UNA SOLA TIERRA

EXPOSICIÓN DÍA DEL MEDIO AMBIENTE 2022

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ENERGÍAS RENOVABLES EN PUERTOS

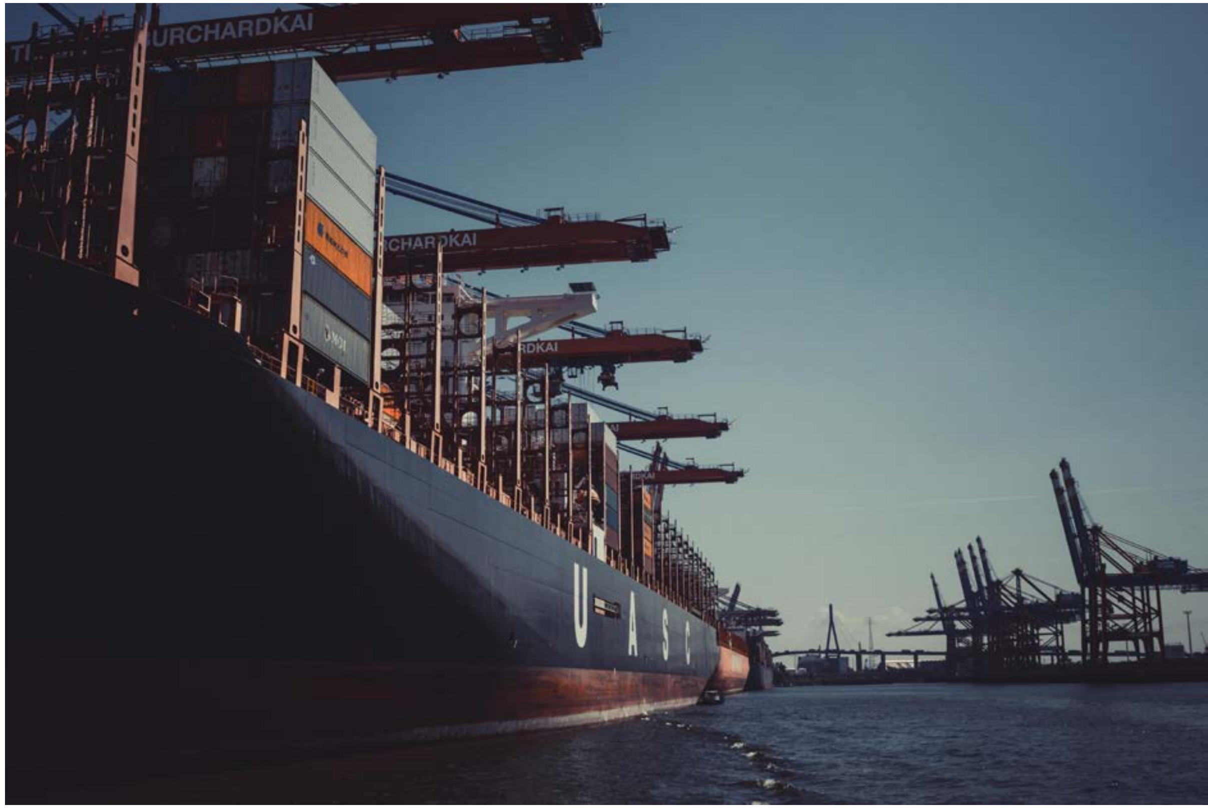
Fotovoltaica: pasado, presente y futuro

Dr. Delfina Muñoz

Delfina Muñoz is strategic project manager and senior researcher at CEA-INES.

She started the heterojunction solar cells adventure in 2004 during her PhD and since then, she has been working in research, development and technological transfer of the photovoltaic technology.

Today, she combines advanced research on sustainable advanced technologies for PV with management of European and Chilean projects and participates actively in the European network supporting the deployment of photovoltaics.



