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goPV

Oct. 26th

Overview of the Glogal PV Market

(14:30-16:30)

GLOBAL OPTIMIZATION OF INTEGRATED PHOTOVOLTAIC SYSTEM FOR LOW ELECTRICITY COST

Overview of the Glogal PV Market

1. Climate Mitigation Scenarios

   Outlook of PV capacity at the horizon 2040

2. Global PV Market

   PV electricity cost analysis
   Overview of the industrial upstream sector

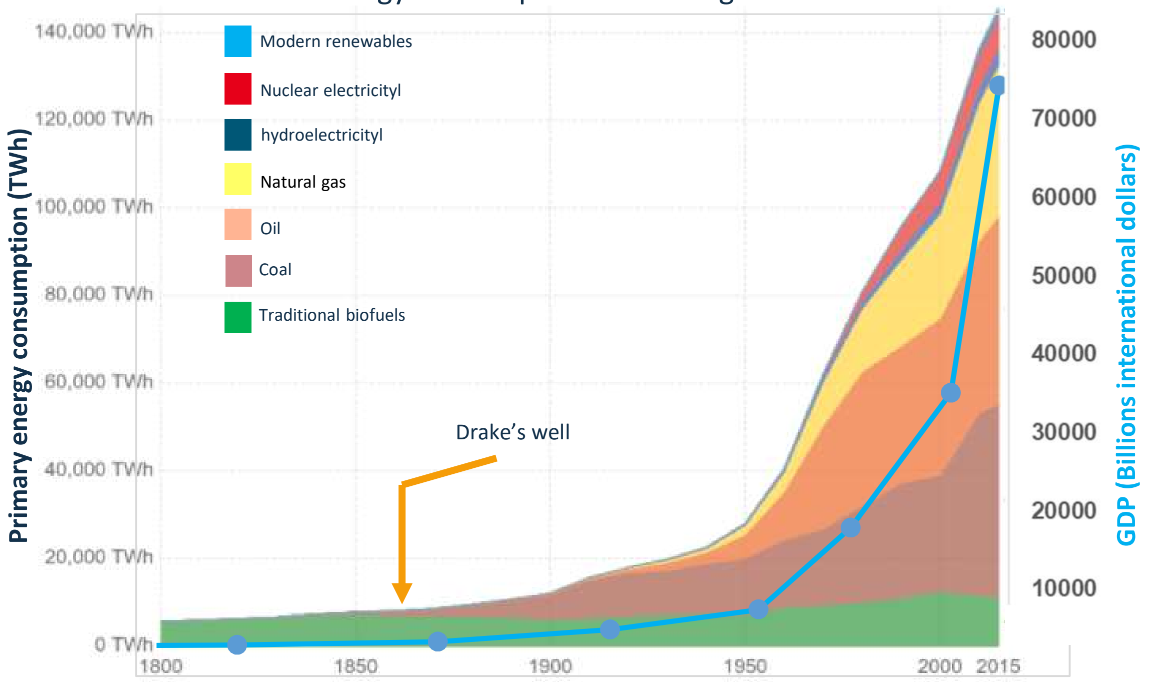
3. Technology landscape

   From cells and modules to system

4. Positioning GOPV developments

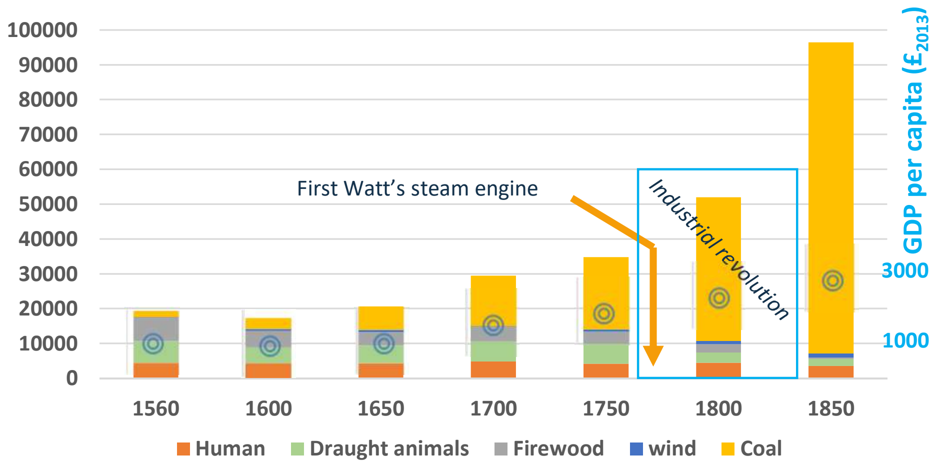
A brief history of energy consumption and GDP

World energy consumption and GDP growth



Source: Vaclav Smil (2017), Energy Transitions: Global and National Perspectives OurWorldInData.org/energy-production-and-changing-energy-sources/ • CC BY-SA

Energy consumption per capita (MJ) and GDP per capita in UK

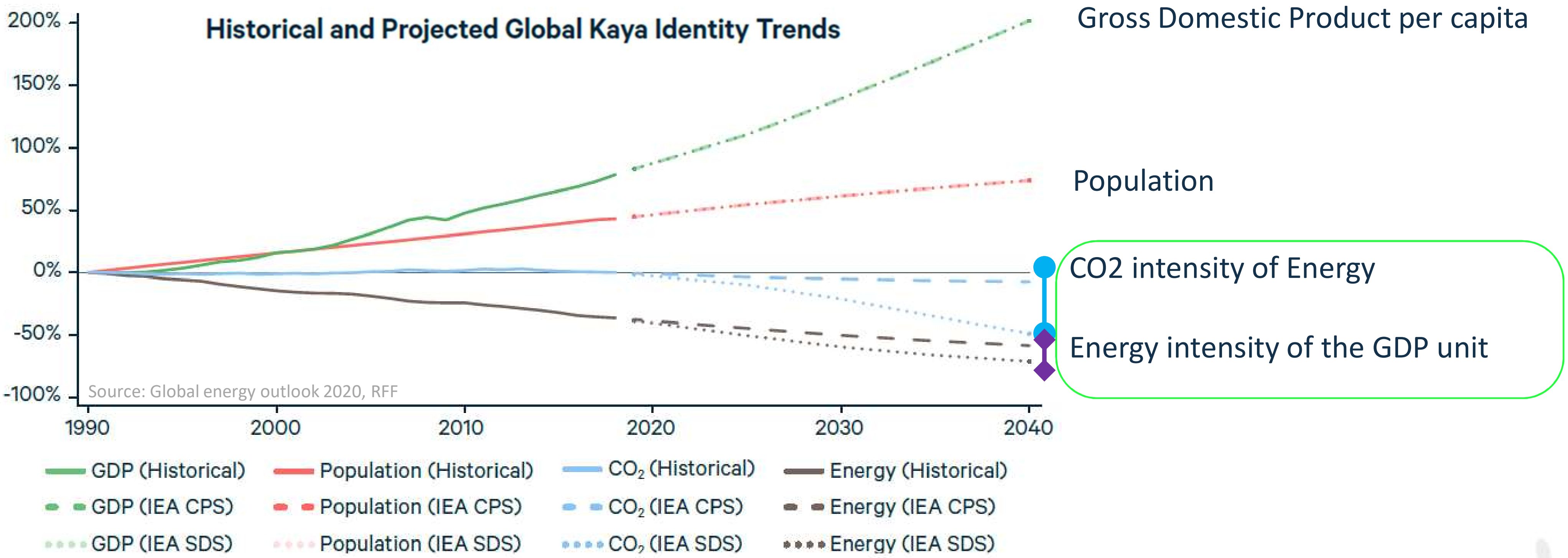


sources: Energy consupltion : Wrigley (2010); (data refers to England and Wales)
GDP: Broadberry, Campbell, Klein, Overton and Van Leeuwen (2015) via Bank of England; (data refers to England until 1700 and UK from then onwards)

- **GDP growth and energy consumption are intimately linked**
- **Abundant and cheap energy is the engine of GDP growth**

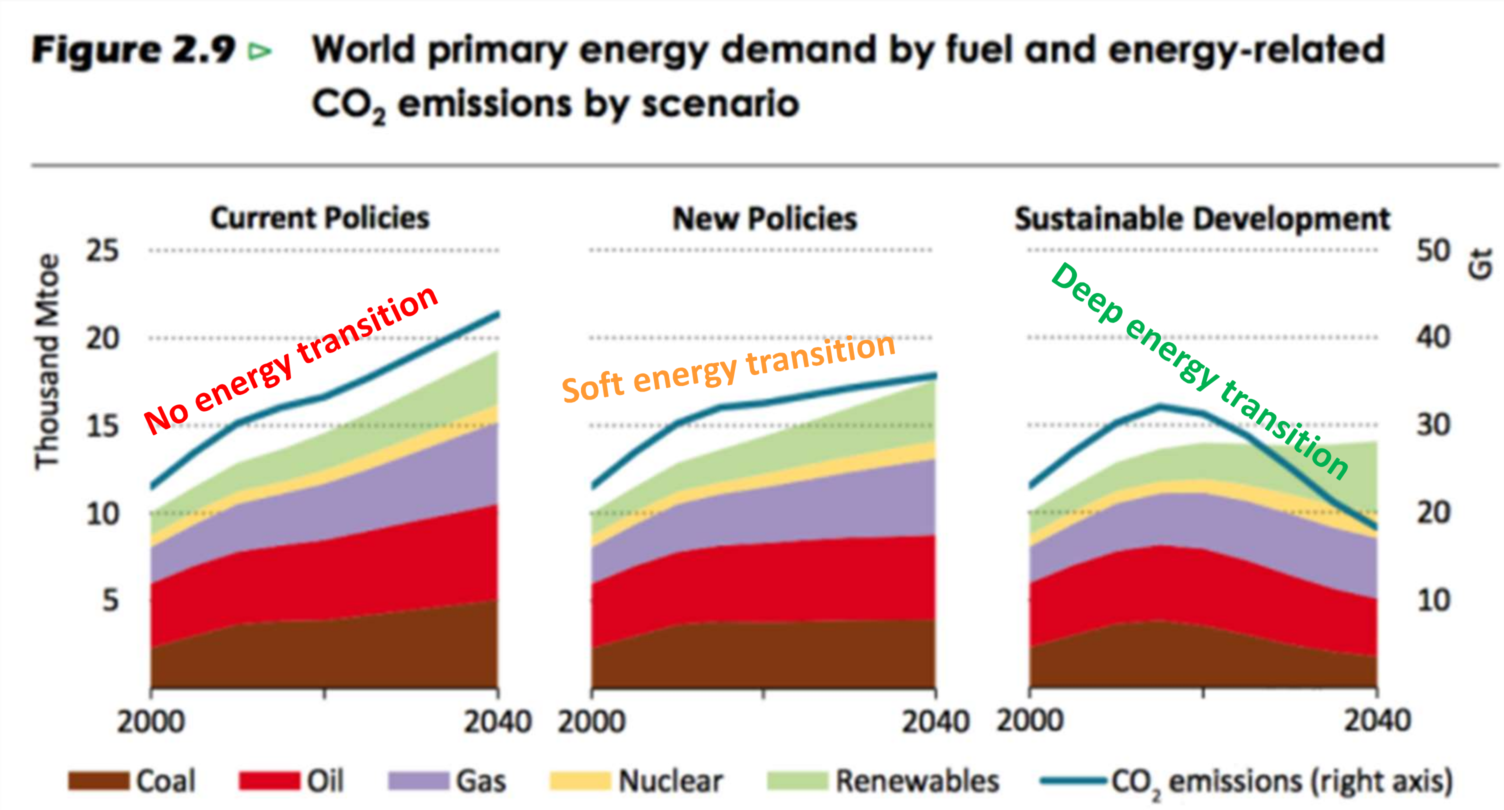
How to maintain GDP growth while preserving the planet?

GHG emission driving factors: the Kaya decomposition



$$\text{Pop} \times \frac{GDP}{Pop} \times \frac{Energy}{GDP} \times \frac{CO2}{Energy} = \textbf{Anthropogenic CO2 emission}$$

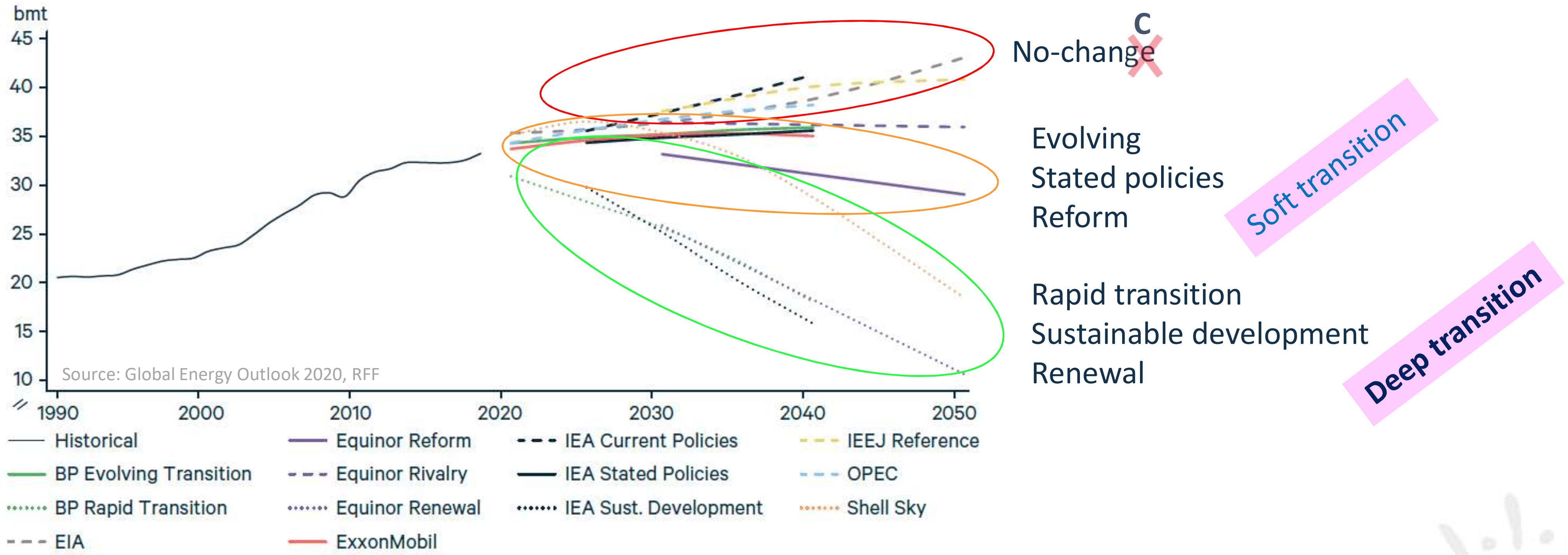
The Energy transition: Three main scenarios



Global energy use by fuel (in billion tonnes oil equivalent) and CO2 emissions (in gigatons) from 2000 through 2040 for each of the three scenarios. Figure 2.9 from the IEA's 2017 World Energy Outlook.

Overview of popular models of energy outlook

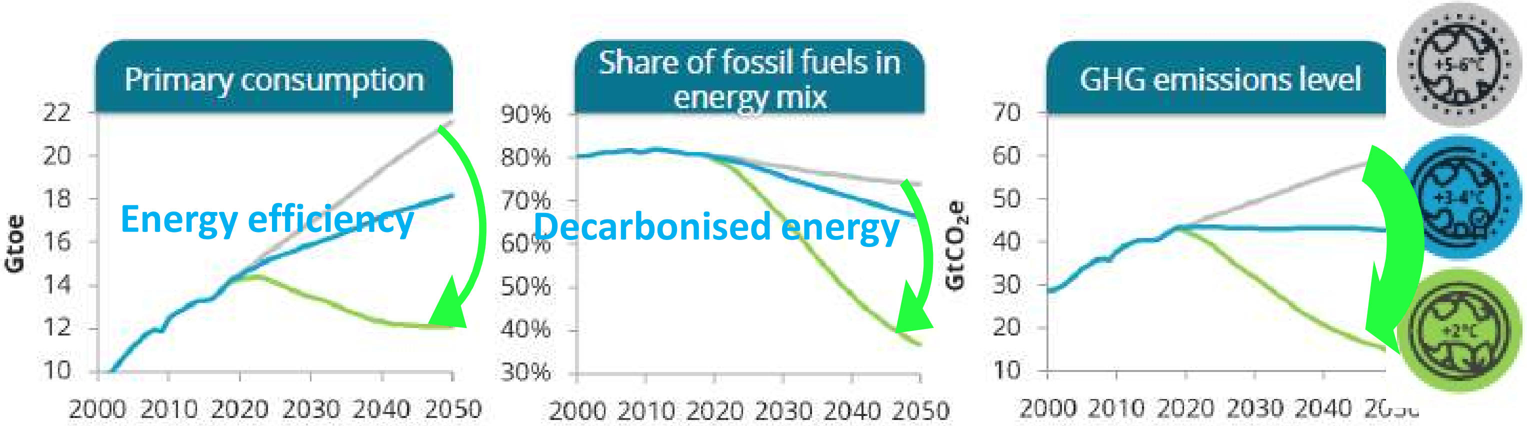
Figure 2. Global Net Carbon Dioxide Emissions



