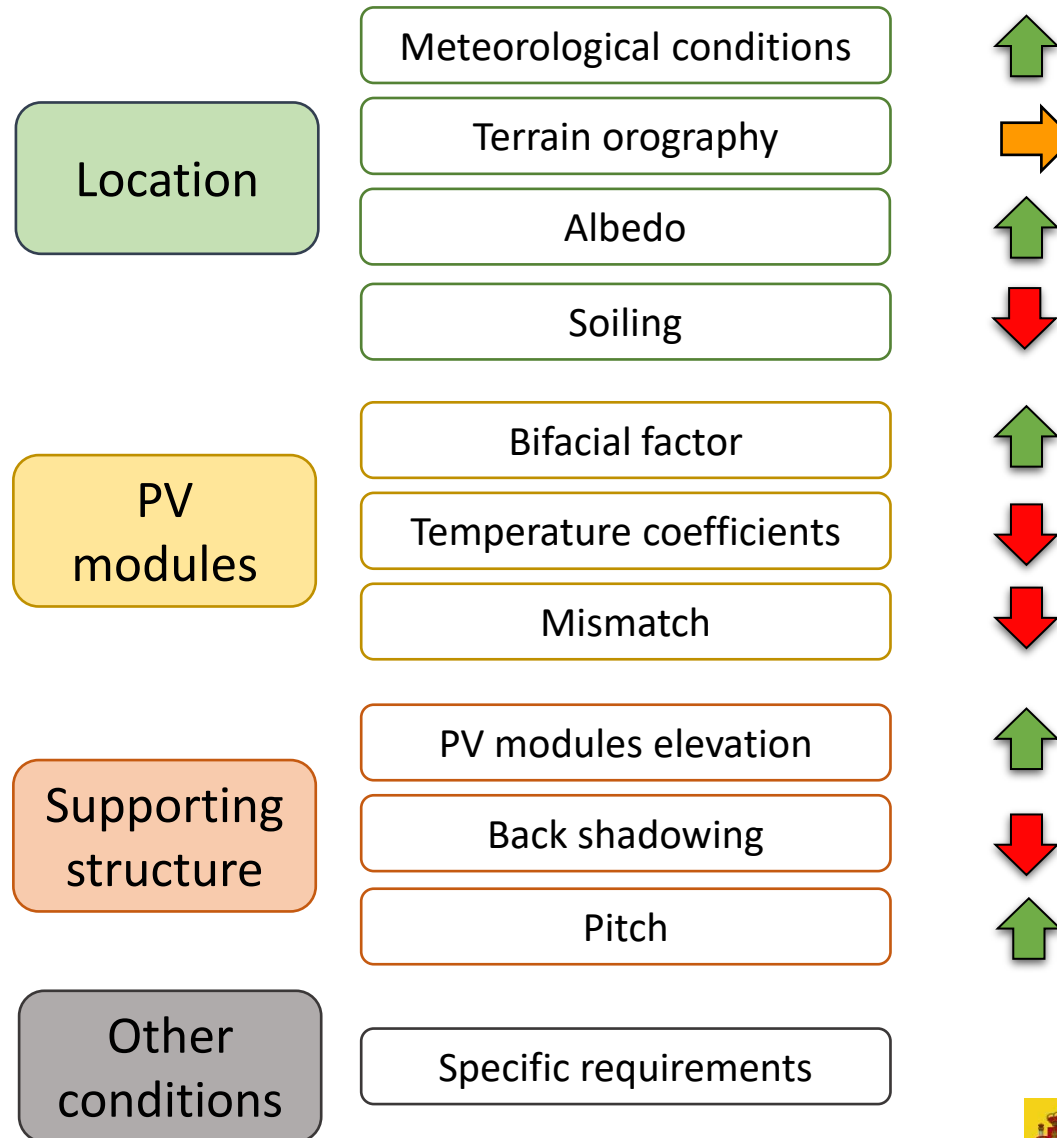
CENER experimental PV plant



Target → Increase energy generation



PV generator aspects



PV generator aspects

Location + PV module +
Supporting structure =

PV generator Design

Other
conditions

Specific requirements

Process: PV generator design

PV module