Photovoltaics: past, present and future

Dr. Delfina Muñoz
Responsable de proyectos estrátegicos
Investigadora principal en celdas y módulos fotovoltaicos de heterounion

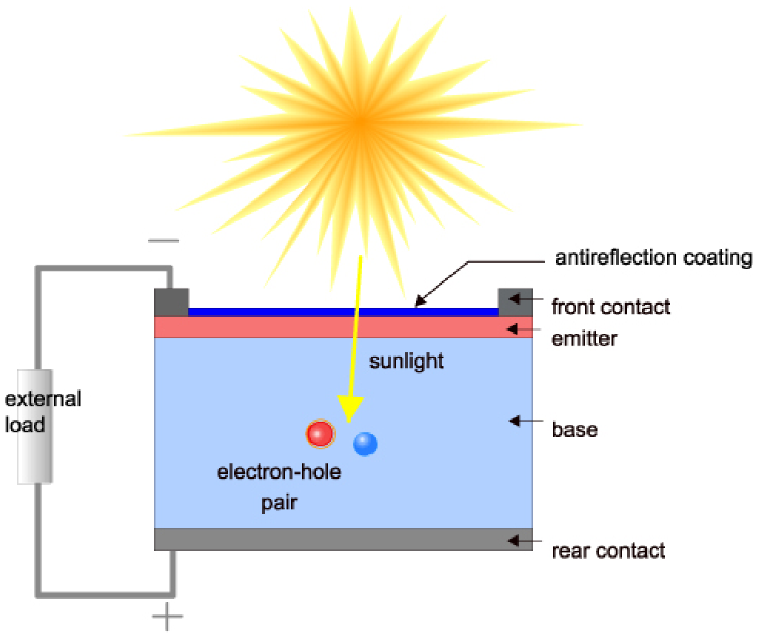
INSTITUT NATIONAL
DE L'ENERGIE SOLAIRE

OUTLOOK

Photovoltaics

Past before 2020	Present 2020-2025	Future after 2025
How to make it work and cost competitive?	Photovoltaics a a whole How to deal with?	How to make it sustainable, everywhere and for everyone?

PHOTOVOTAICS: THE BEGINNING OF THE STORY



1954 Crystalline silicon solar cells the new born

A New Silicon *p-n* Junction Photocell for Converting Solar Radiation into Electrical Power

D. M. Chapin, C. S. Fuller, and G. L. Pearson
Bell Telephone Laboratories, Inc., Murray Hill, New Jersey

(Received January 11, 1954)

THE direct conversion of solar radiation into electrical power by means of a photocell appears more promising as a result of recent work on silicon *p-n* junctions. Because the radiant energy is used without first being converted to heat, the theoretical efficiency is high.

Photons of 1.02 electron volts ($\lambda=1.2$ microns) are able to produce electron-hole pairs in silicon. In the presence of a *p-n* barrier, these electron-hole pairs are separated and made to do work in an external circuit. All of the light of wavelength shorter than 1.2 microns is potentially useful for generating electron-hole pairs but the efficiency of energy conversion decreases for short wavelengths because the energy above the necessary 1.02 electron

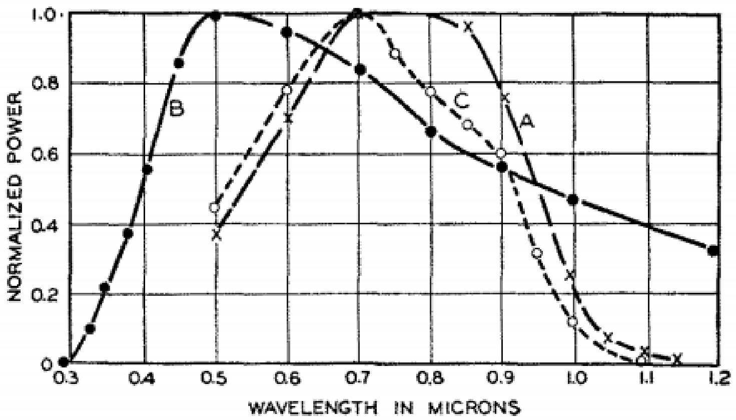


Fig. 1. Normalized spectral energy distribution. (A) Silicon photocell equi-energy response. (B) Solar energy at earth's surface. (C) Curve *A* times Curve *B*.