The Two Pillars of the Energy Transition

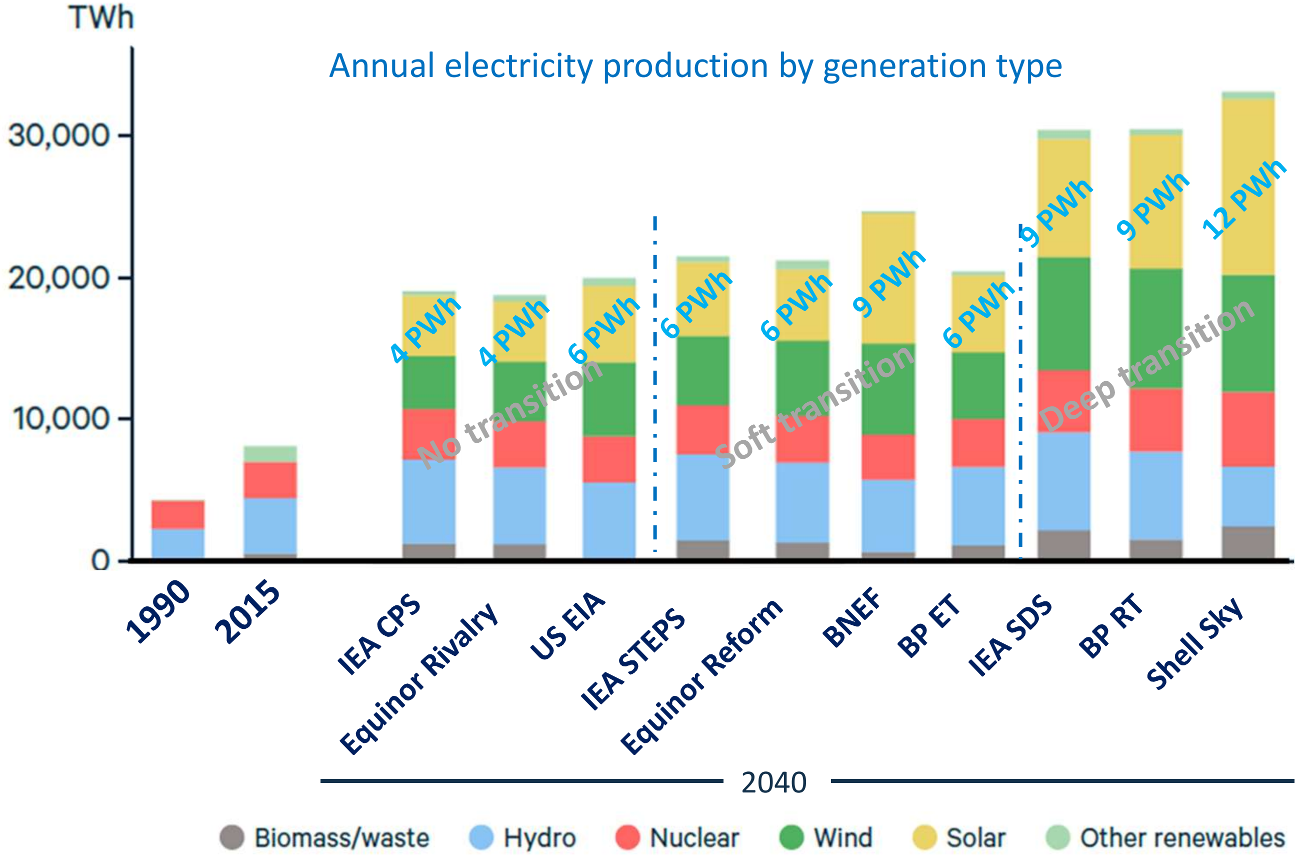
Kaya Model

- **CO2 intensity of Energy**
- **Energy intensity of the GDP unit**



Energy Efficiency AND Renewables

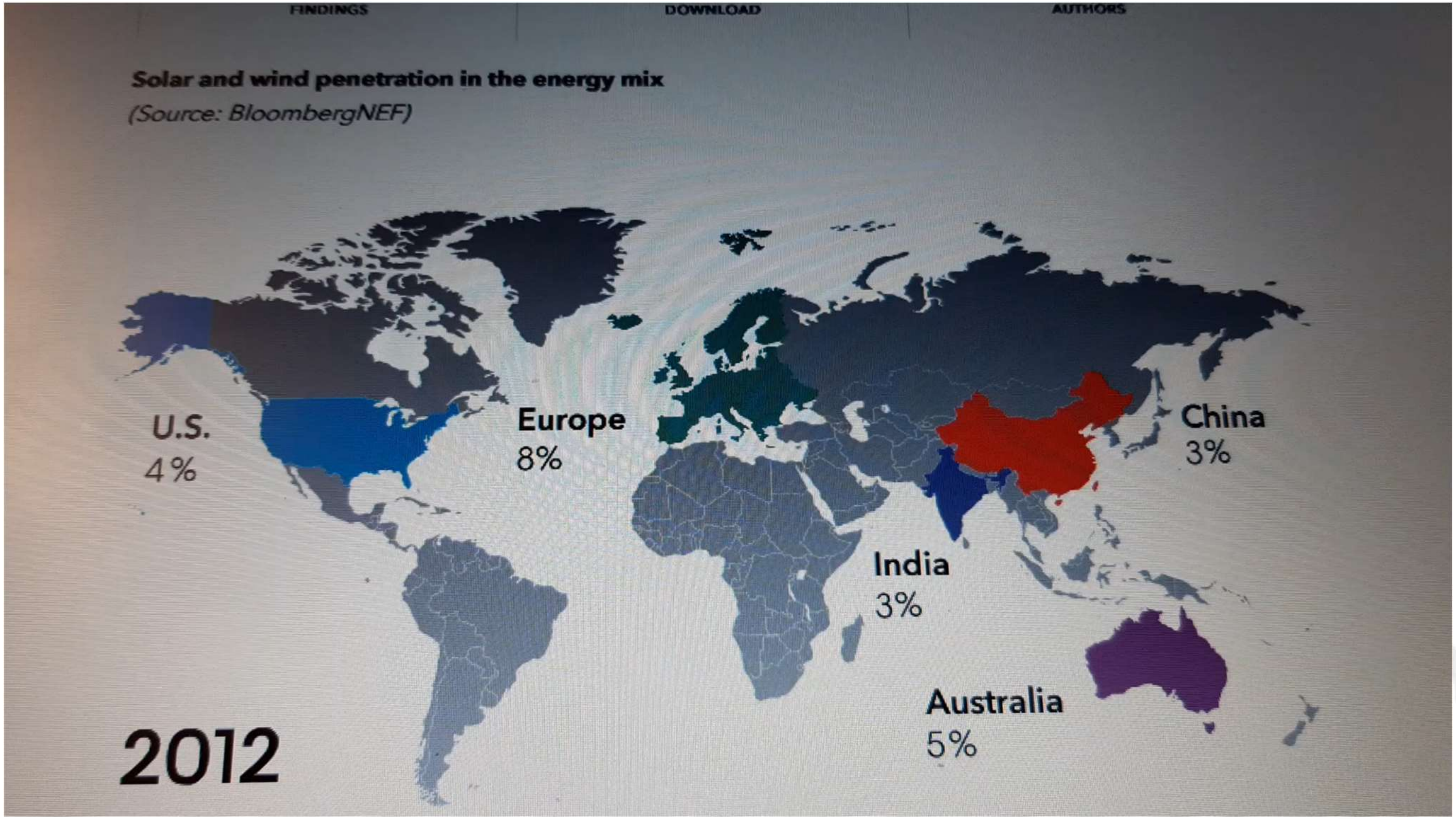
Outlook of Electricity generation



All scenarios agree on : a large electrification of uses
a large increase of PV in electricity production

6 – 9 PWh/yr of solar electricity in 2040 (vs 720 TWh in 2019)

Deployment of Renewables : Solar and Wind



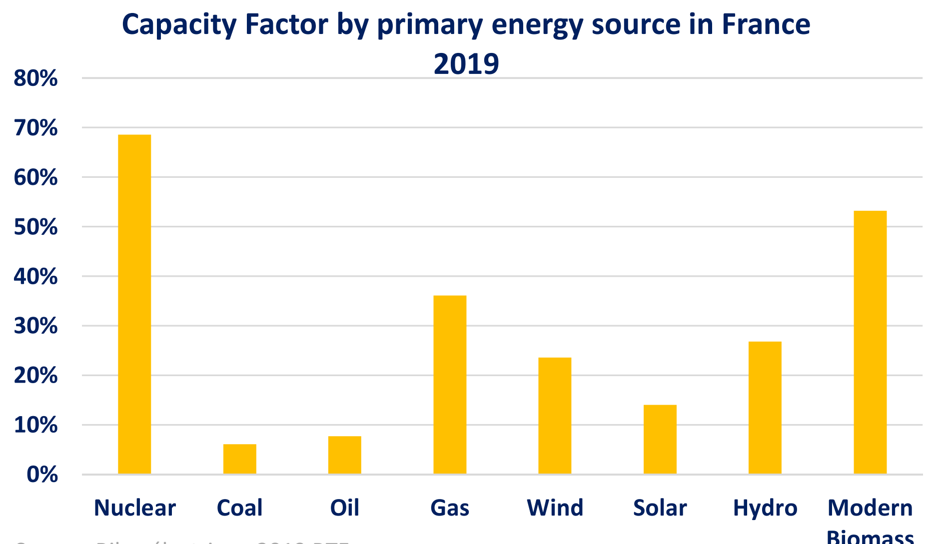
Power Generation and Installed Capacity

Capacity Factor

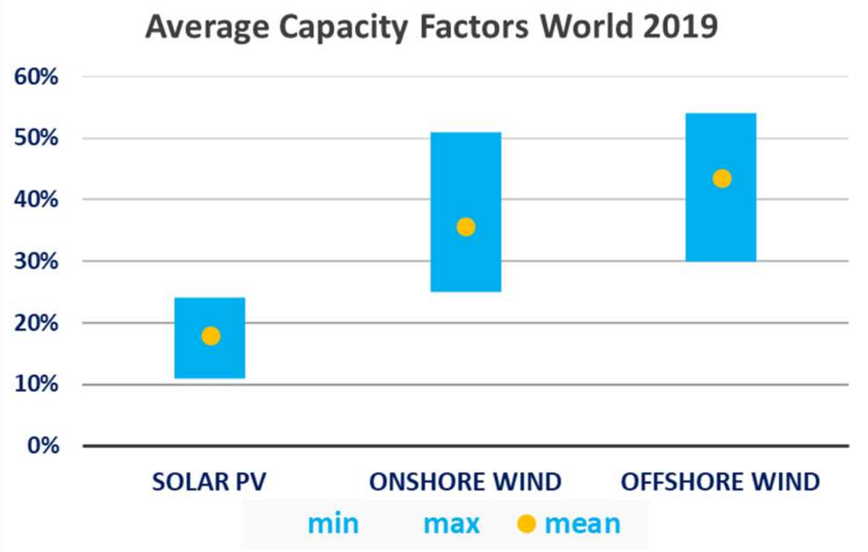
$$CF = \frac{\text{Annual Producible (MWh)}}{\text{Installed Capacity (MW)} \times 365 \times 24}$$

Depends on:

- Localisation (resource, weather)
- type of use (base or make-up)

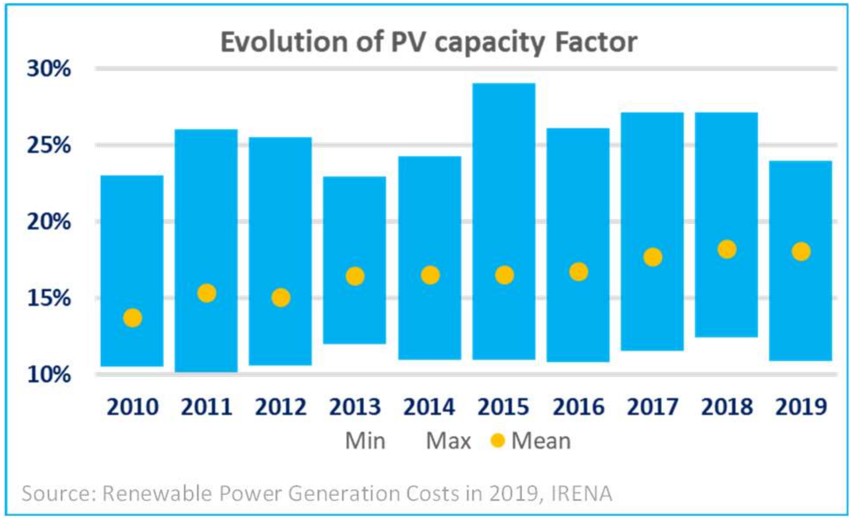


Source: Bilan électrique 2019 RTE



Source: Renewable Power Generation Costs in 2019

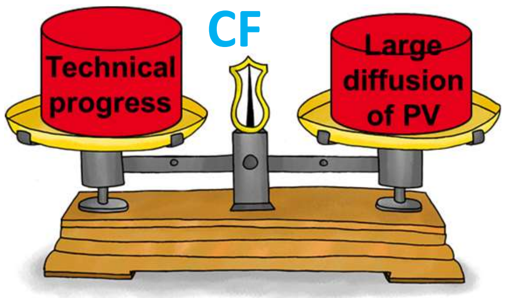
Evolution of PV Capacity Factor



More PV in sunnier areas
Technical progress on PV components
Improved energy availabity of PV plants

Installations in less favourable areas
(Large diffusion of PV around the world)

2020 - 2040

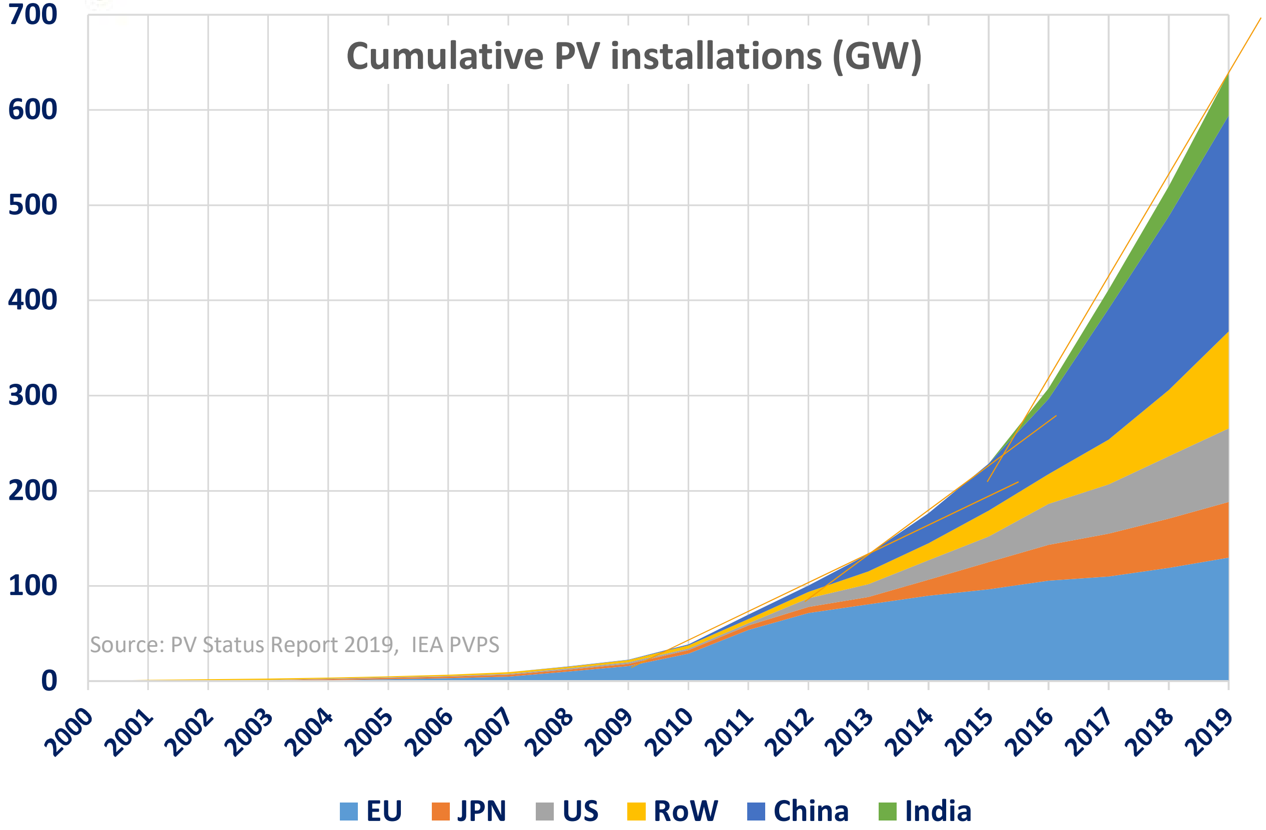


Capacity Factor ≈18-20%

5-6 TW of PV to produce 9 PWh/yr
7-8 TW of PV to produce 12 PWh/yr

GLOBAL PV MARKET

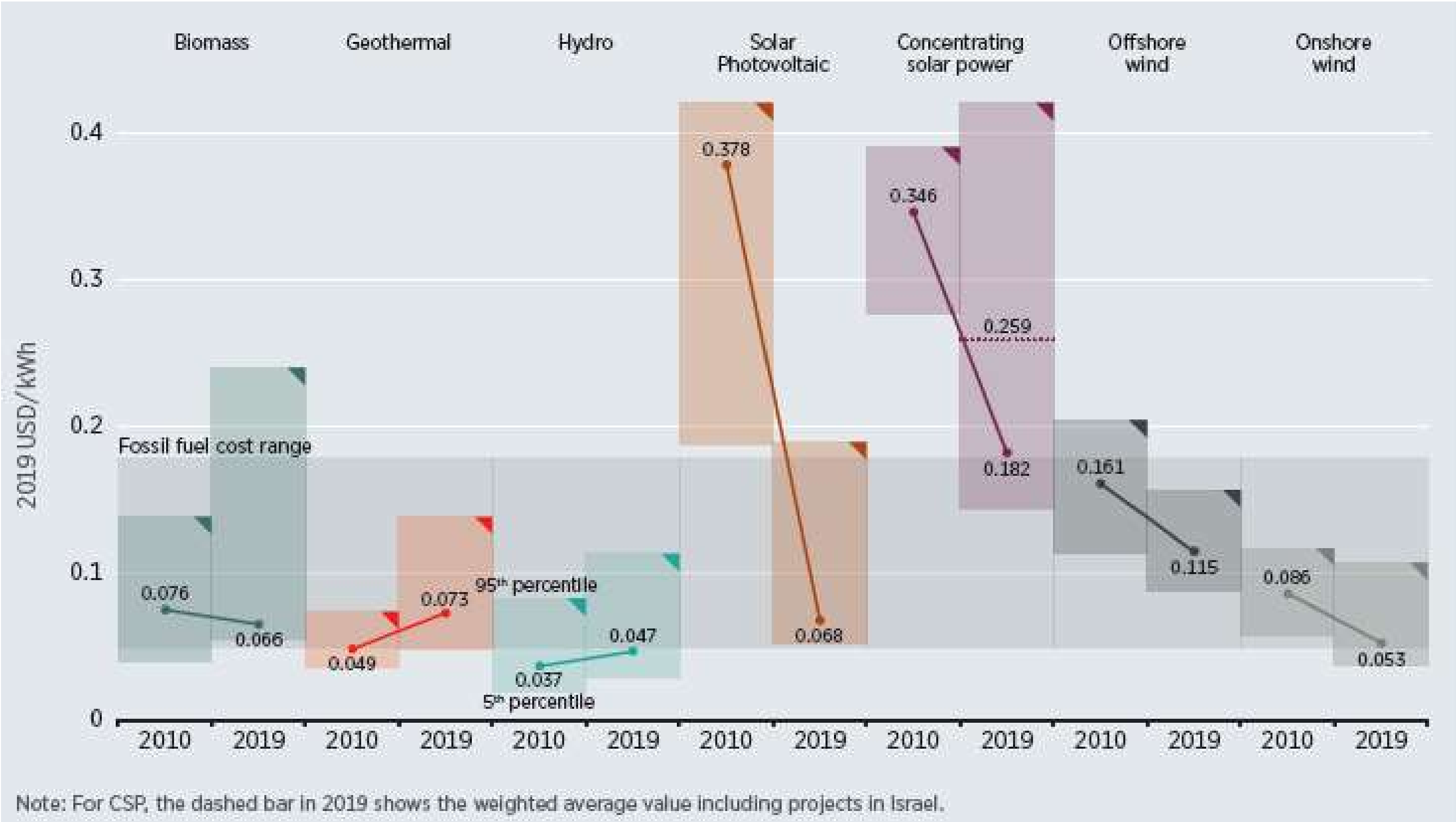
A Recent History but Fast Growing PV Market



- **600 GW of PV installed in 2019**
- **Accelerated growth since 2013**
  China took the lead in annual growth
- **In 2016, India and RoW joined**

PV is a cost competitive technology

LCOE of Utility-Scale Renewable Energy Sources 2010 and 2019



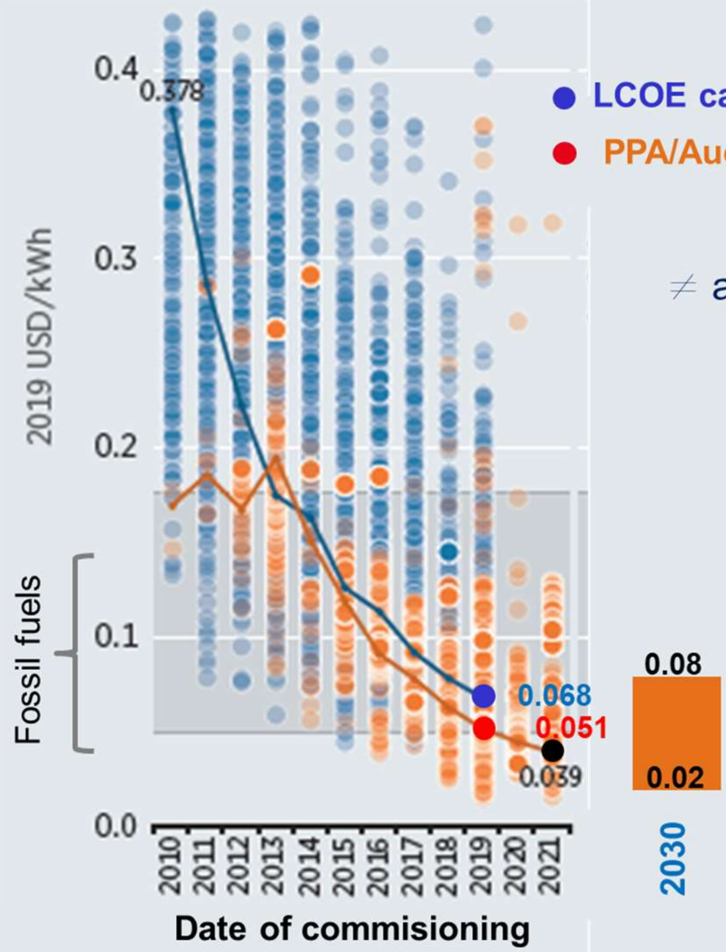
Source: Renewable Power Generation Costs in 2019, IRENA

$$LCOE = \frac{Total\ cost\ for\ the\ whole\ PV\ plant lifetime}{Total\ energy\ production\ for\ the\ whole\ PV\ plant lifetime}$$

PV electricty cost decreased by >80% from 2010

PV is at the lower range of fossil fuel electricity generation, below 60 €/MWh (calculated with a WACC of 7,5%)

Recent PV Cost Evolution and Short Term Outlook



≠ assumptions in LCOE vs PPA (WACC, O&M, installation costs)

- WACC reduction from 7.5% to 5% for OECD countries
  - ➡ 20 % reduction of PV electricity cost

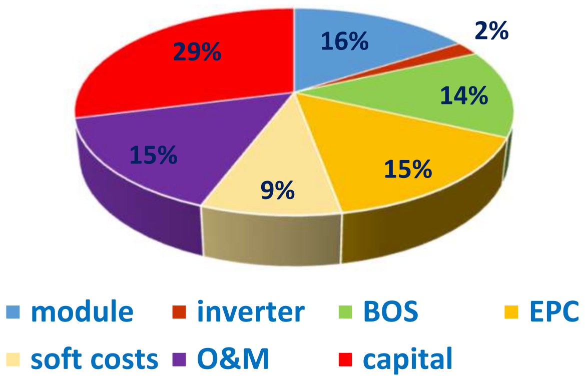
Projected weighted average cost for PV electricity in 2021:
39 $/MWh (33 €/MWh)