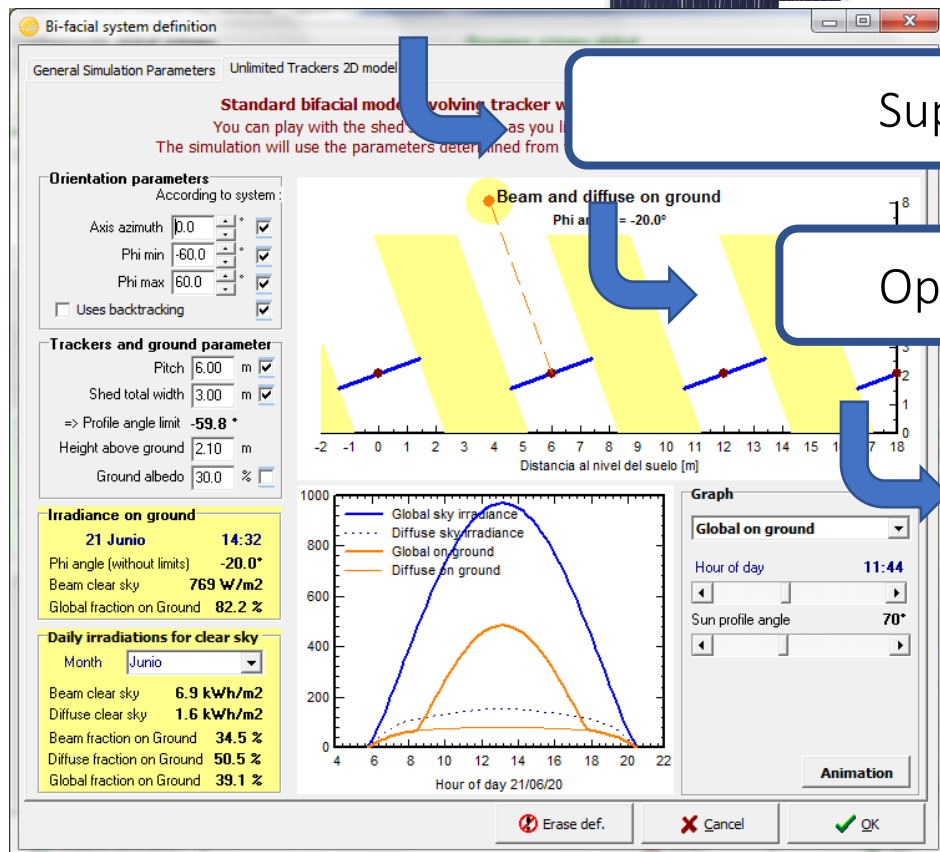
Type of supporting structure (fixed tilted plane or tracking system)

Supporting structure mechanical design

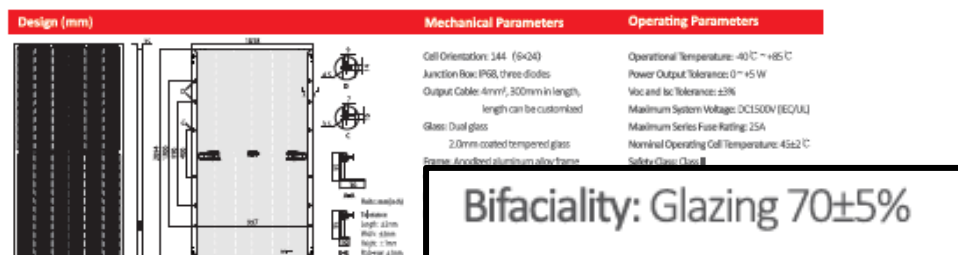
Operating conditions of the supporting structures

Electrical connections (important in PV bifacial projects)