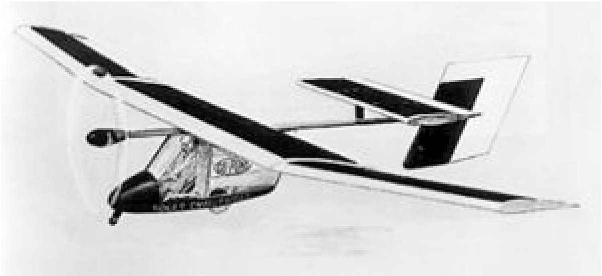
PHOTOVOTAICS: FIRST PRODUCTION AND APPLICATIONS

1963: Sharp produces first commercial Si modules 8.8% efficiency

1973: Worldwide oil crisis spurs many nations to consider renewable energy including PV

1978 : World production of $1MW_p$

1981: Paul MacCready built Solar Challenger, the first aircraft to run on solar power, and flew it across the English Channel from France to the U.K



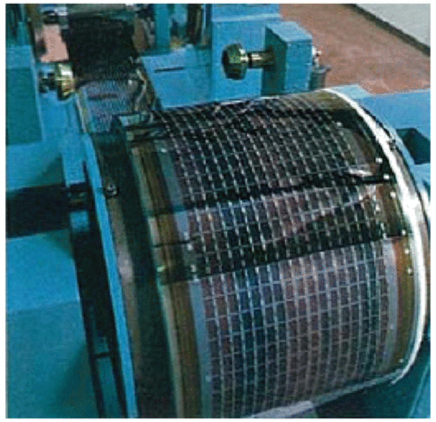
A drawing of the Solar Challenger

History of Contribution of Photovoltaic Cells to Telecommunications

Junji Hirokane*, Tatsuo Saga*, Tetsuroh Muramatsu*, and Isao Shirakawa**

* Solar Systems Development Group, Sharp Corporation, 282-1 Hajikami, Katsuragi-shi, Nara, 639-2198 Japan