Projected cost range for PV electricity in 2030:
20 to 80 $/MWh (17 to 68 €/MWh)

Source: Renewable Power Generation Costs in 2019, IRENA

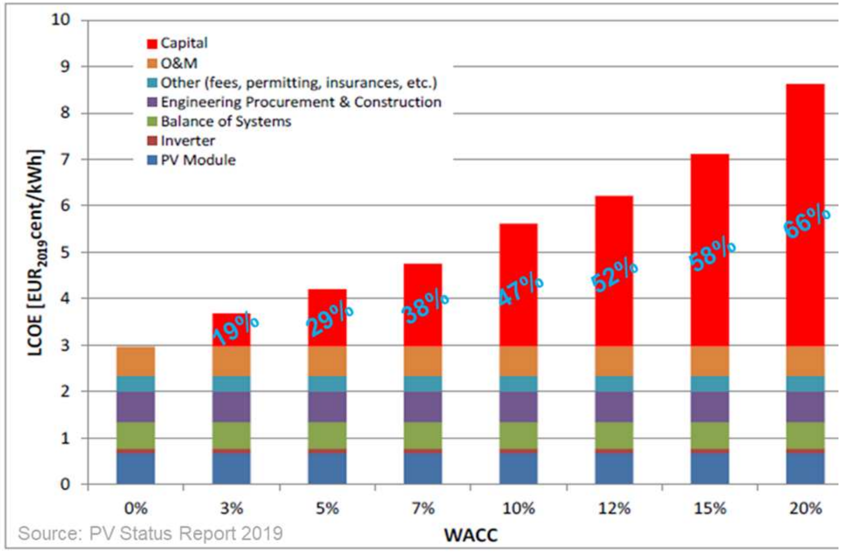
PV Electricity Cost Breakdown

Utility scale PV - LCOE Breakdown
(calc for a WACC = 5%)



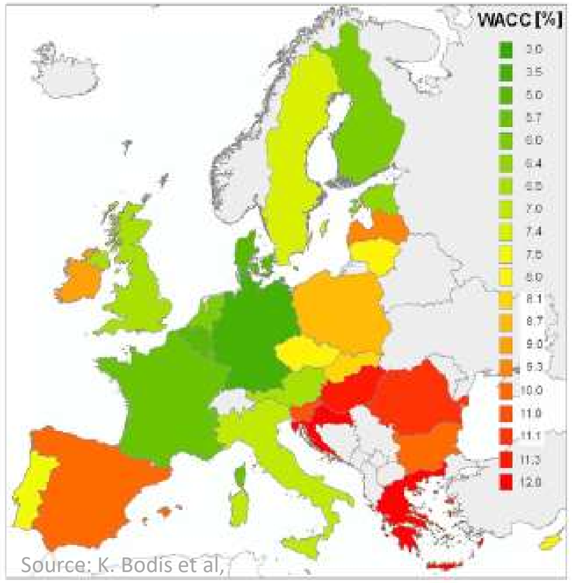
Source: PV Status Report 2019

Figure 11: Influence of WACC on LCOE



Source: PV Status Report 2019

(a) weighted average cost of capital (WACC)



Source: K. Bodis et al,
Renew. Sust. Energy Rev., 114 (2019) 109309

System cost accounts for 56% of LCOE

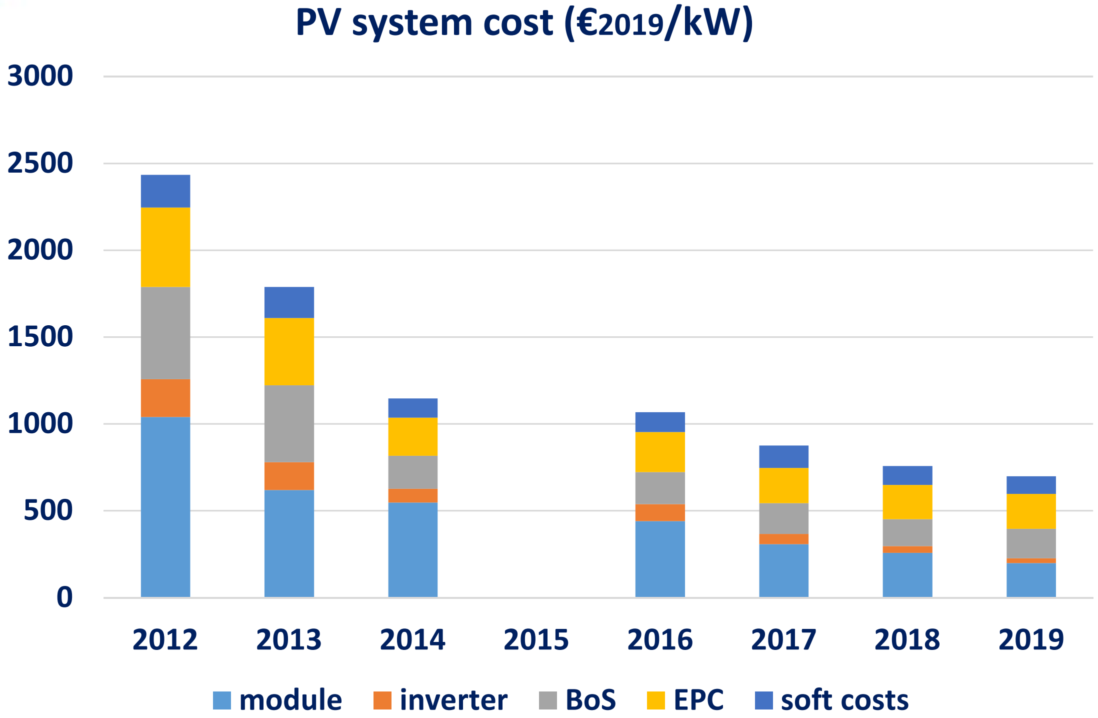
Large impact of Financing of utility scale projects on LCOE

- Inflation rate
- Profitability assessment
- Risk assessment (technical, geo-political, ..)

Inceasing development of PV and maturity → **Decreasing WACC**

$\approx$5% for OECD countries in 2020

Evolution of PV System cost



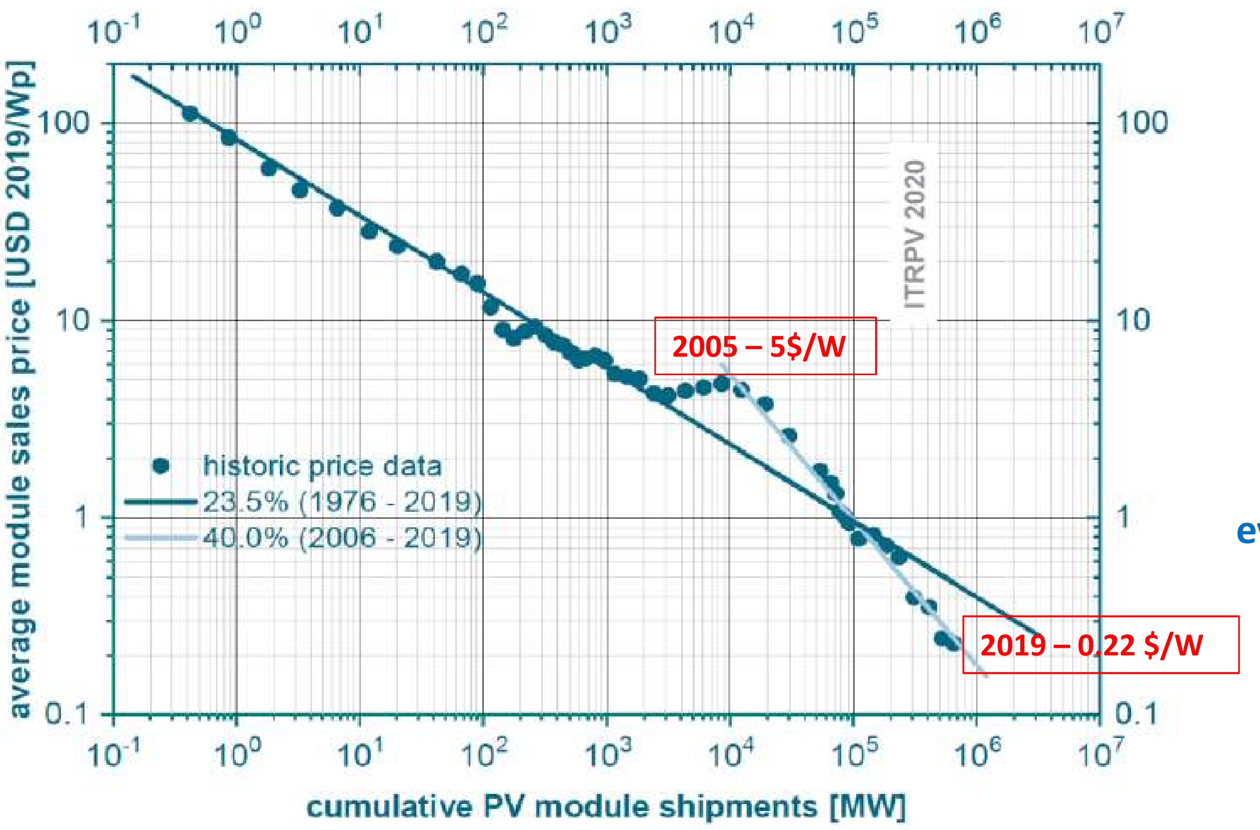
Source: PV Status Reports 2012-2019

	Cost decrease 2012 → 2019
Module	-81%
Inverter	-87%
BOS	-68%
EPC	-56%
Soft Costs	-45%
Total PV system	-71%

PV components price fall drives the competitivity of solar PV

Evolution of PV Component's price Illustrated by the Module Learning Curve

Learning curve for module price as a function of cumulative shipments



<u>**Learning curve eq.**</u>

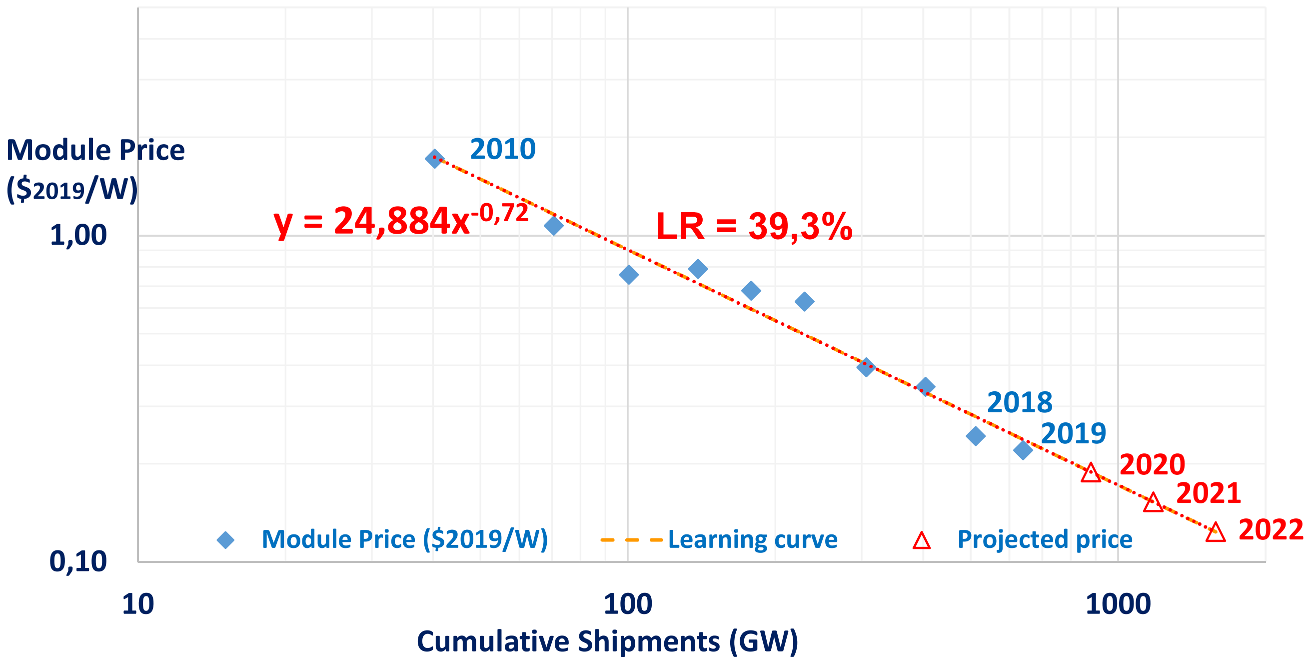
$P_t = P_0 (S_t/S_0)^{-b}$

$PR = 2^{-b}$

$LR = 1 - PR$

Module price decreases by LR % every doubling of cumulative shipments

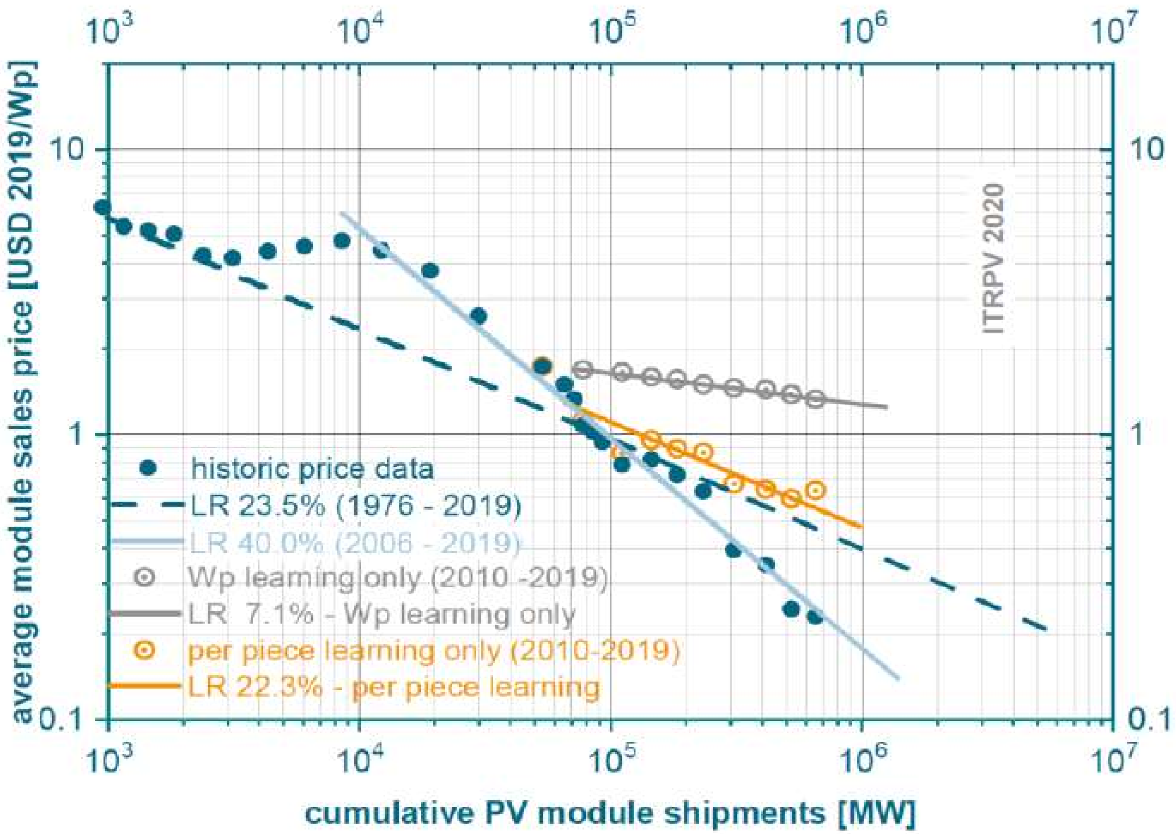
Module price learning curve



1 TW of installed PV possible in 2021

!! Module at 0.15 – 0.16 $/W !!

Analysis of the module learning curve

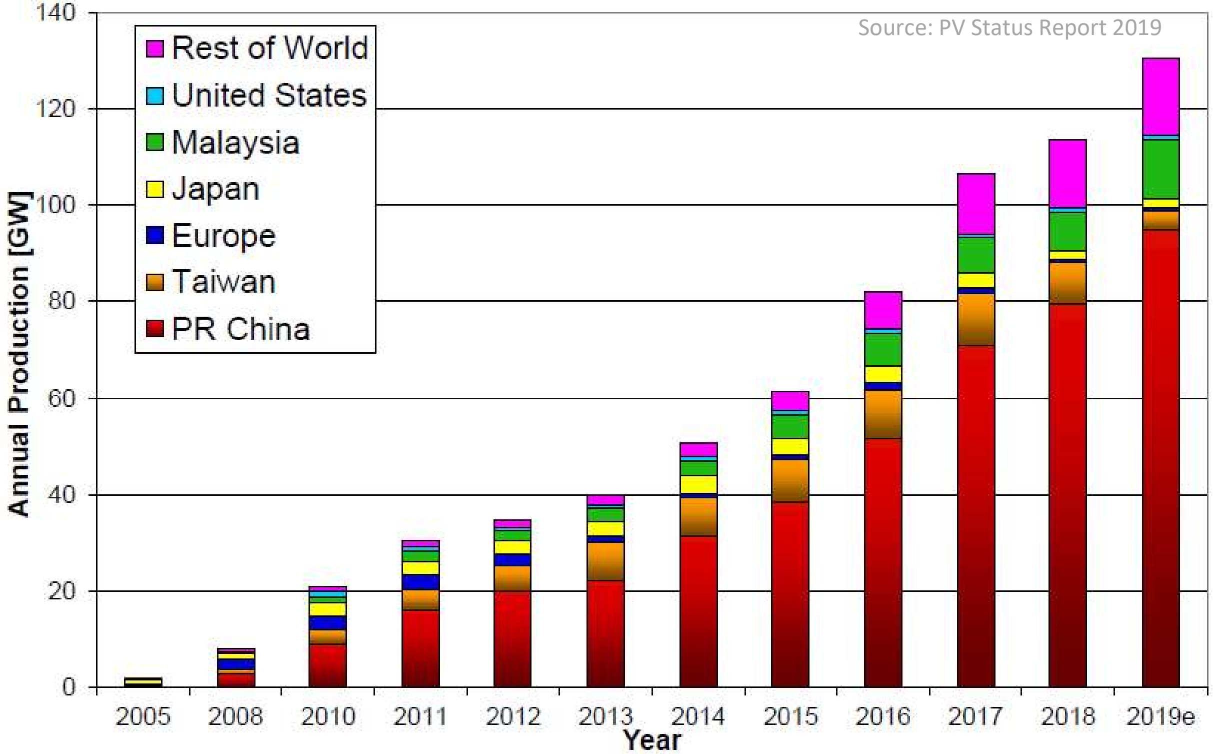


Module price decrease due to:

- First, Productivity gains
- Second, efficiency gains

PV Market Analysis: Production and Production Capacity

World PV cell/module production from 2005 to 2019 (estimate)