Simulation of PV generator (PVSYST, SAM, ...) => LCOE estimation



Bifacial PV module specifications



Electrical Characteristics

Model Number

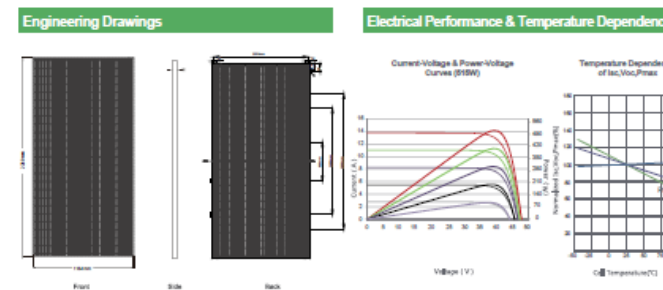
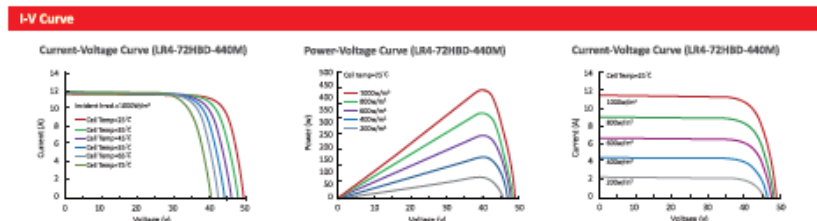
Test uncertainty for Pmax: ±3%

Testing Condition	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
Maximum Power (Pmax/W)	425	317.4	430	321.1	435	324.9	440	328.6	445	332.3	450	336.1	455	339.8
Open Circuit Voltage (Voc/V)	48.7	45.6	48.9	45.8	49.1	45.9	49.2	46.0	49.4	46.2	49.6	46.4	49.8	46.6
Short Circuit Current (Isc/A)	11.22	9.06	11.30	9.13	11.36	9.18	11.45	9.25	11.52	9.30	11.58	9.35	11.65	9.41
Voltage at Maximum Power (Vmp/V)	40.4	37.7	40.6	37.9	40.8	38.0	41.0	38.2	41.2	38.4	41.4	38.6	41.6	38.8
Current at Maximum Power (Imp/A)	10.52	8.42	10.60	8.49	10.66	8.54	10.73	8.60	10.80	8.65	10.87	8.70	10.93	8.76

Electrical characteristics with different rear side power gain (reference to 445W front)

Pmax /W	Voc/V	Isc /A	Vmp/V	Imp /A	Pmax gain
467	49.4	12.09	41.2	11.34	5%
490	49.4	12.67	41.2	11.88	10%
512	49.5	13.24	41.3	12.42	15%
534	49.5	13.82	41.3	12.96	20%
556	49.5	14.40	41.3	13.50	25%

Temperature Coefficient of Isc	+0.0007%/°C	Front Side Maximum Static Loading	2400Pa
Temperature Coefficient of Voc	-0.284%/°C	Rear Side Maximum Static Loading	2400Pa
Temperature Coefficient of Pmax	-0.350%/°C	Hailstone Test	25mm Hailstone at the speed of 23m/s



Mechanical Characteristics

Cell Type	P type Mono-crystalline
No. of cells	144 (2x72)
Dimensions	2230±1134×35mm (87.80×44.65×1.38 inch)
Weight	28.79 kg (62.47 lbs)
Front Glass	3.2mm Anti-Reflection Coating, High Transmission, Low Iron, Tempered Glass
Frame	Anodized Aluminum Alloy
Junction Box	IP68 Rated
Output Cables	TUV 1×4.0mm ² (+) 290mm, (-) 145mm or Customized length

Packaging Configuration

1 (One stack)

4.2pcs/stack, 620pcs/ 40'HQ Container

SPECIFICATIONS

	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
Power (Pmax)	510Wp	379Wp	515Wp	383Wp	520Wp	387Wp	525Wp	391Wp	530Wp	394Wp
Power Voltage (Vmp)	41.80V	38.44V	41.70V	38.55V	41.80V	38.61V	41.90V	38.75V	42.00V	38.89V
Power Current (Imp)	12.25A	9.87A	12.35A	9.94A	12.44A	10.02A	12.53A	10.09A	12.62A	10.15A
Voltage (Voc)	48.14V	46.28V	48.24V	46.38V	48.34V	46.47V	48.44V	46.57V	48.54V	46.68V
Current (Isc)	12.95A	10.48A	13.07A	10.56A	13.16A	10.63A	13.25A	10.70A	13.34A	10.77A
Efficiency STC (%)	20.17%	20.37%	20.56%	20.76%	20.96%					
Operating Temperature (°C)	-40°C ~ +85°C									
Maximum system voltage	1500VDC (IEC)									
Maximum series fuse rating	25A									