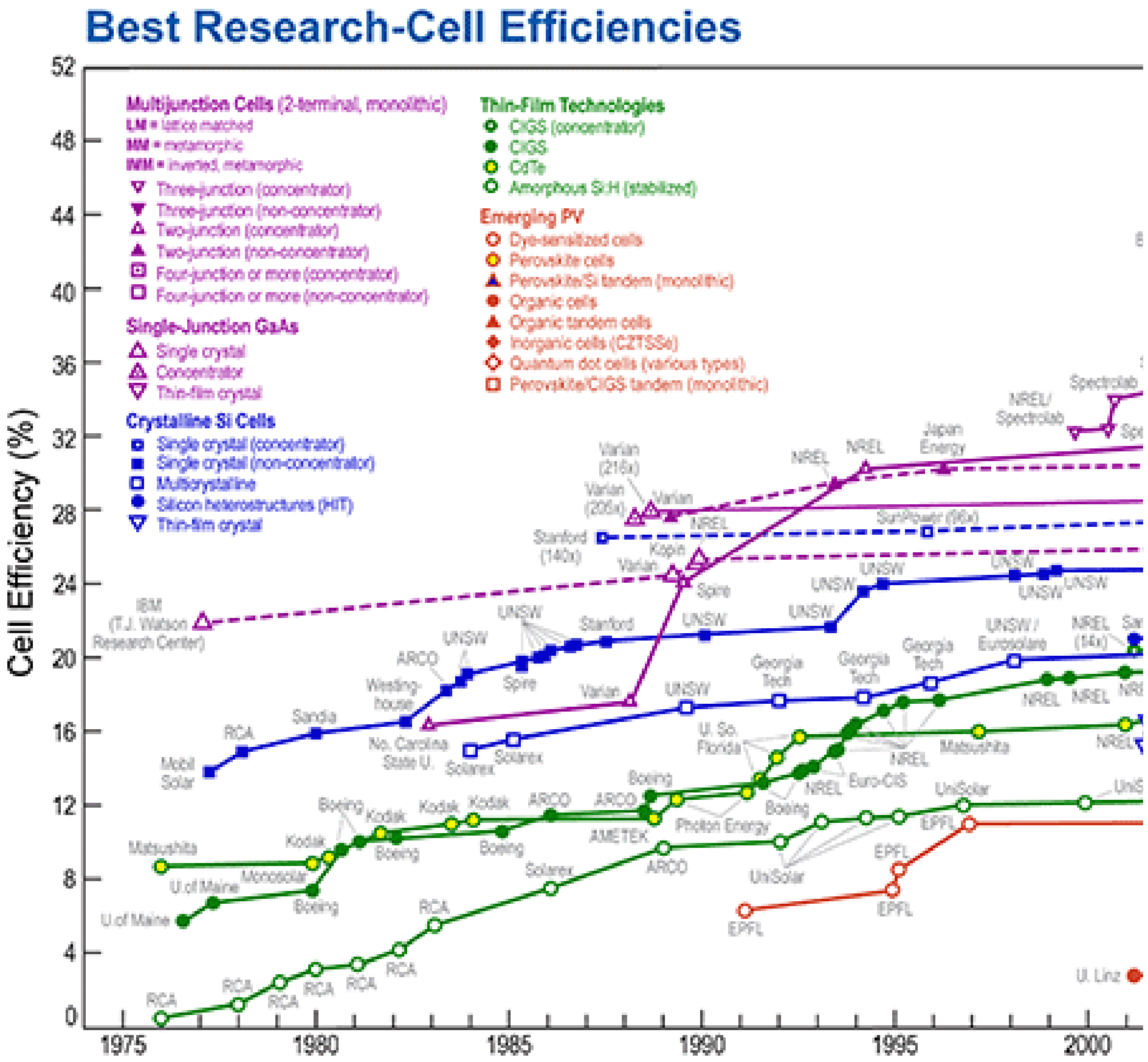
** Graduate School of Applied Informatics, University of Hyogo, 1-3-3 HigasiKawasaki-cho, Chuo-ku, Kobe, 650-0044 Japan



1983 First roll-to-roll cells by Sharp

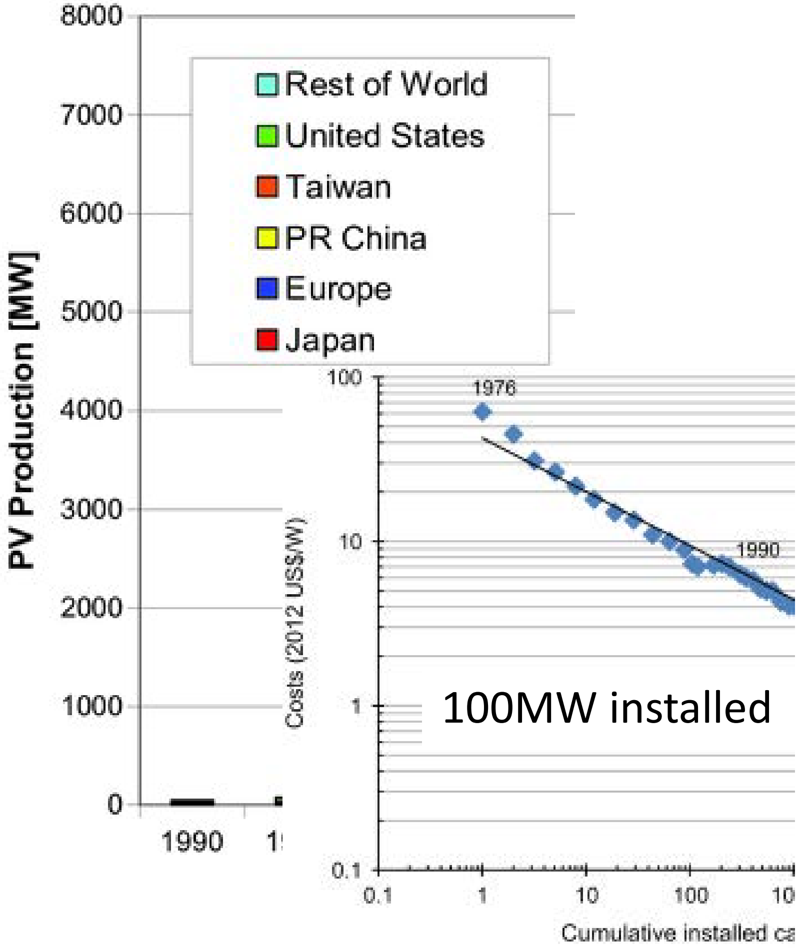
Ogami-Jima Lighthouse of output 238W, the world's largest as of 1966.