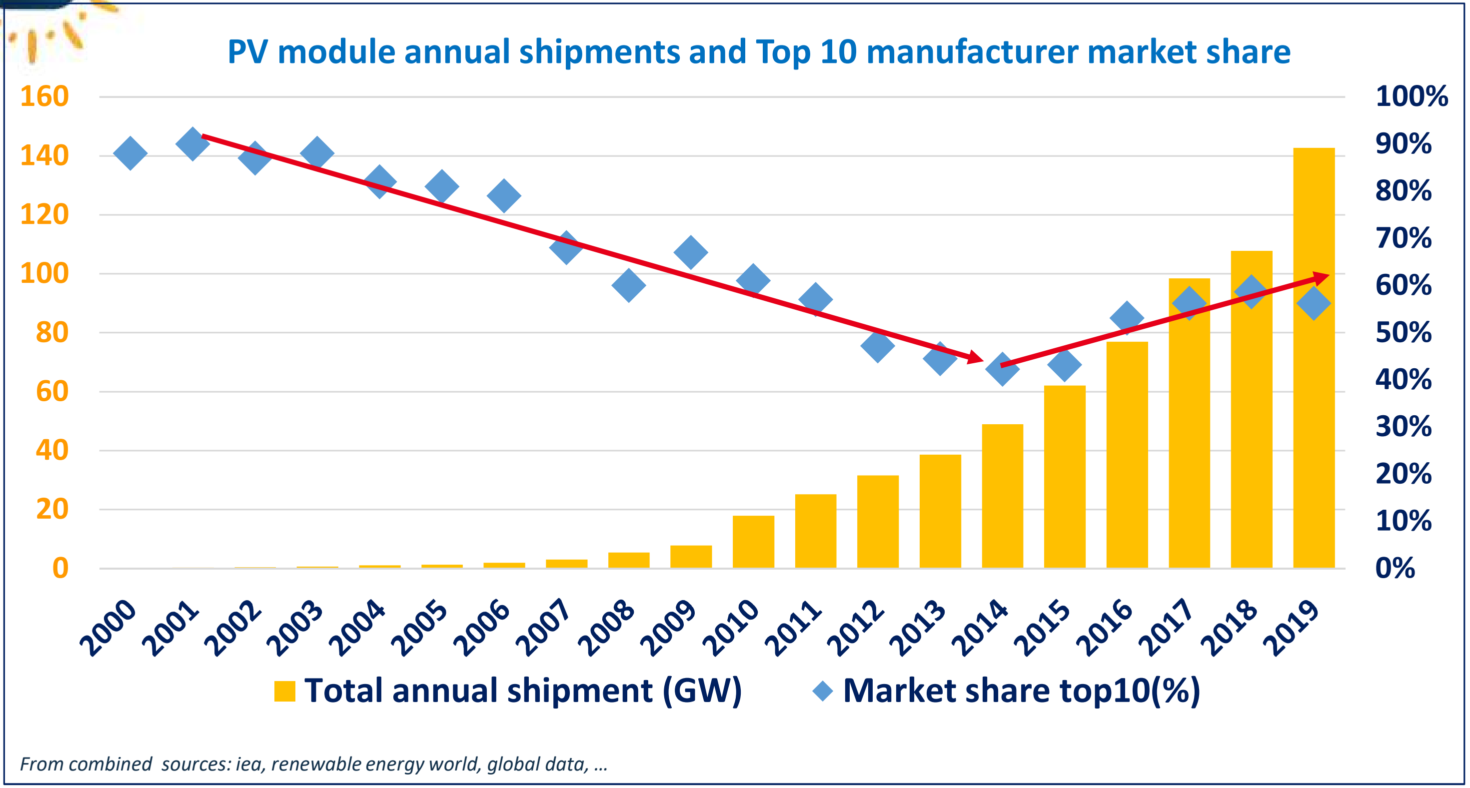
Continuous increase of the PV module production

China + South Asia dominate the production
EU accounts for 3% of module production

Development of production capacities covering the whole value chain:

- **Polysilicon**
- **Ingot-wafer**
- **Cell**
- **Module**
- **Inverter**

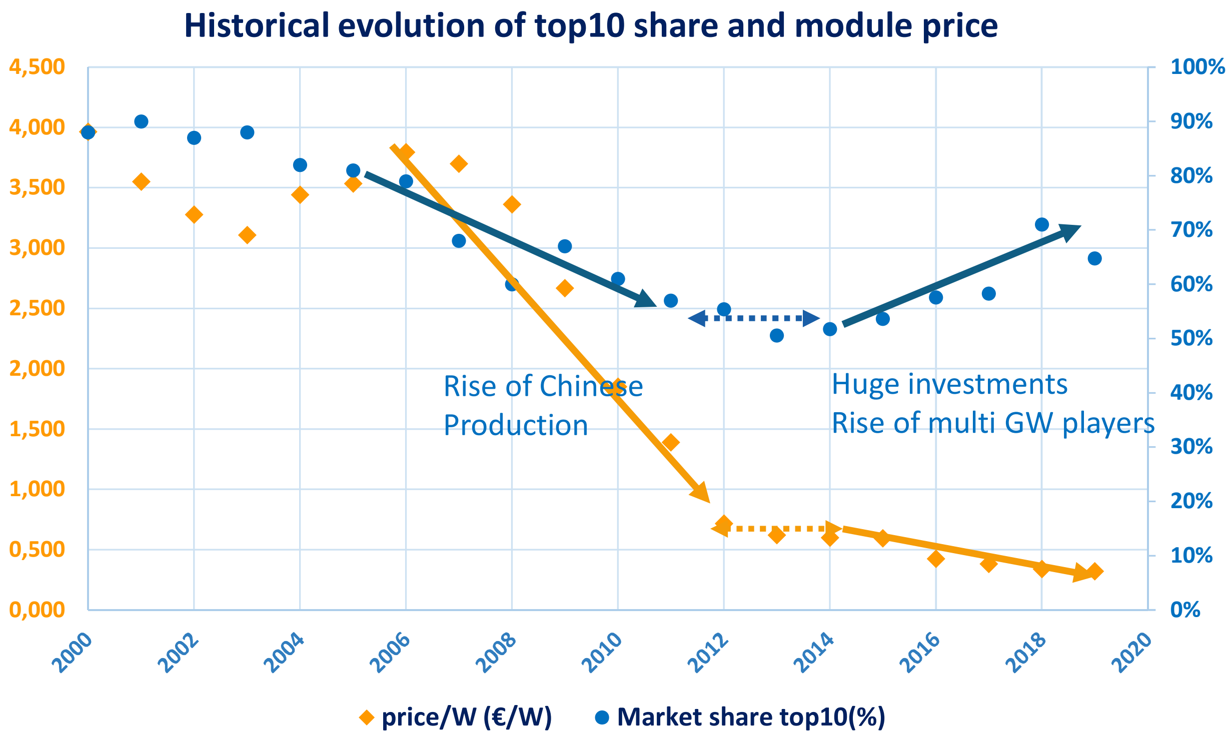
The PV Module Production Landscape



Ranking	Company	2019 shipments (GW)
1	Jinko Solar	14,2
2	JA Solar	10,3
3	Trina Solar	9,7
4	Longi Solar	9
5	Canadian Solar	8,5
6	Hanwha Q Cells	7,3
7	Risen energy	7
8	First Solar	5,5
9	GCL	4,8
10	Shungfeng	4

From 2014, strong market consolidation
Rise of players > 10 GW
Vertically integrated manufacturers dominate the market ….

PV Module Price and production landscape



- Very large production plants are being developed in China
- Economy of scale allows production cost reduction
- Fast Investment pace push the upcoming of newest technologies

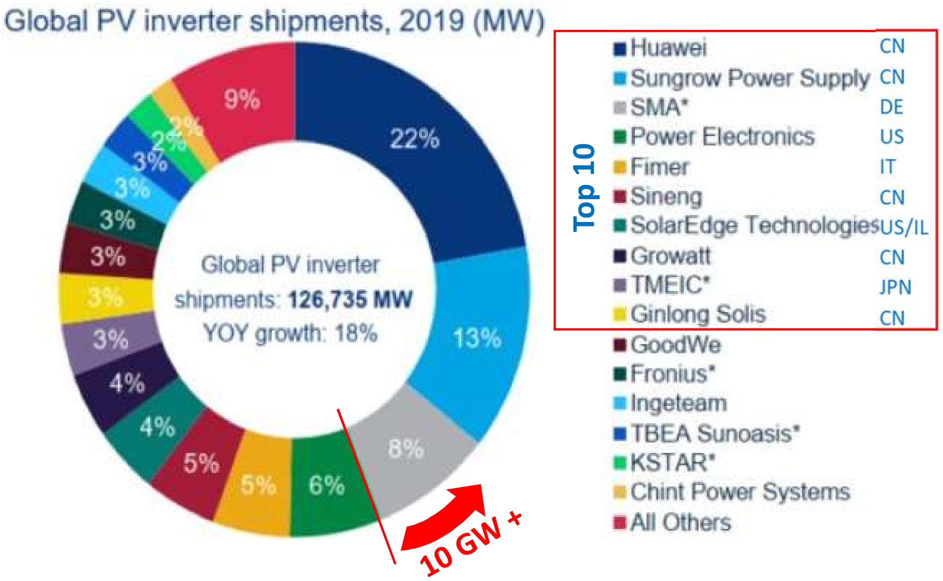
Vertical integration

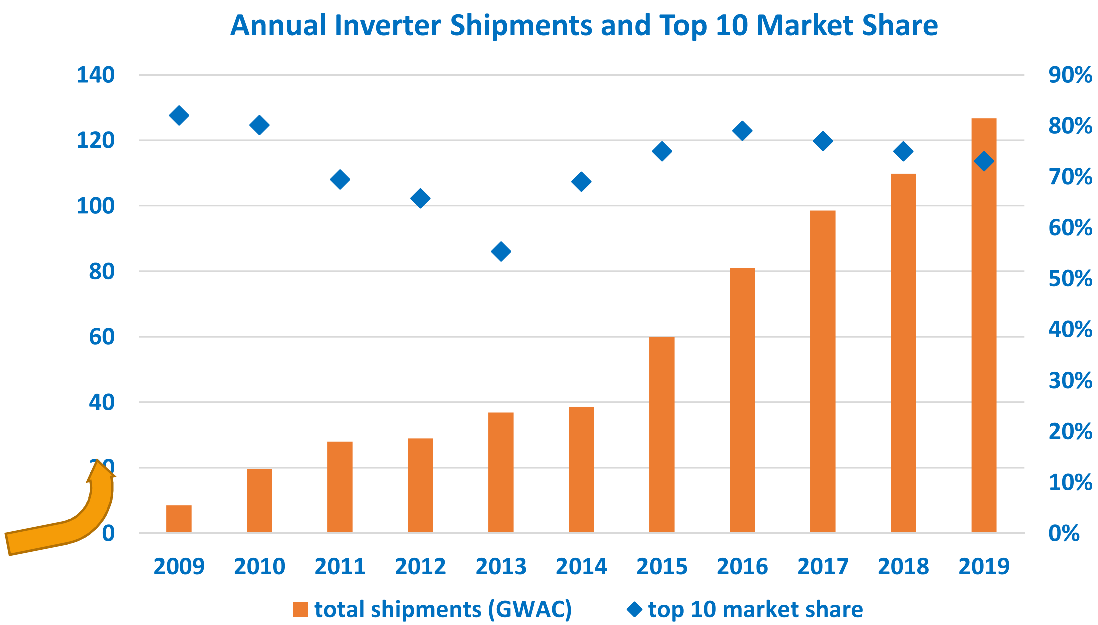
Company	module shipments 2019		Ingot	Wafer	Cell	Module	Project Dev.	
Jinko Solar	14,2	GW	X	X	X	X	X	
JA Solar	10,3	GW	x	X	X	X	-	
Trina Solar	9,7	GW	X	X	X	X	X	+trackers, inverters
Longi Solar	9	GW	X	X	X	X	X	
Canadian Solar	8,5	GW	X	X	X	X	X	
Hanwha Q Cells	7,3	GW	-	-	X	X	X	+ polysilicon
Risen energy	7	GW	-	X	X	X	X	
First Solar	5,5	GW	NA	NA	NA	X	X	
GCL	4,8	GW	X	X	X	X	X	+ polysilicon
Shunfeng	4	GW	-	X	X	X	X	

Etc....

Most important PV players have chosen to be vertically integrated

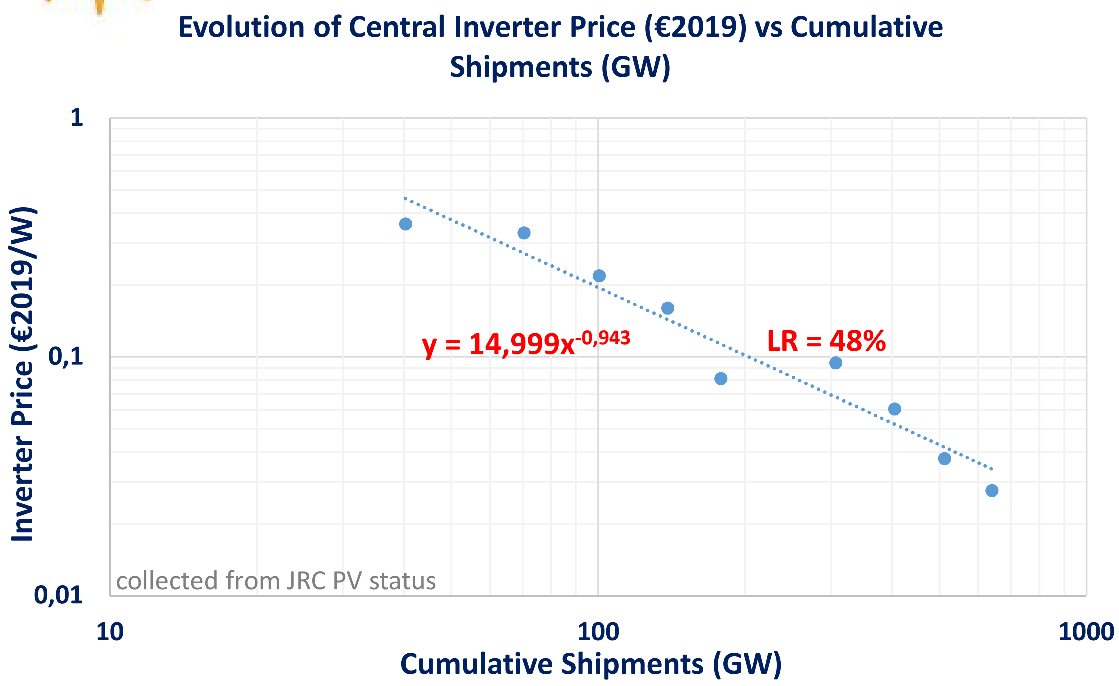
The Inverter Market





From 2013, fast market consolidation
3 players > 10GW
5/10 top players outside China

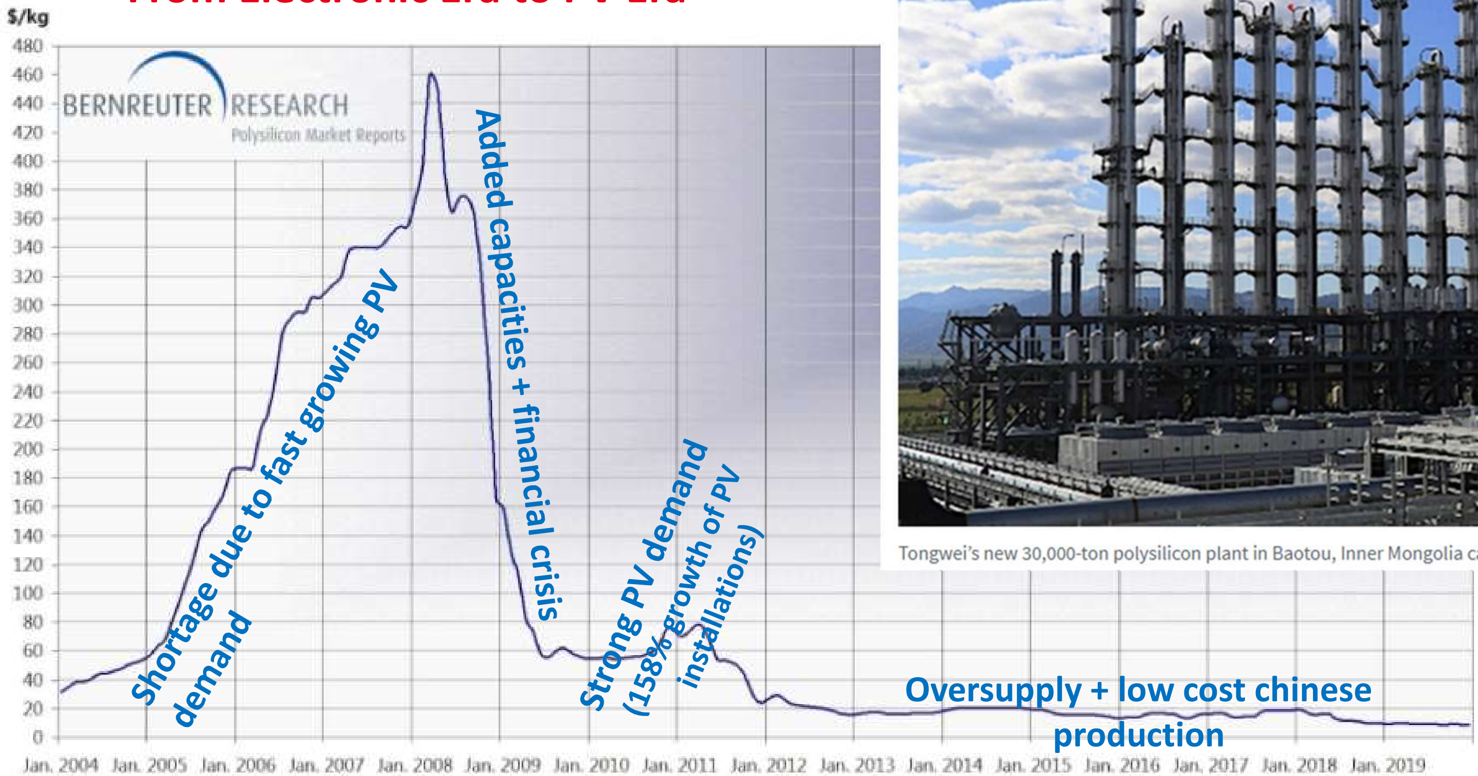
The Inverter Learning Curve



Not as much analyses compared to modules but an even faster cost decrease

The Polysilicon Market

From Electronic Era to PV Era

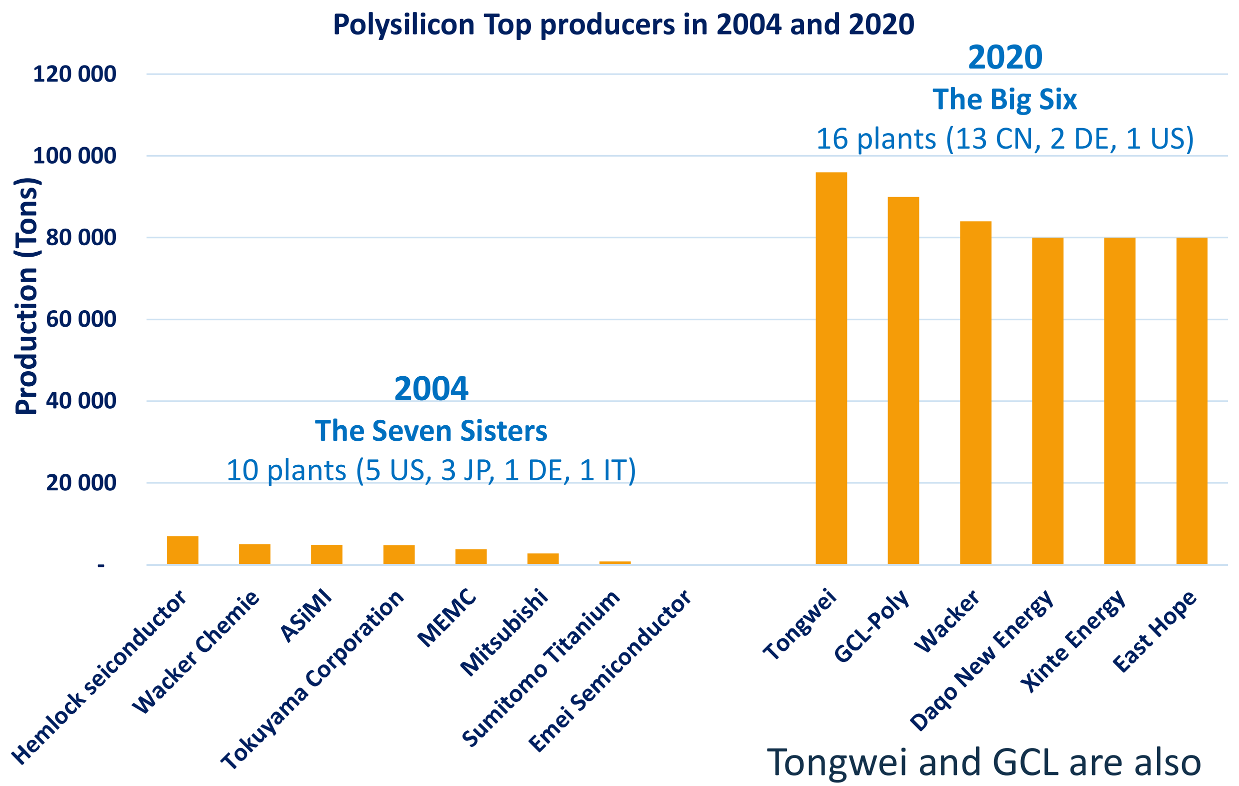


The polysilicon shortage from 2004 to 2008 drove the spot price to astronomic heights above $400/kg before it crashed down to $55/kg within 15 months – Data sources: UBS/BNEF/PVinsights (2004 - 2010), EnergyTrend (2011 - 2019); Chart: Bernreuter Research

Tongwei's new 30,000-ton polysilicon plant in Baotou, Inner Mongolia came on stream in October 2018 – Image: Xinhua