BIFACIAL OUTPUT-REARSIDE POWER GAIN

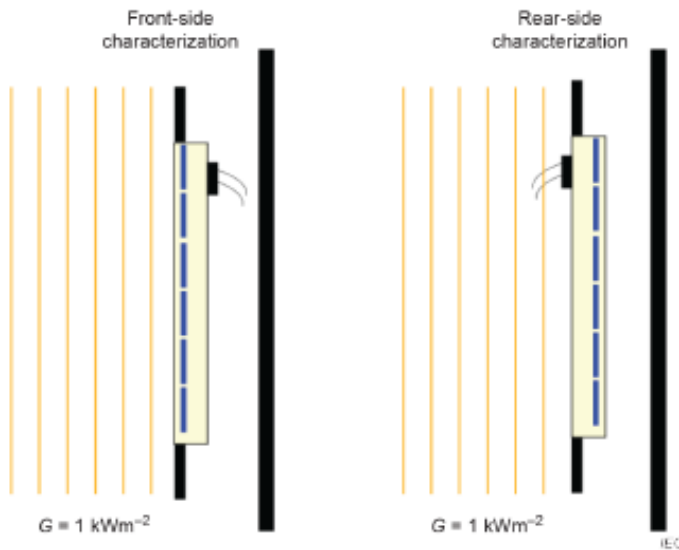
5%	Maximum Power (Pmax)	536Wp	541Wp	546Wp	551Wp	557Wp
	Module Efficiency STC (%)	21.18%	21.38%	21.59%	21.80%	22.01%
15%	Maximum Power (Pmax)	587Wp	592Wp	598Wp	604Wp	610Wp
	Module Efficiency STC (%)	23.19%	23.42%	23.65%	23.87%	24.10%
25%	Maximum Power (Pmax)	638Wp	644Wp	650Wp	656Wp	663Wp
	Module Efficiency STC (%)	25.21%	25.46%	25.70%	25.95%	26.20%