PHOTOVOTAICS: ALWAYS IMPROVING, DIFFERENT TECHNOLOGIES



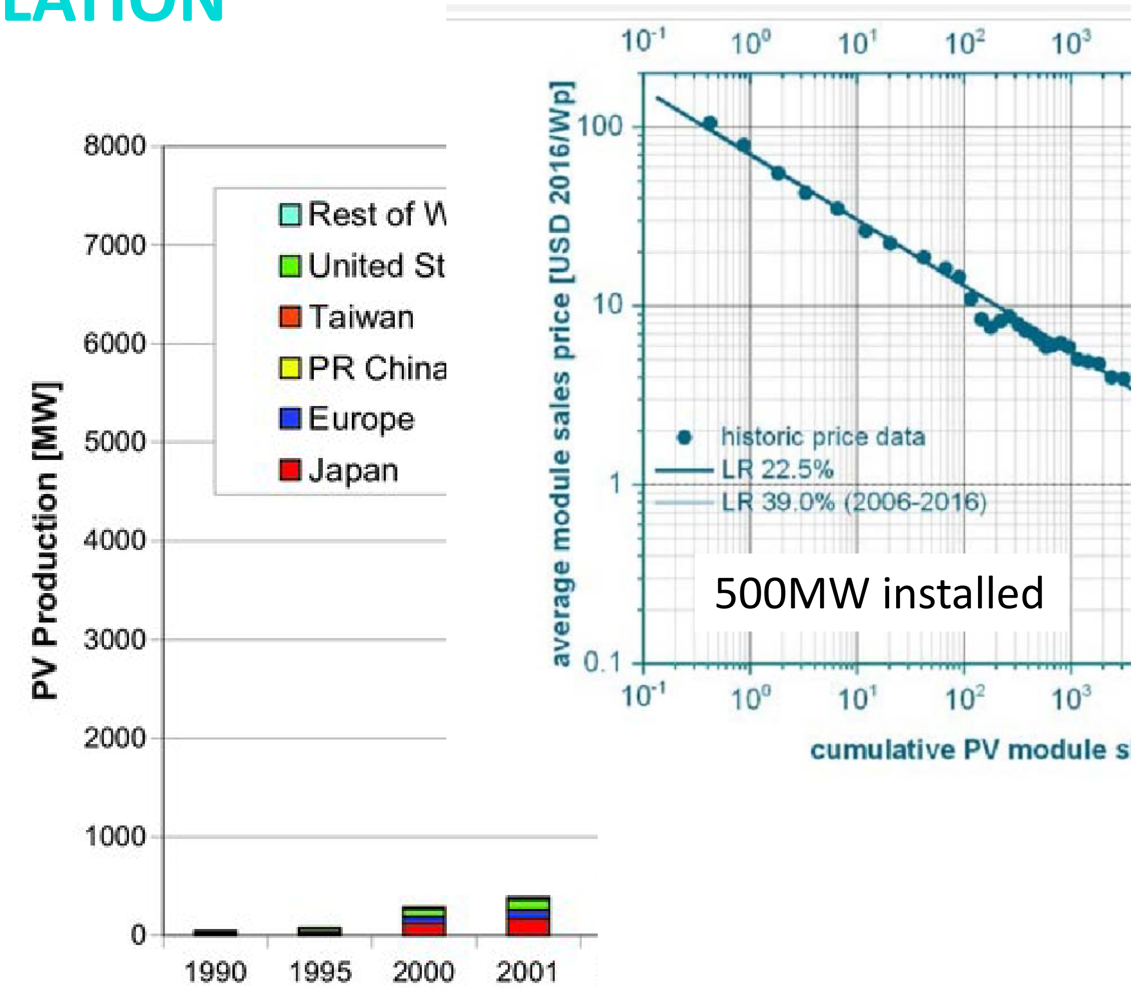
- C-Si technologies for land Applications
- III/V technologies for Space Applications
- Thin film and emerging technologies for niche applications