From 2013 continuous decline of cost of PV polysilicon

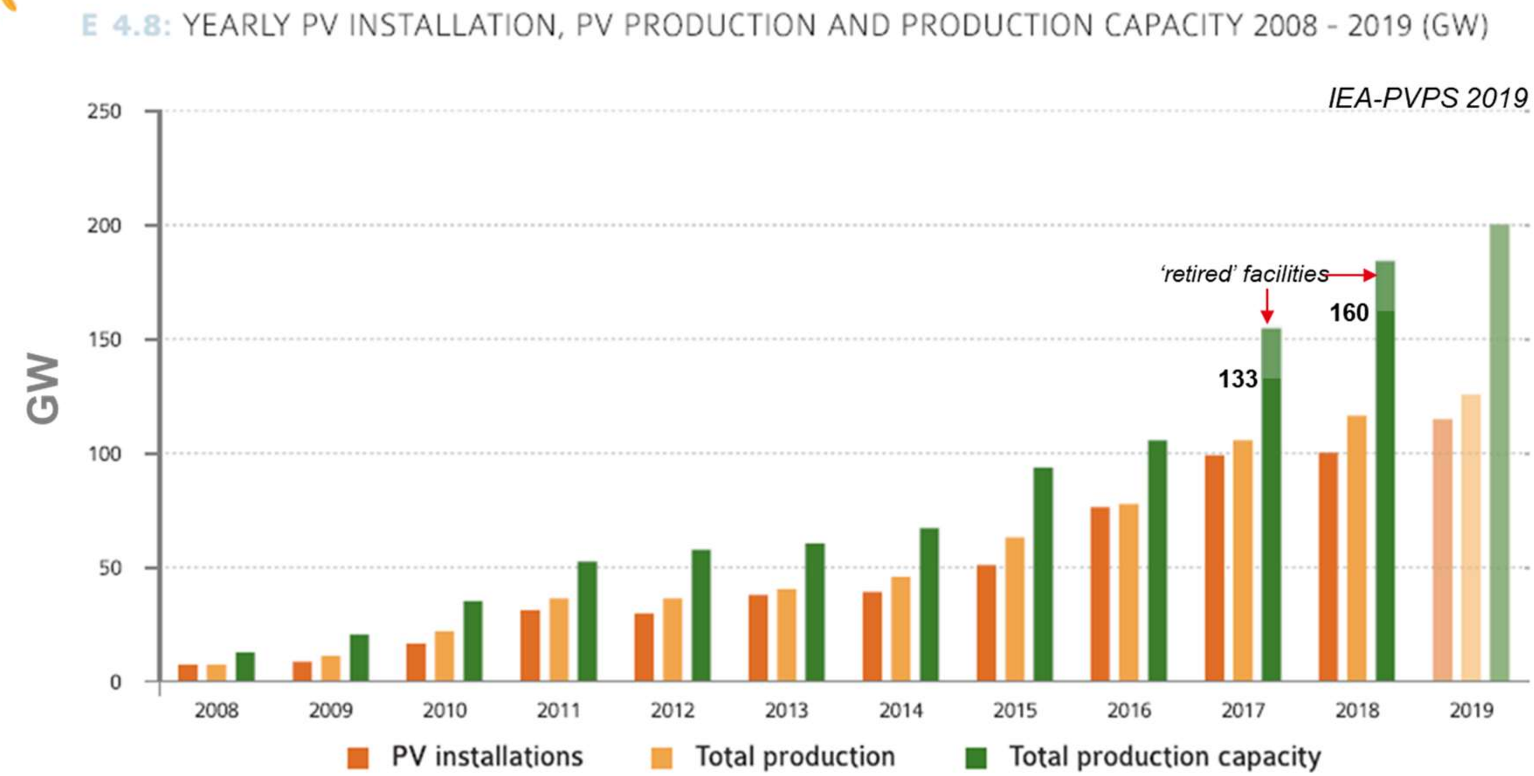
Polysilicon:
From western production for electronics to eastern production for PV



Tongwei and GCL are also producing ingots, wafers*, cells and modules

* For GCL only

PV market analysis and forecast



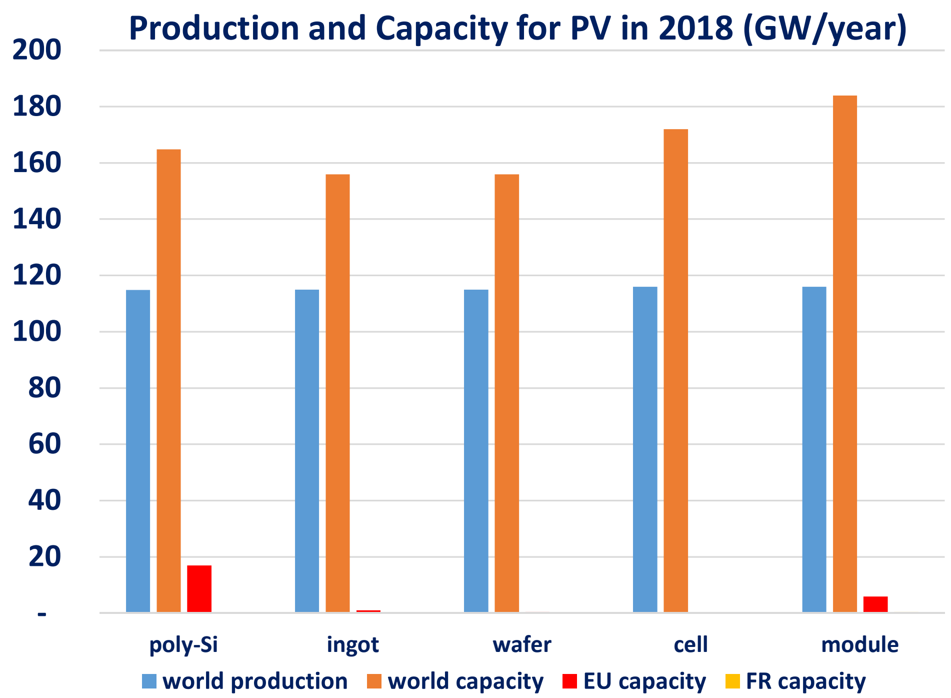
A PV market characterized by long lasting production over-capacities
The general trend to over-capacities will continue to put pressure on prices

PV market analysis and forecast

Production and Capacity for PV in 2018 (GW/year)

	poly-Si	ingot	wafer	cell	module
World production	115	115	115	116	116
World capacity	165	156	156	172	184
EU capacity	17	1,1	0,5	0,2	6
FR capacity	-	0,25	0,05	-	1

Source: IEA-PVPS Trends in photovoltaic applications – 2019 and CEA



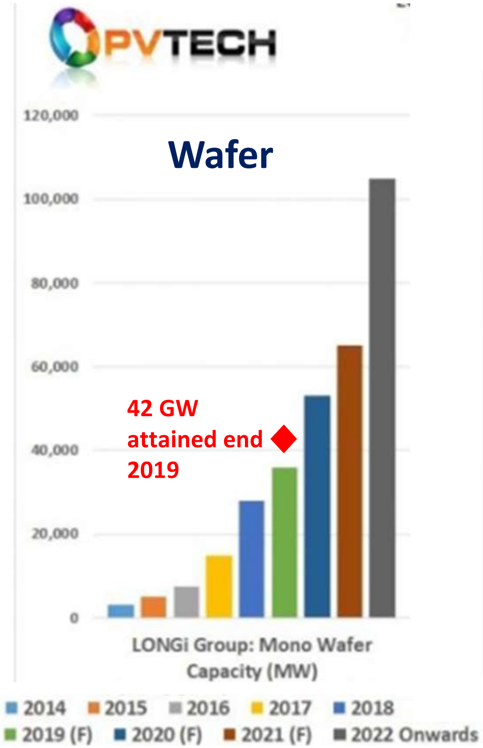
Production over-capacities in the whole upstream PV sector
Less competitive fabs are retired (ex : OCI closed its Korean fab of PV Poly-Silicon)

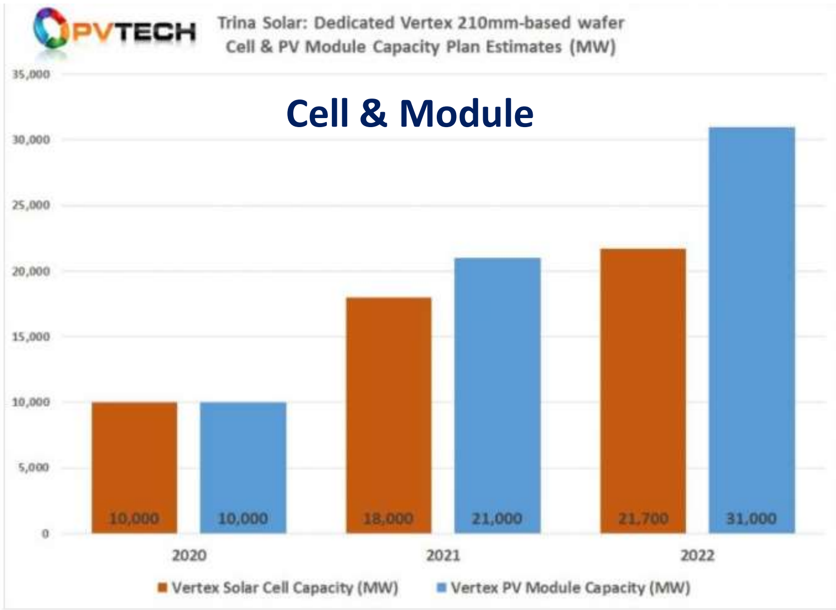
Continuing Investment Dynamic in China

source: PV Tech	210 mm	182 mm
Cell Expansion Capacity Announced in 2020	120 GW	90 GW

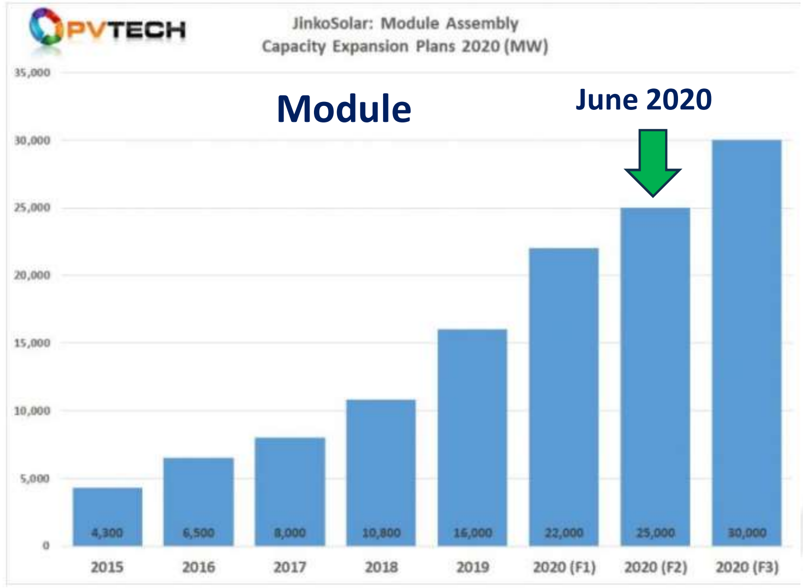
A new investment dynamic caused by the increase in wafer size

Few examples:





Trina Solar noted that according to its strategic plan, PV module production capacity would not be less than 50GW at the end of 2021.



JinkoSolar did not disclose where the module capacity expansions had occured or where the new plants would be located.

Announced capacity expansions to continue with price pressure

PV industry development and climate mitigation target

Deep Transition / Sustainable scenario → 5-6 TW of PV to produce 9 PWh/yr
7-8 TW of PV to produce 12 PWh/yr

Outlook of annual installation rate for a scenario at 10 TW of installed capacity

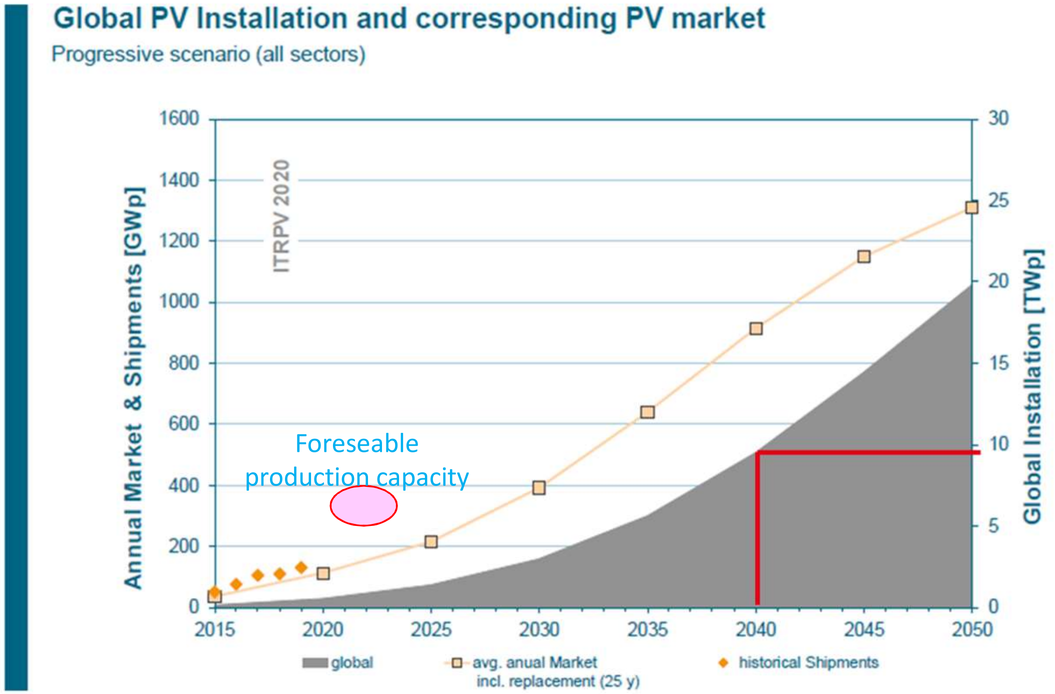
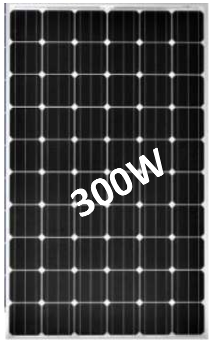


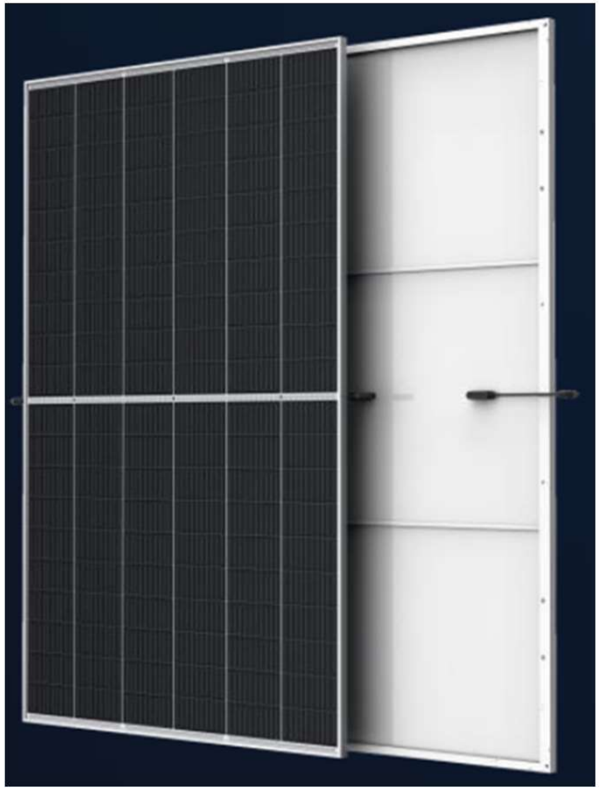
Fig. 86: Scenario 2: annual PV market and corresponding cummulated global installation of 19.8 TWp installed PV in 2050 including replacements after 25 years, acording to [37].

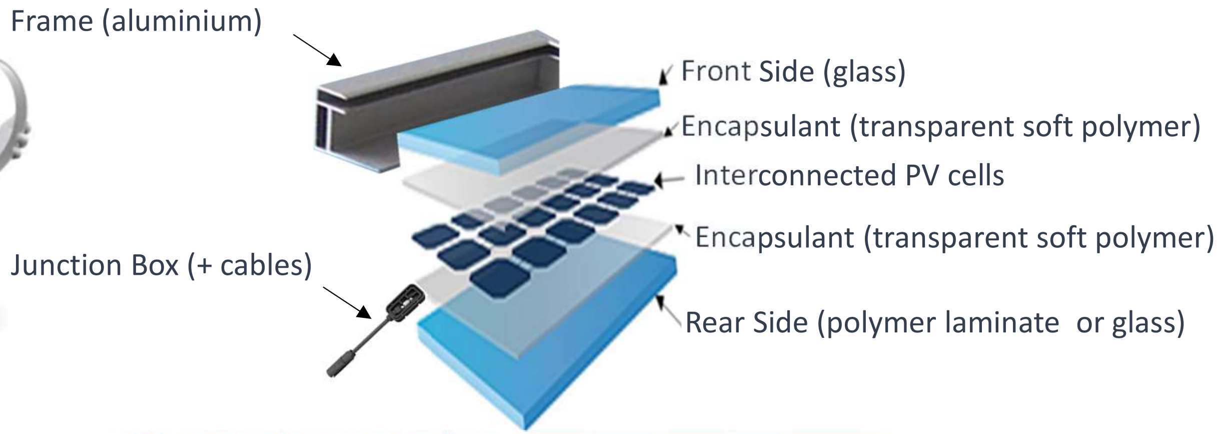
PV industry has a development pace above the requirements to fulfil the sustainable development scenarios