NOCT: ☀ Irradiance 800W/m² 🌡 Ambient Temperature 20°C 🌤 AM=1.5 🌬 Wind Speed 1m/s

* Power measurement tolerance: ± 3%

Maximum power measurement

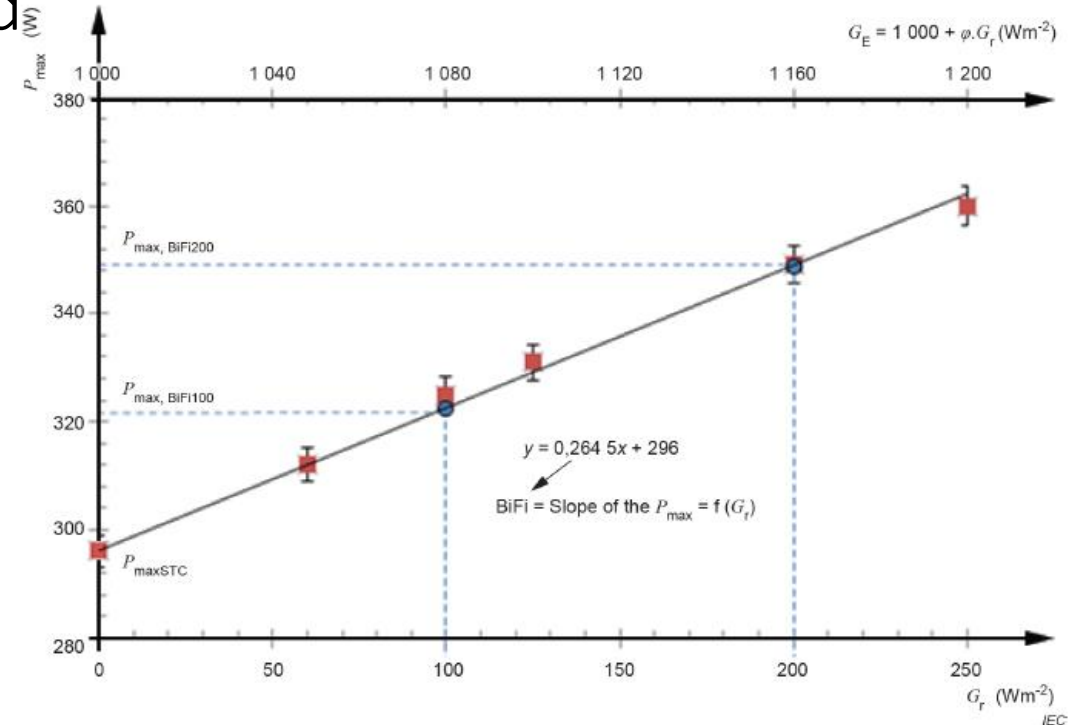
- Defined in IEC 60904-1-2 standard



$$\varphi_{Isc} = \frac{Isc_r}{Isc_f}$$

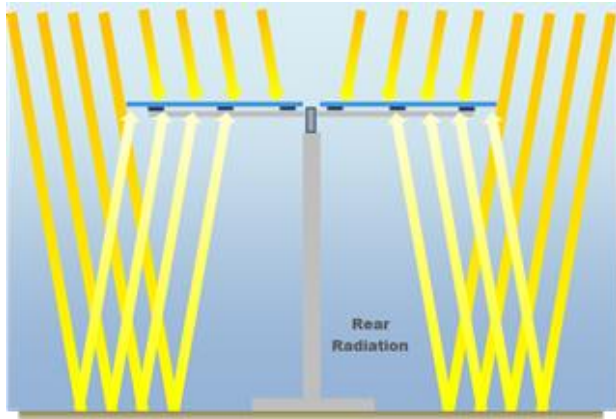
$$\varphi_{Pmax} = \frac{Pmax_r}{Pmax_f}$$

$$\varphi_{Voc} = \frac{Voc_r}{Voc_f}$$



- Bifaciality: φ_{Isc} , φ_{Pmax} , φ_{Voc}
- BiFi: Rear irradiance driven power gain yield
- BSTC: $(1000 + \min(\varphi_{Isc}, \varphi_{Pm}) \cdot 135) \text{ Wm}^{-2}$, 25 °C, AM1.5

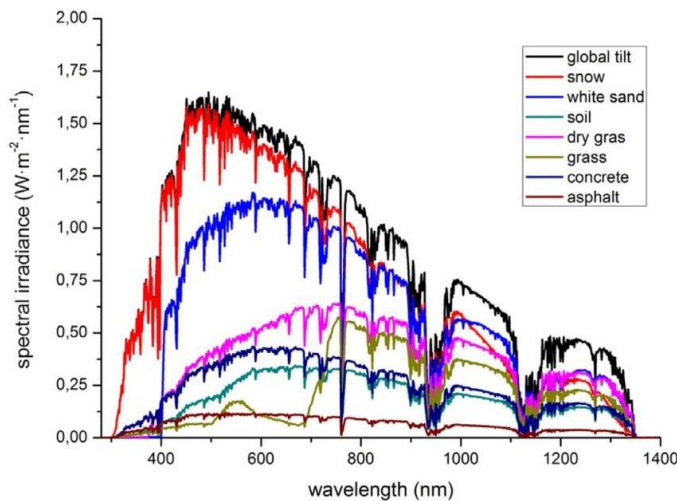
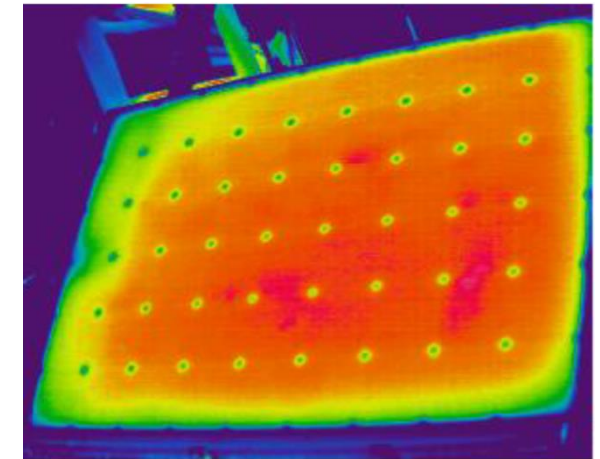
Factors affecting energy generation