PHOTOVOLTAICS: CAPACITY AND INSTALLATION



100MW installed

5 years:
Production x 5



500MW installed

Renewable Energy Snapshots 2009 Book
Office for Official Publications of the European Communities

PHOTOVOLTAICS: CAPACITY AND INSTALLATION

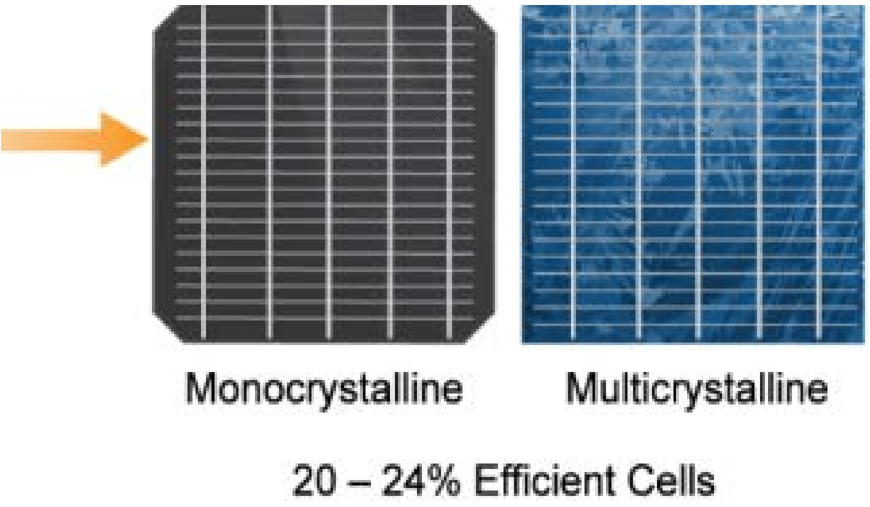
Multicrystalline plant on fixed structures