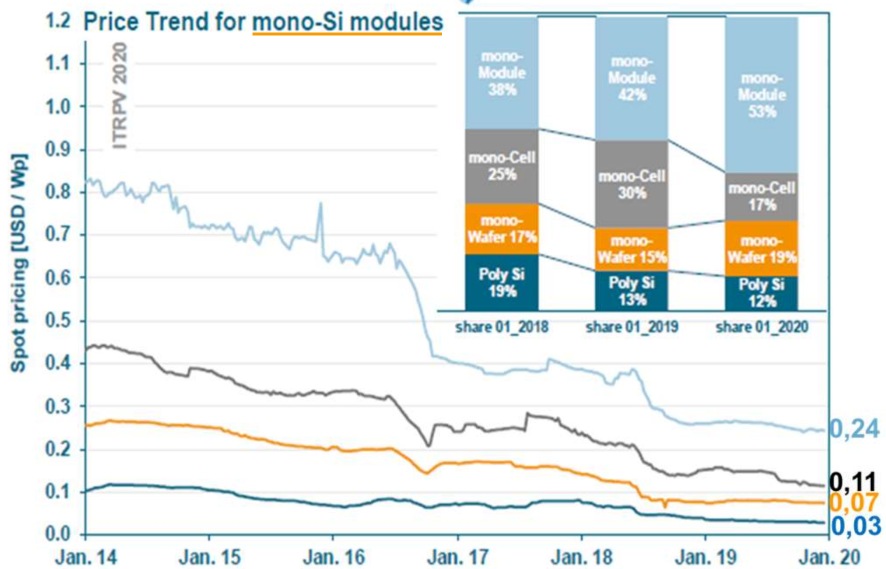


GLOBAL PV MARKET
TECHNOLOGY LANDSCAPE

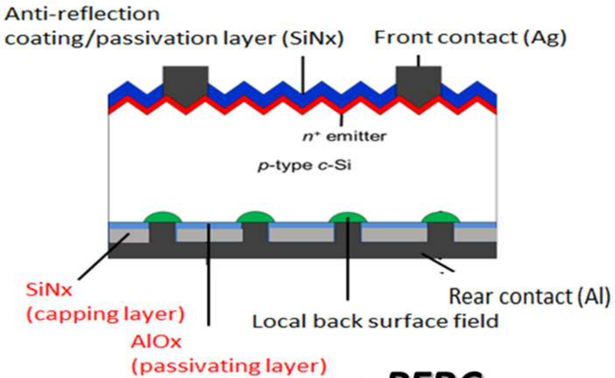
Generality on Photovoltaic Module



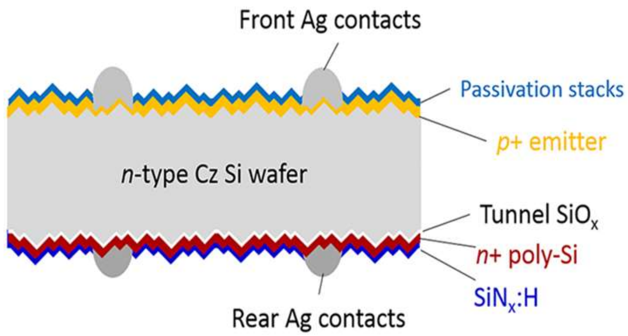




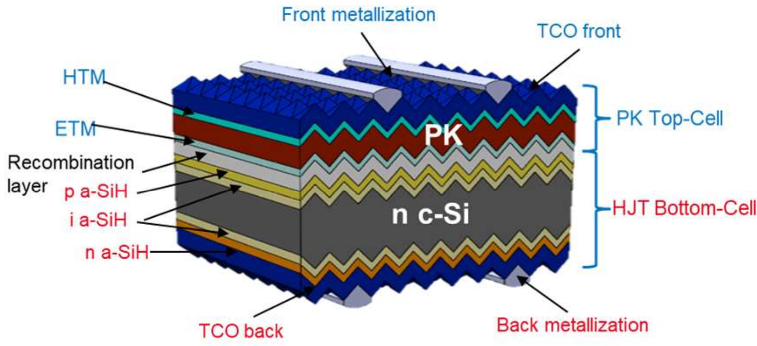
Different Cell Technologies



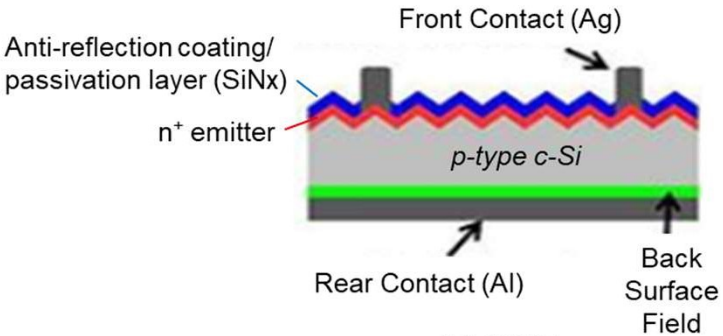
p-PERC



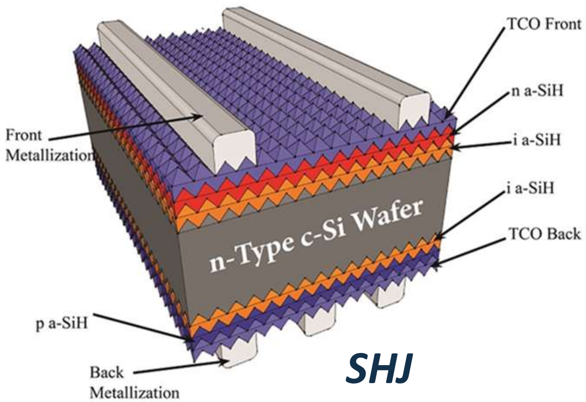
n-TOPCon



Tandem PK/HJT

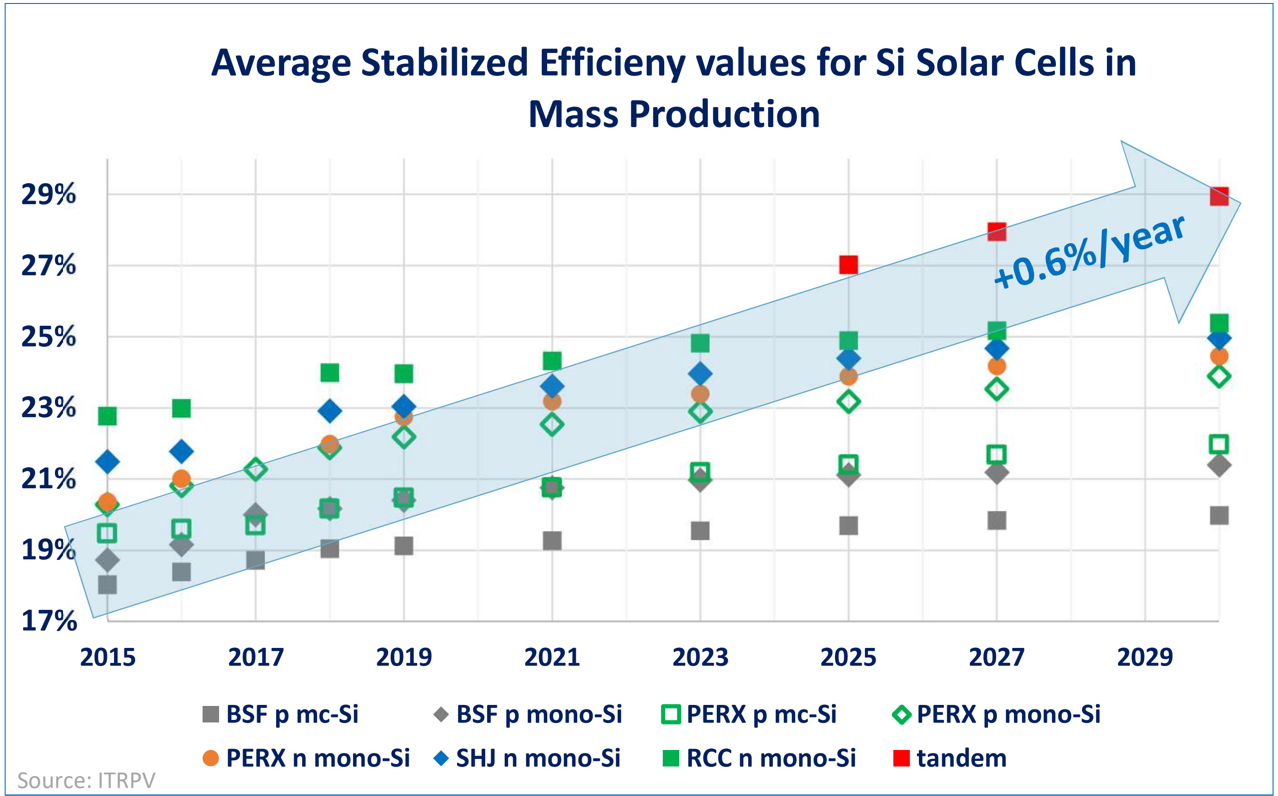


Al-BSF



SHJ

Cell efficiency global trend

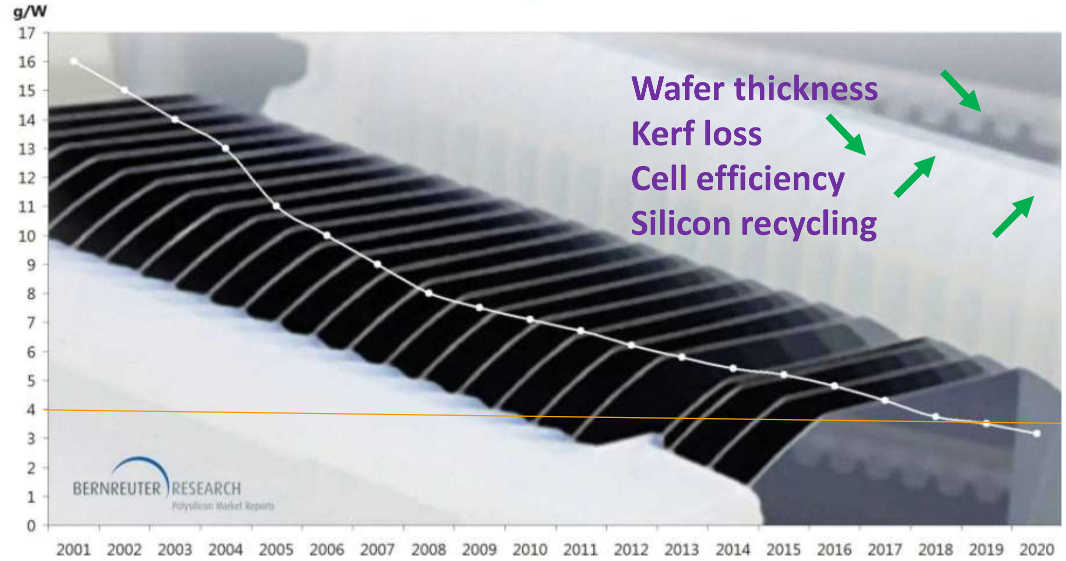


Continuous improvement of average cell efficiency causes turnover in dominant cell technology

Decreasing Use of Raw Materials for Cost Reduction

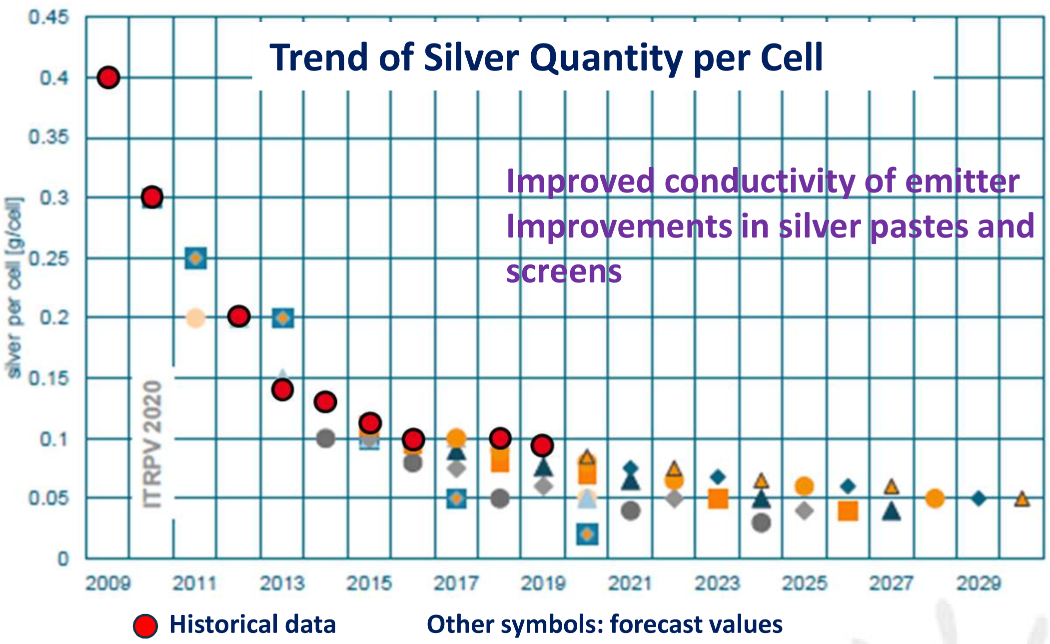
Silicon

Specific silicon consumption for solar cells in grams per watt between 2001 and 2020



Technical progress in wafer production and continuous improvement of solar cell efficiencies have steadily reduced the specific silicon consumption in grams per watt (g/W) of solar cell power – Image: Zhonghuan Semiconductor; Chart: Bernreuter Research

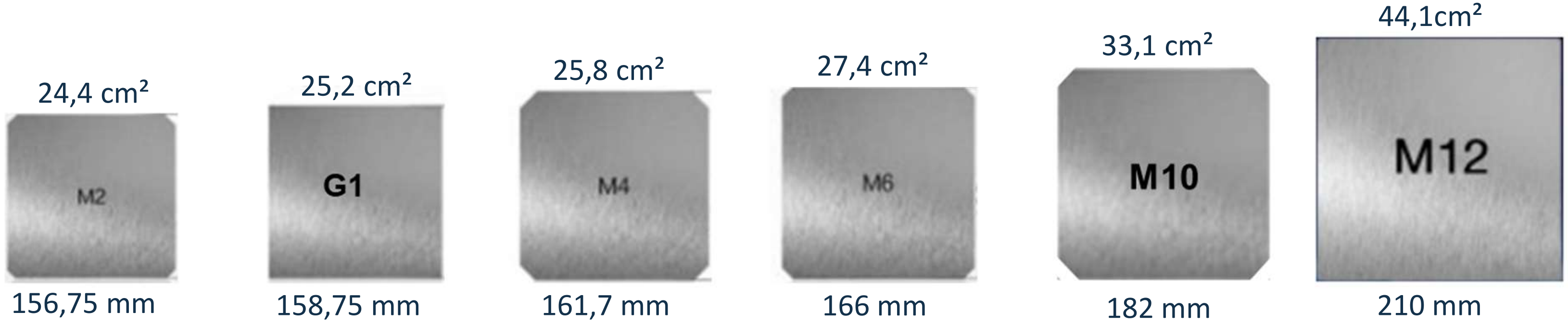
Silver



Material efficiency is continuously improving
key to reduce cost and environmental impact

The Revolution of Large Area Wafers and 500W+ (and beyond) Modules

	Wafer Size	
source: PV Tech	**210 mm**	**182 mm**
Cell Expansion Capacity Announced in 2020	**120 GW**	**90 GW**



- G1 wafer = industry standard in 2020; M2 fast decline
- 166 mm (M6) launched by Longi mid 2019
- 210 mm (G12) launched by TZS in Aug 2019
- 182 mm (M10) adopted by 7 leading companies in June 2020
- 210 mm supported through the creation of 600W+ Photovoltaic Open Innovation Ecological Alliance (57 members in sept. 2020)

Four main wafer sizes will coexist in the next fex years:
G1, M6, M10, G12

What size of wafers for high power modules?

Industrial move very recent, many options on the table

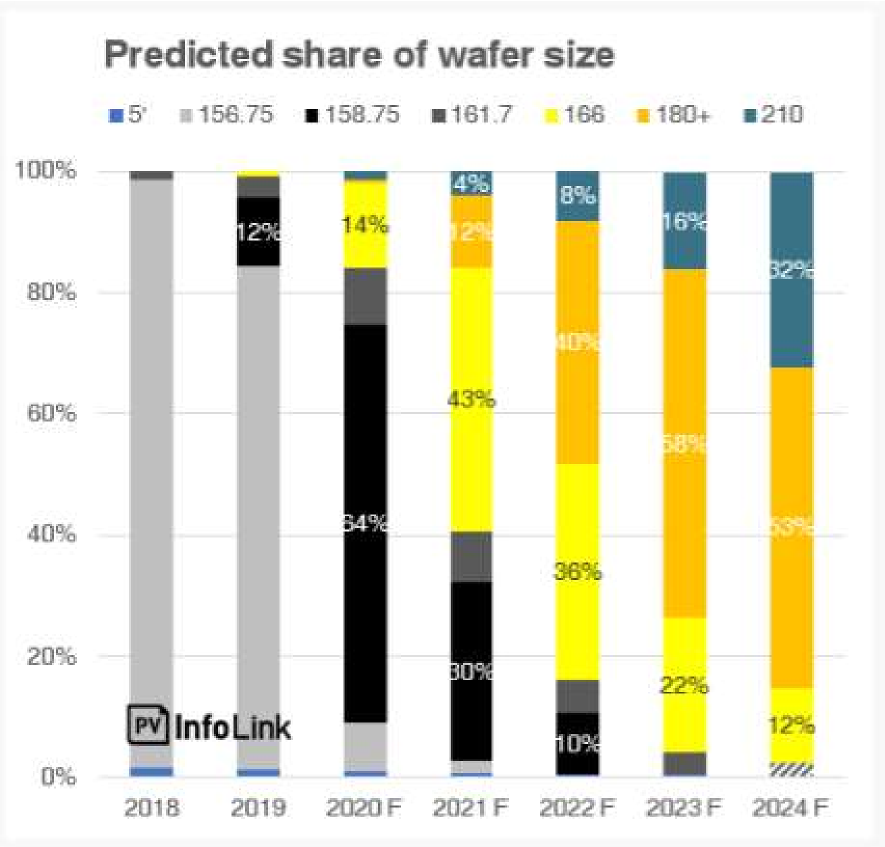
Evolution difficult to predict

Possible scenario

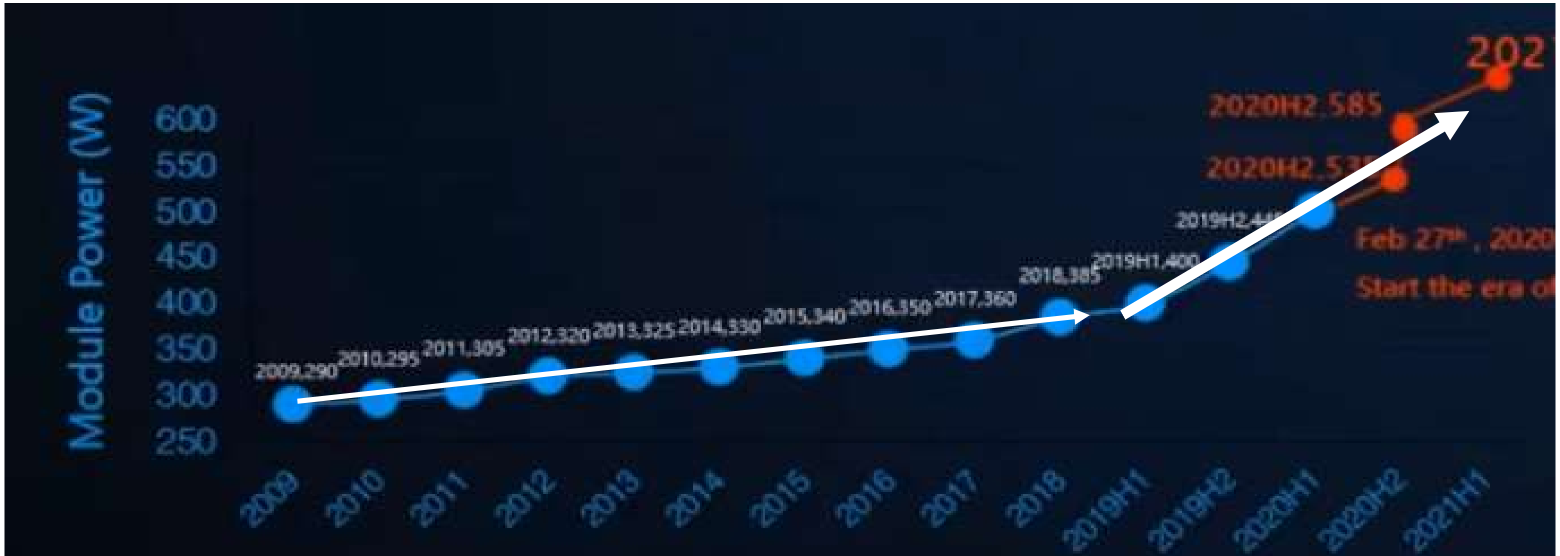
1. **2019-2020: M2 (previous std for decades) rapidly declines**

2. **2020-2022: G1 and M6 are transitory industrial solutions (compatible with present production lines)**

3. **From 2022 : M10 and G12 coexist as market std (new production lines to be fabricated and started)**



The Push to High Power Modules



Source: Trina Solar, Vertex module presentation

From 2019 H1, boom in module power increase
General trend followed by all tier 1 module manufacturers
Targeted market: Power plants

Some 500W+ modules

Company	Product	Cell Technology	Wafer Size mm	Cell format	n° equiv, Full cells	Module output W	Efficiency %	area m²
Trina Solar	Vertex	PERC	210	1/3 cut	50	**505**	21.1	2.39
JinkoSolar	Tiger Pro	PERC	182	1/2 cut	72	**540**	21.3	2.53
Longi Solar	Hi-MO 5	PERC	182	1/2 cut	72	**540**	21.1	2.56
Maxeon	Performance 5	PERC	210	shingled	57,1	**545**	21.1	2.58
Canadian Solar	HiKu6	PERC	182	1/2 cut	72	**545**	21.3	2.56
JA Solar	DeepBlue 3,0	PERC	182	1/2 cut	72	**545**	21.1	2.59
Talesun	BISTAR PRO	PERC	182	1/2 cut	72	**545**	21	2.59
Risen	TITAN +	PERC	210	1/2 cut	55	**550**	21	2.61
Trina Solar	Vertex	PERC	210	1/2 cut	55	**550**	21.2	2.61
JinkoSolar	Tiger Pro	PERC	182	1/2 cut	78	**585**	21.4	2.73
Canadian Solar	HiKu6	PERC	182	1/2 cut	78	**590**	21.3	2.77
Talesun	Bistar Pro	PERC	182	1/2 cut	78	**590**	21	2.81
Risen	TITAN +	PERC	210	1/2 cut	60	**600**	21.2	2.83
Trina Solar	Vertex	PERC	210	1/2 cut	60	**605**	21.4	2.83
JinkoSolar	Tiger Pro TR	TOPCon	182	1/2 cut	78	**610**	22.3	2.73
Jolywood	Niwa Super	TOPCon	210	1/2 cut	78	**615**	22.1	2.78
JA Solar	JumboBlue	PERC	210	1/3 cut	80	**800**	20.5	3.92

- 21%+ for PERC modules ; 22%+ for premium TOPCon modules
- **Size of modules from 2.5 up to 2.8 m²**

➡ **Utility-scale powerplant market :**
Obj = reduction of LCOE

How High Power Modules Reduce LCOE

Some presentations available:
JA Solar: https://www.pv-tech.org/products/ja-solars-deepblue-3.0-panels-drive-pv-power-plant-lcoe-down-to-new-levels
Trina Solar: https://www.youtube.com/watch?v=EWuenRVdGIo
Longi: https://www.youtube.com/watch?v=V76nPJvRQCg
Jinko: https://www.pv-tech.org/products/jinkosolars-tiger-pro-modules-designed-to-lead-lcoe-reductions-with-max-580

$$\text{LCOE} = \frac{\text{Cost } (\textbf{Module} + \textbf{e-BOS} + \textbf{s-BOS} + \textbf{EPC} + \text{Soft} + \textbf{O\&M}) - \text{residual value}}{\textbf{Producible}}$$