IRRADIANCE

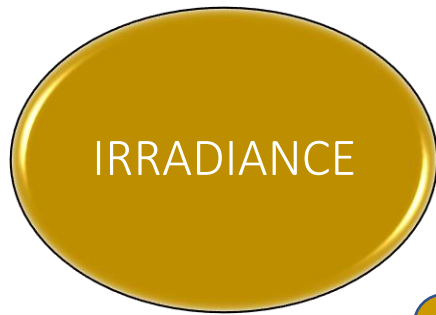


MODULE TEMPERATURE



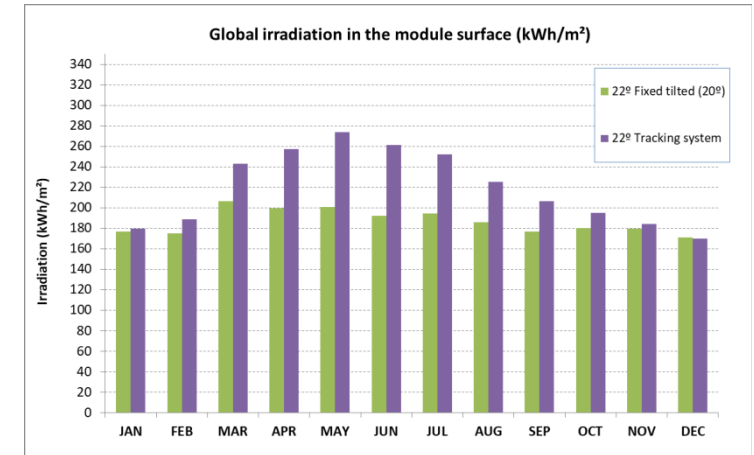
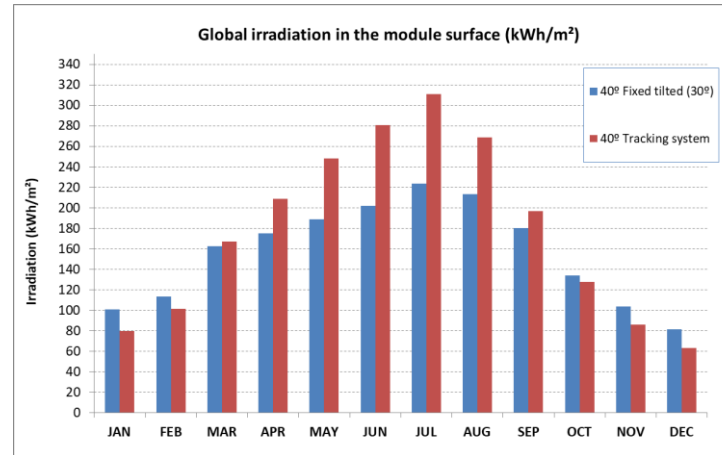
SPECTRAL DISTRIBUTION

Factors affecting energy generation



FRONT
IRRADIANCE

REAR
IRRADIANCE



1. ALBEDO:

- Depends on soil
- Variability

2. MODULE ELEVATION:

- Increases bifacial gain

3. PITCH:

- Increases bifacial gain

4. NON-UNIFORMITY:

- Caused by shadows
- Higher rear irradiance in the edges of the tracker
- Rear soiling

Factors affecting energy generation

- Modelled in IEC 61853-2 standard:
 - $T_m - T_{amb} = \frac{G}{u_0 + u_1 \cdot v}$
- u_0, u_1 depends on module type and mounting system
- Higher irradiance – Higher module temperature
 - Not necessarily higher than monofacial ($\neq u_0, u_1$)
- Irradiance non-uniformities – Localized heating
- Higher elevation – Higher wind speed (in open field)
 - Lower module temperature. Relevant?
- Max. Power temperature coefficient $\approx (-0,35 - -0,40) \text{ } \%/^{\circ}\text{C}$

MODULE
TEMPERATURE

Conclusions

- Clear growing trend for bifacial PV installations
- Higher complexity in project design
- Parameters for bifacial module characterization: Bifaciality, BiFi
- Many factors to be considered in the project design:
 - Albedo, Module elevation, pitch, Non-uniformities...

Thank You Very Much!

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