Qualitative impacts of high power modules on power plant LCOE

Module	lower cost per Watt	higher producible	
e-BOS	less cables	less combiner boxes	less inverters (when lower Voc)
s-BOS	less mounting structures	less land use	more costly fasteners
EPC	less labour (construction/installation)		
O&M	less components		

High power modules
- Large area
- High voltage or High current

Compatibilty issues with rest of PV components:
- Tracker (or fixed structure)
- Inverter

Assessment of LCOE gains

Highly dependant on hypotheses (module, plant location, fixed/tracker, monofacial/bifacial, etc**)**

Calculations made by module producers

Values to be considered as a trend

Study case 1: Deep blue series from JA Solar

158 mm cells
72 cells half cut

S = 2.01 m²
Voc = 50.1V
Isc = 10.4A

166 mm cells
72 cells half cut

S = 2.23 m²
Voc = 49.7V
Isc = 11.4A

182 mm cells
72 cells half cut

S = 2.55 m²
Voc = 49.7V
Isc = 13.4A

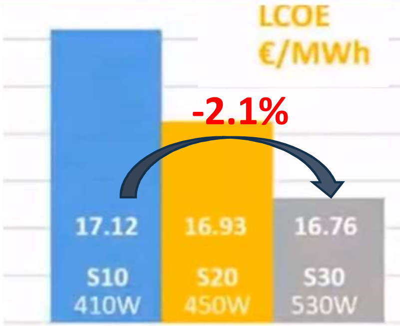
PLANT CHARACTERISTICS

- Same Peak Power 127MWp (106MWn)
- 2P tracker
- String Inverter
- Price parity on modules

	S10 – 410W	S20 – 450W	S30 – 530W
Module Dimensions	2015 x 996 x 40 mm	2120 x 1052 x 40 mm	2260 x 1120 x 40 mm
Number of Modules	311,561	283,989	241,000
Modules Increment	0	-27,572 pcs	-70,561 pcs
Area	154 Ha	153 Ha	141 Ha
Area Increment	0.0%	-0.65%	-8.44%
Number of Trackers	3,462	3,155	2,678
Tracker Increment	0.0%	-8.85%	-22.65%

CASE 1 Heavy Wind Load Conditions

	S10 – 410W	S20 – 450W	S30 – 530W
Tracker Cost	+2.2%	0%	+1.0%
LCOE	0%	-1.13%	-2.08%



CASE 1 100MW PV Plant
Heavy Wind Load Conditions
Cadiz, Spain (139km/h)

- Edge trackers are shorters to comply with EUROCODE
- Fasteners shall be longer to whitstand same mechanical loads

CASE 2 Normal Wind Load Conditions

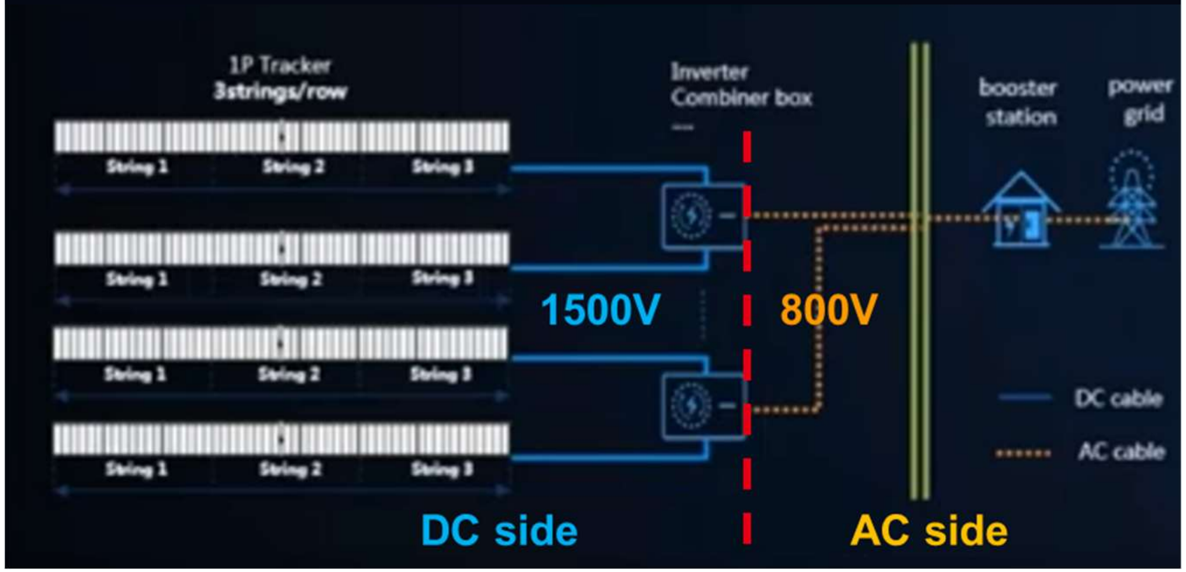
	S10 – 410W	S20 – 450W	S30 – 530W
Tracker Cost	+10.9%	+3.9%	0%
LCOE	0%	-1.78%	-3.29%

CASE 2 100MW PV Plant
Normal Wind Load Conditions
Fortaleza, Brasil (108km/h)

- Same length of external/internal trackers
- Massive tracker cost savings
- Less CAPEX improving LCOE

Study case 2: Low voltage Vertex module from Trina Solar

Schematic view of a PV plant



5x11 layout allows to decrease Voc down to 38V (vs 50V for 72 cells layout)

$$P_S = P_M * N = P_M * \frac{1500}{V_{OC}[1+(t-25)*K_V]}$$

P_S : String power
P_M : Module power
N : Module pcs per string
V_{OC} : Open circuit voltage
K_V : Voc temperature coefficient

Module	Module Quantity/String	Per Module Power	Total Power per String
Trina Solar VERTEX 550W series	36	550W (Voc =38.1V)	19800W
Reference Module	27	540W (Voc = 49.7V)	14580W

+36%

BOS and LCOE savings assessment

Project site : Texas, US Latitude: 34.36° Longitude: -99.89°

Annual GHI: 1,865 kWh/m2 Average temperature: 17.5°C

Project size : 100MW

String inverter, 1P tracker design

Module price is assumed to be the same for comparison.

Bi-facial	535	545
String	26pcs/String	35pcs/String
BOS $/kwh	0.6015	0.5625
BOS	Base case	-6.49%
LCOE $/kwh	0.0434	0.0418
LCOE	Base case	-3.78%

*The result is highly dependent on the input assumptions, and should not be taken as a guidance for specific projects

Combining savings from high power and low voltage → -6 to -8% LCOE

Massive adoption of large area wafers and high power modules by PV industry will contribute to further decrease LCOE of PV plants …

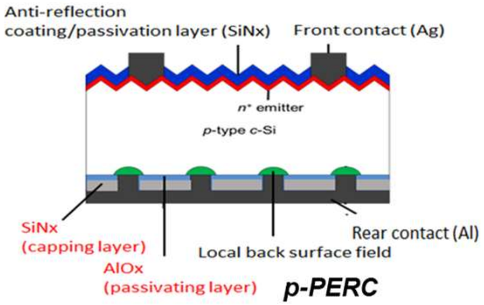
It requires adaptations/modifications of:

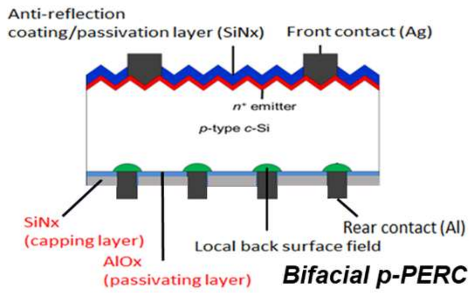
- Mono-Cz Ingot pullers and wafering equipments
- Cell and module fab lines
- Glass and foil sizes
- Mounting structures
- Fasteners
- Inverters
- Plant design
- Installation procedures

…. Bifaciality and high efficiency matter also

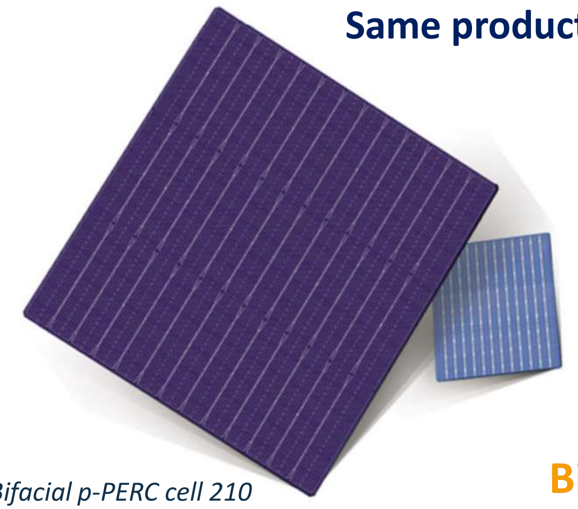
Bifacial Cells and Modules

PERC cell structure makes bifaciality easy

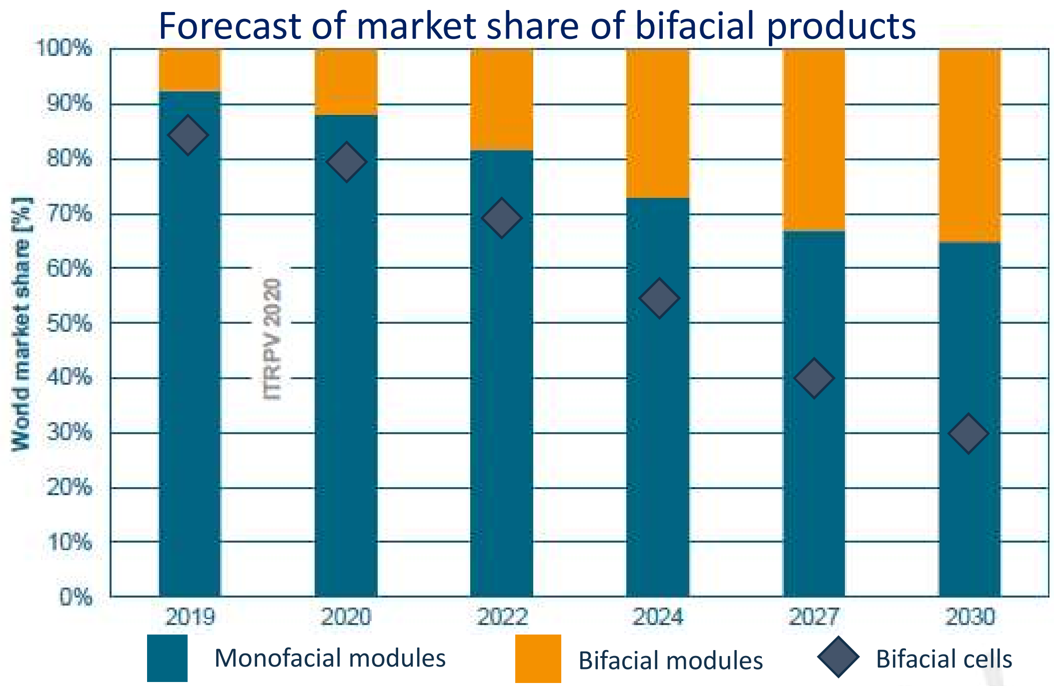




Same production cost



Bifacial p-PERC cell 210 mm (Aikosolar)



Bifacial modules will develop in PV plant market

What bifacial gain can be expe

C. Deline et al, PVSC-46, Chicago, IL 2019

Bifacial Plus Tracking Boosts Solar Energy Yield by 27 Percent

Recent testing shows bifacial PERC modules can significantly increase energy yields.

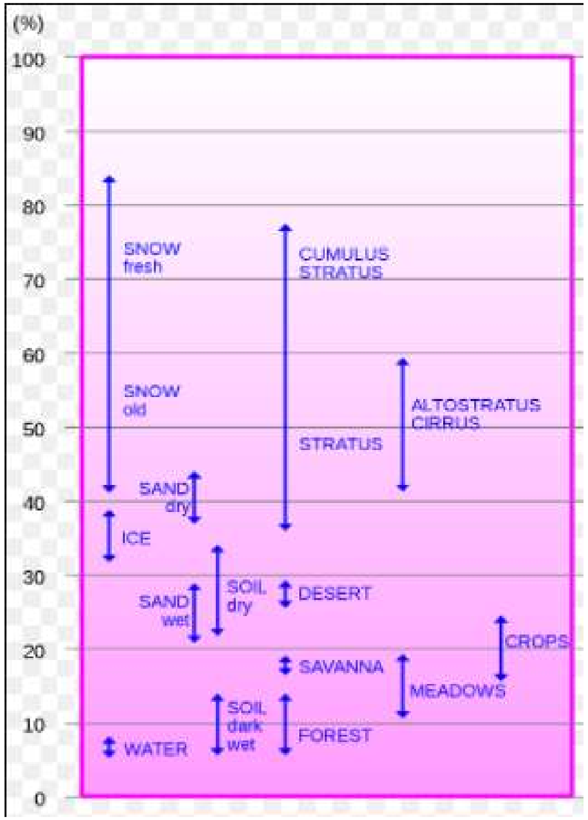
GTM CREATIVE STRATEGIES | APRIL 18, 2018

Bifacial energy gain BG_E

$$= E_{Bifacial}/E_{Mono} - 1$$

$$= ??$$

albedo of various surfaces

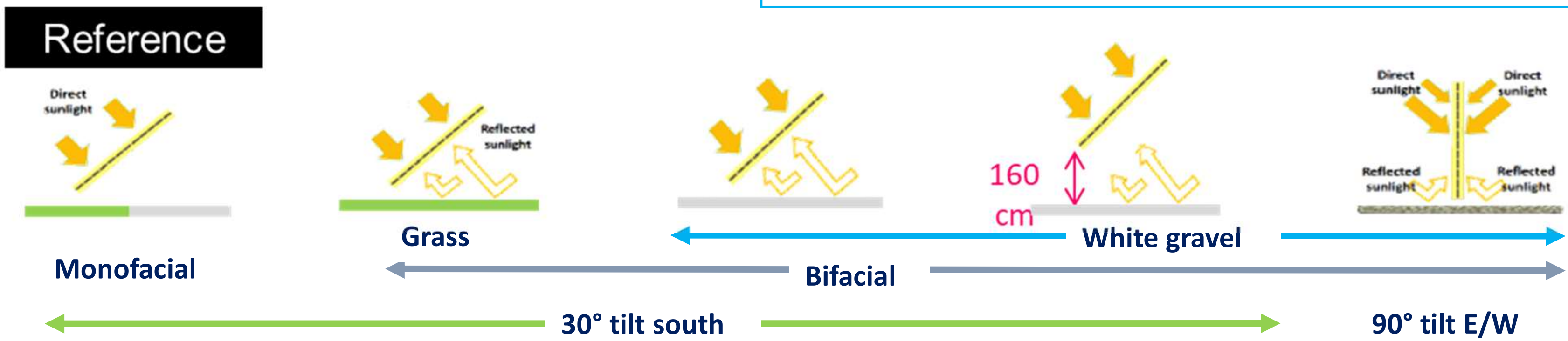


Many values circulate (too optimistic?)
Depending on irradiation cdts and albedo

Bifacial gain assessment

Bifacial gain measured at INES on 3kW systems
fixed mounting
1 year measurements

$$\text{LCOE} = \frac{\text{Cost } (\textbf{Module} + \textbf{e-BOS} + \textbf{s-BOS} + \textbf{EPC} + \text{Soft} + \textbf{O\&M}) - \text{residual value}}{\textbf{Producible}}$$



Bifacial gain	+10%	+12%	+19%	-10%

LCOE savings (=, for +10% and +12%)

LCOE savings < 19%
(higher s-BOS cost)

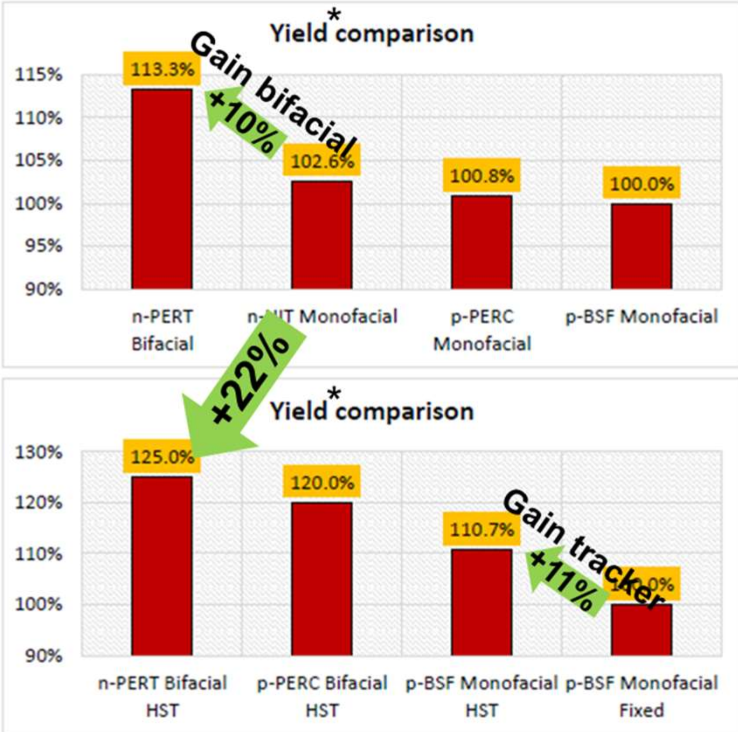
Bifacial + tracker gain

Combining bifacial gain and tracking gain? At what extent?

Longi has communicated on 27% overall gain when combining bifacial PERC modules and 1 axis tracker (HSAT)

Qinghai Gonghe Demo Base 100MW, 2016
(latitude 36° N)

- Use Jolywood bifacial n-PERT modules
- Yield=power generation/installed capacity

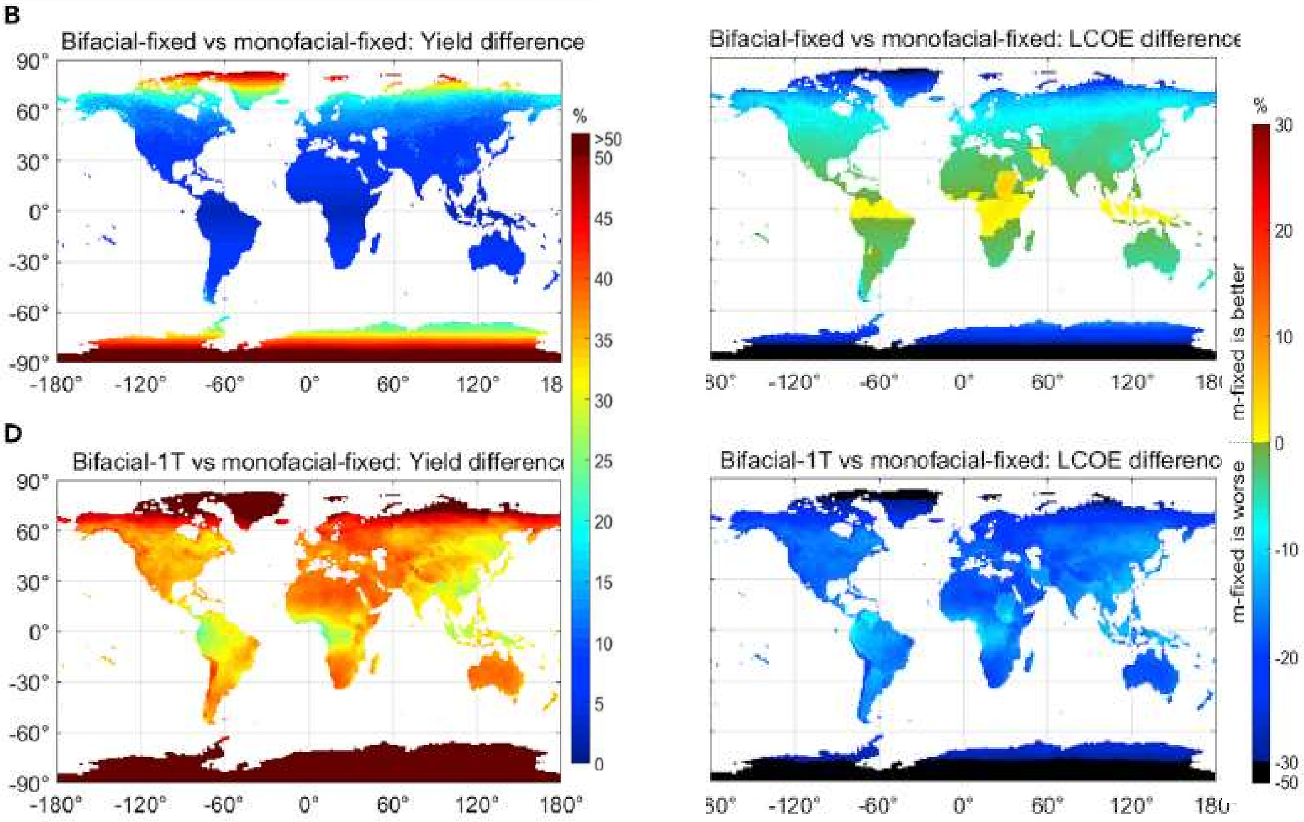


*(Normalized kWh/kW)

Bifacial and tracking gains add up

Global implementation of 'bifacial + tracking' solution

Recent study: Rodriguez-Gallegos et al. Joule 4, 1514-1541 (2020)



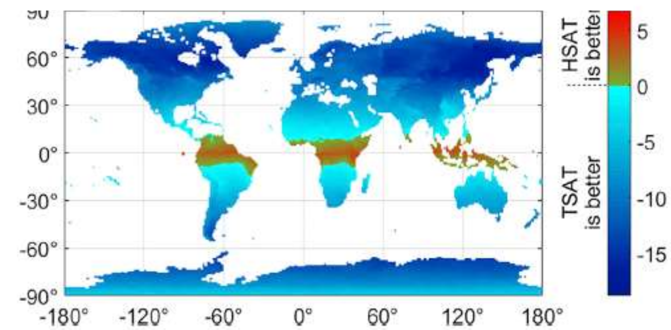
Specific site characteristics can modify deeply the simulation results

Bifacial + Tracking can

- **boost yield by up to 35%**
- **lower LCOE by up to 20%**

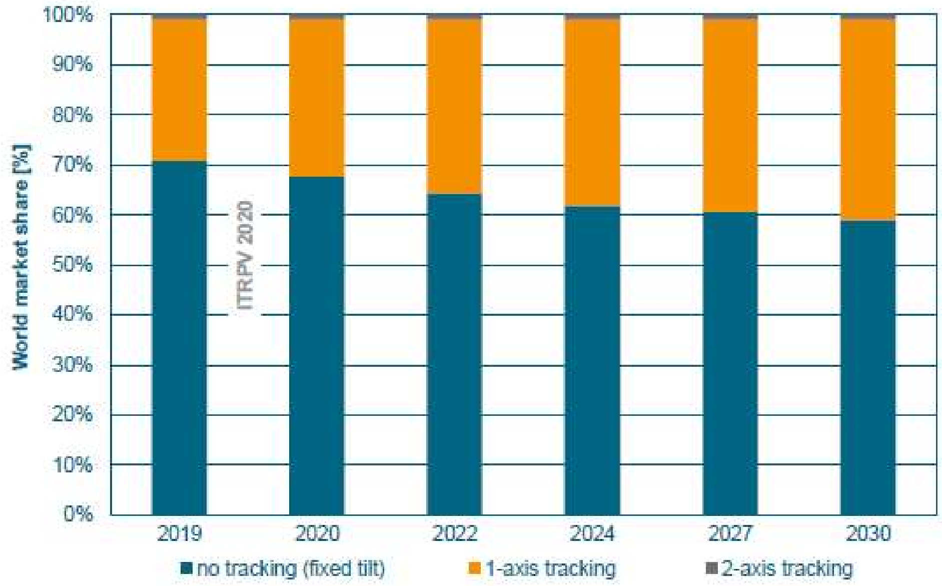
Tilted single axis trackers overperform horizontal trackers except close to equator

Bifacial TSAT vs bifacial HSAT: Energy yield difference



Solar Tracker's Market Outlook

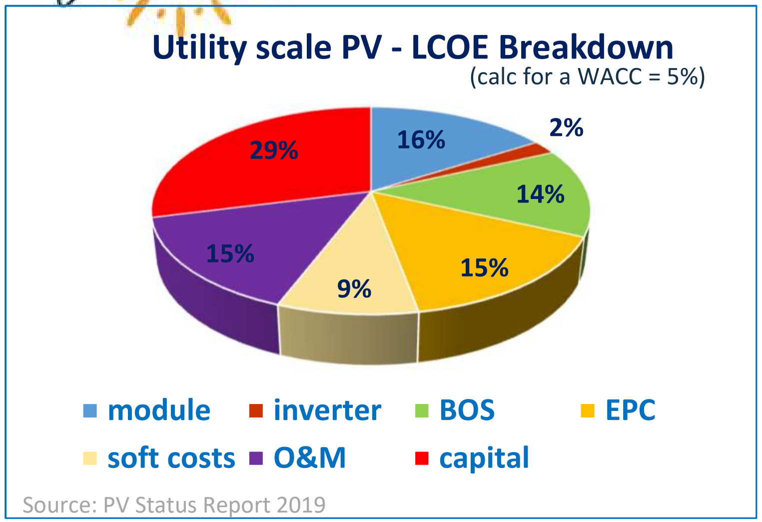
Tracking systems for c-Si PV



1-axis tracking has a market share of 30%

Share of 40% is projected for 2030
(appears conservative when looking on potential gains)

Positioning GOPV Developments



GOPV General/societal objectives

- Reduction of the cost of PV electricity for increasing its competitiveness and its share in the European electricity mix
- Creation of added value for European industrial players to be competitive on the global market

GOPV quantified objectives at system level

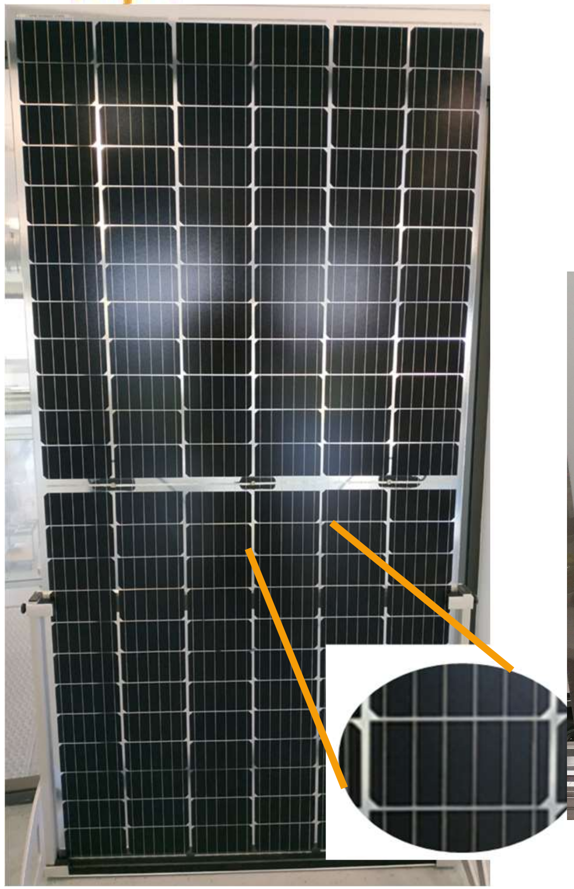
Underlying objectives	Target	Baseline (§2.1.1)	GOPV Gain
Annual energy production rate	2360 kWh (AC)/KW	1700 kWh(AC)/kWp	+39 %
Service lifetime	35 years (1 inverter change)	25 years (2 inverter changes)	+10 years
CAPEX (excl. EPC)	0.38 €/W	0.47 €/W [9]	- 0.09 €/W
OPEX	10 c€/W/year	12 c€/W/year	- 2 c€/ kWp/year
Overall objectives	Target	Baseline	GOPV Gain
LCOE	0.02 €/kWh	0.04 €/kWh	- 0,02 €/kWh
EPBT (module)	1 year	1.4 years	-40 %

for GHI= 1900 kWh/m²/year

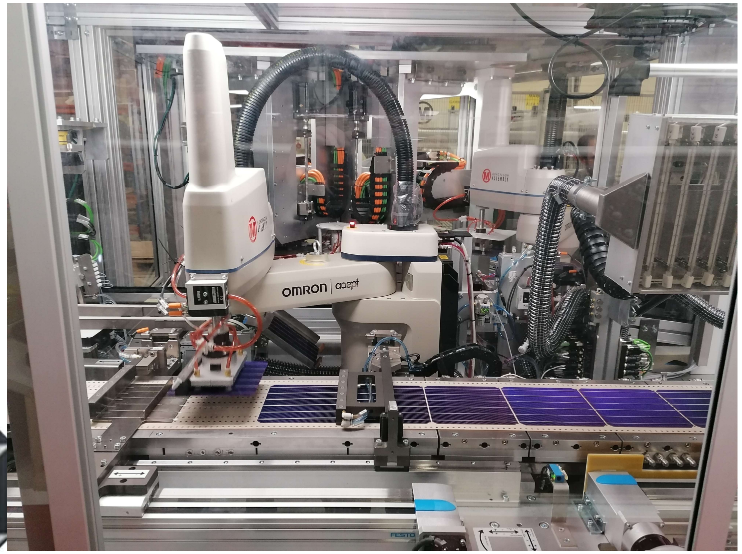
Development of advanced components

PV plant cost element	GOPV developed component	Main characteristics	Targeted cost	Targeted lifetime
Module	Bifacial HJT modules	400W + bifaciality ≥ 90%	0,22€/W	35 years
Tracker	1 axis tracker	Built with alternative materials to hot dip galvanized Steel	0,11€/W	35 years
Inverter	SiC based string inverter	166 kVA + Energy efficiency ≥ 99%	0,04€/W	17.5 years
O&M	Advanced fault detection & diagnostics tool	Energy availability ≥ 99.5%	10k€/MW/Year	-

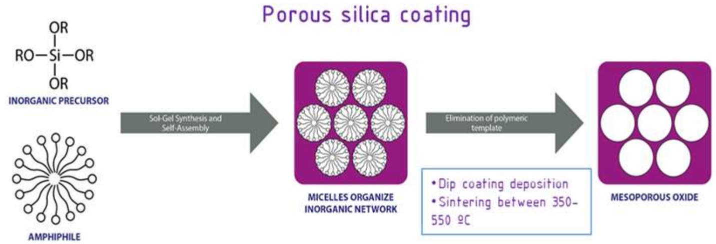
GOPV Module



- Bifacial HJT module 72 cells layout (M2): 370W
- Cell thickness: 120 μm; Ag per cell: 140 mg; 6 BB
- Cell interconnection by glueing technology
- ECA per half-cell: 30 mg (ribbon width: 0.8 mm)
- Industrial stringer prototype



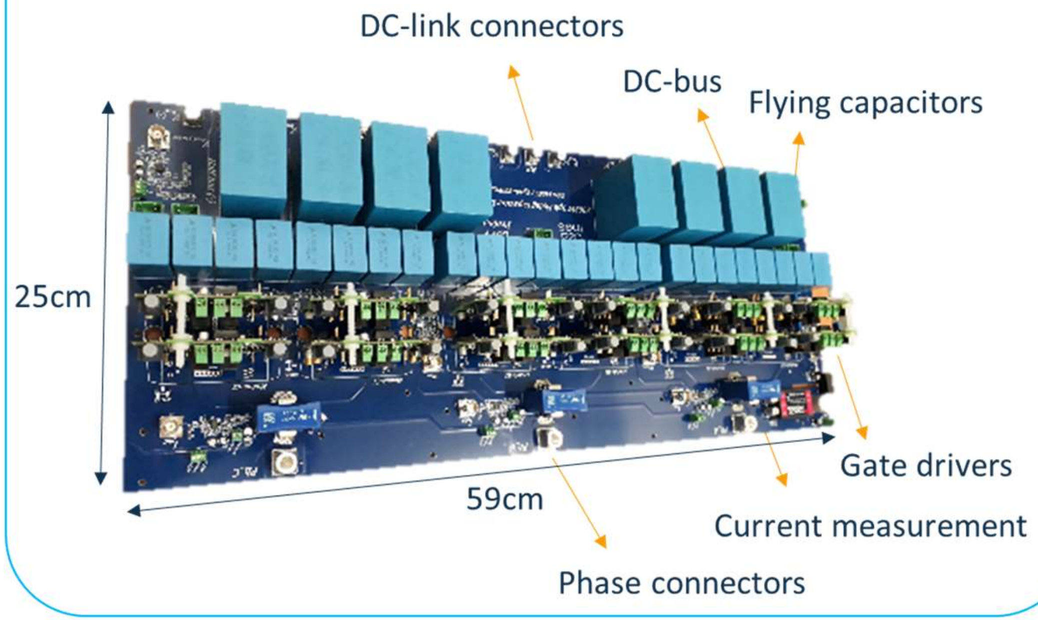
- Glass-glass encapsulation
- AR/AS coating : Closed-cell mesoporous silica



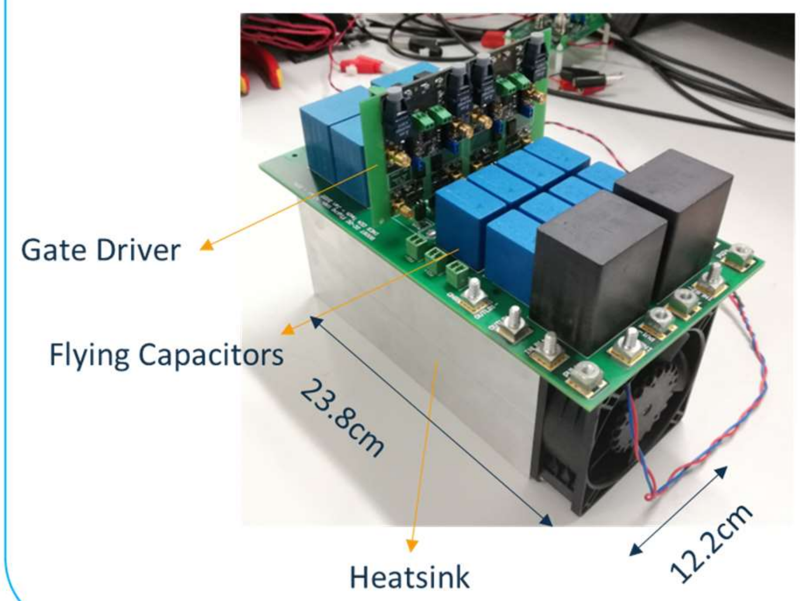
GOPV Inverter

166kVA multi-MPPT Inverter base on Flying Capacitor topology

DC/AC Power Board



DC/DC Power Board



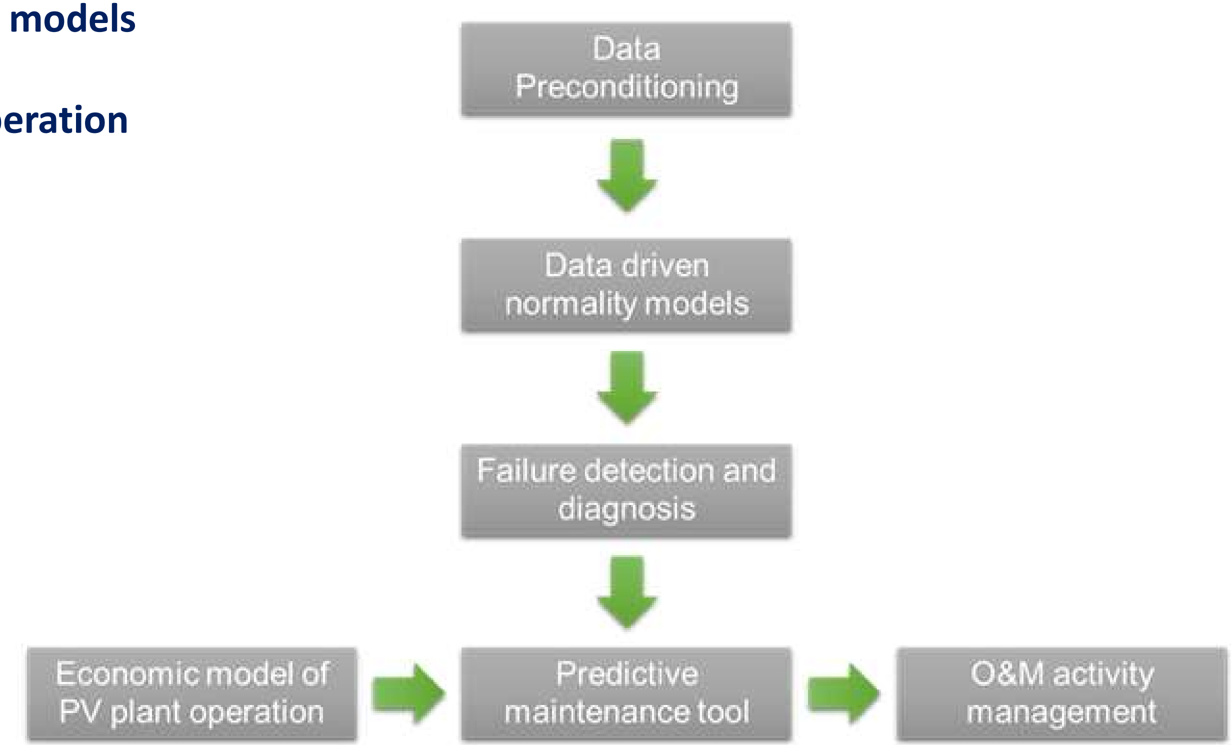
Up to 1500V_{OC} PV string, inject full power on 800V 3~ grid (600V and 690V 3~ grids @ reduced power)
Multi MPPT: 2 PV strings per MPPT, 8 MPPT in parallel (=16 strings)
Integrate SiC devices

GOPV Tracker

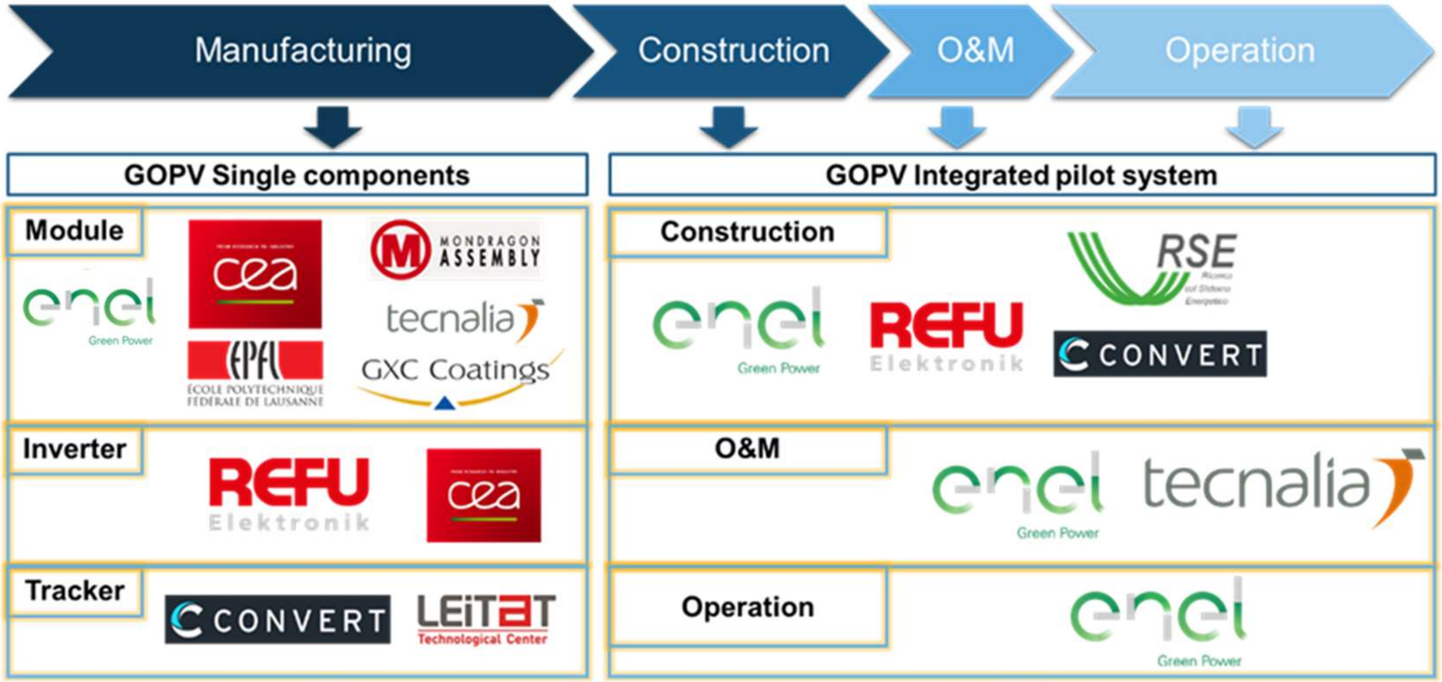
2P 1-axis tracker (HSAT)
28 modules /tracker
Tracker structure from Weathering Steel (vs Hot Dip Galvanized steel for std)
Module support from WS and/or GFRP (Glass Fiber Reinforced Polymer)
Structural behaviour validated by wind tunnel tests

GOPV O&M Toolkit

- **Failure detection and diagnosis models**
- **Predictive maintenance tool**
- **Economic model of PV plant operation**



GOPV Partnership



GLOBAL OPTIMIZATION OF INTEGRATED PHOTOVOLTAIC SYSTEM FOR LOW ELECTRICITY COST

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792059

Thank you for your attention!

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