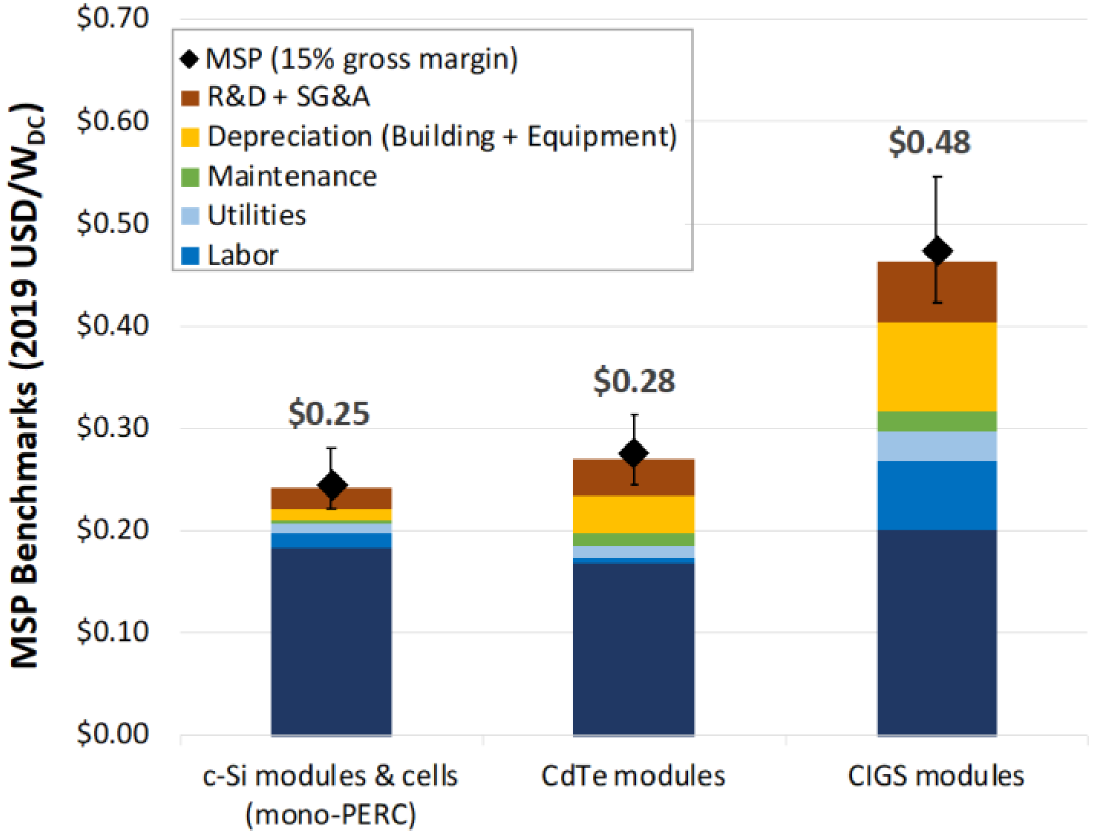
Rooftop installation

Isolated areas applications

PHOTOVOLTAICS IN 2020: EFFICIENCY AND COST

Efficiency



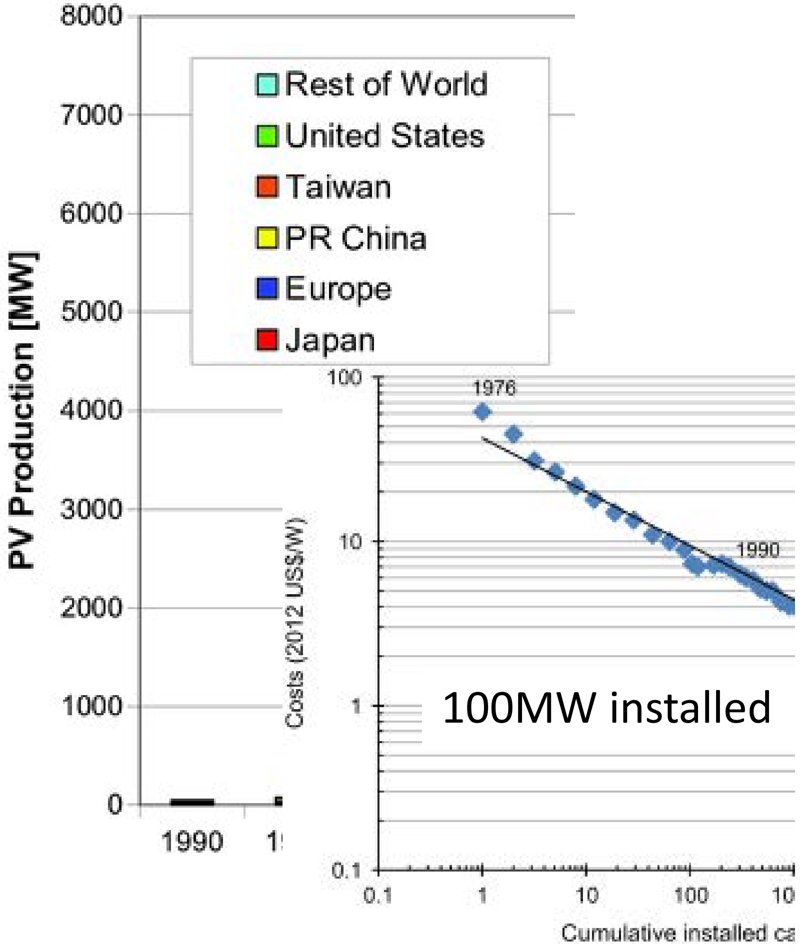


DC = direct current, R&D = research and development, SG&A = sales, general, and administrative, USD = U.S. dollars.

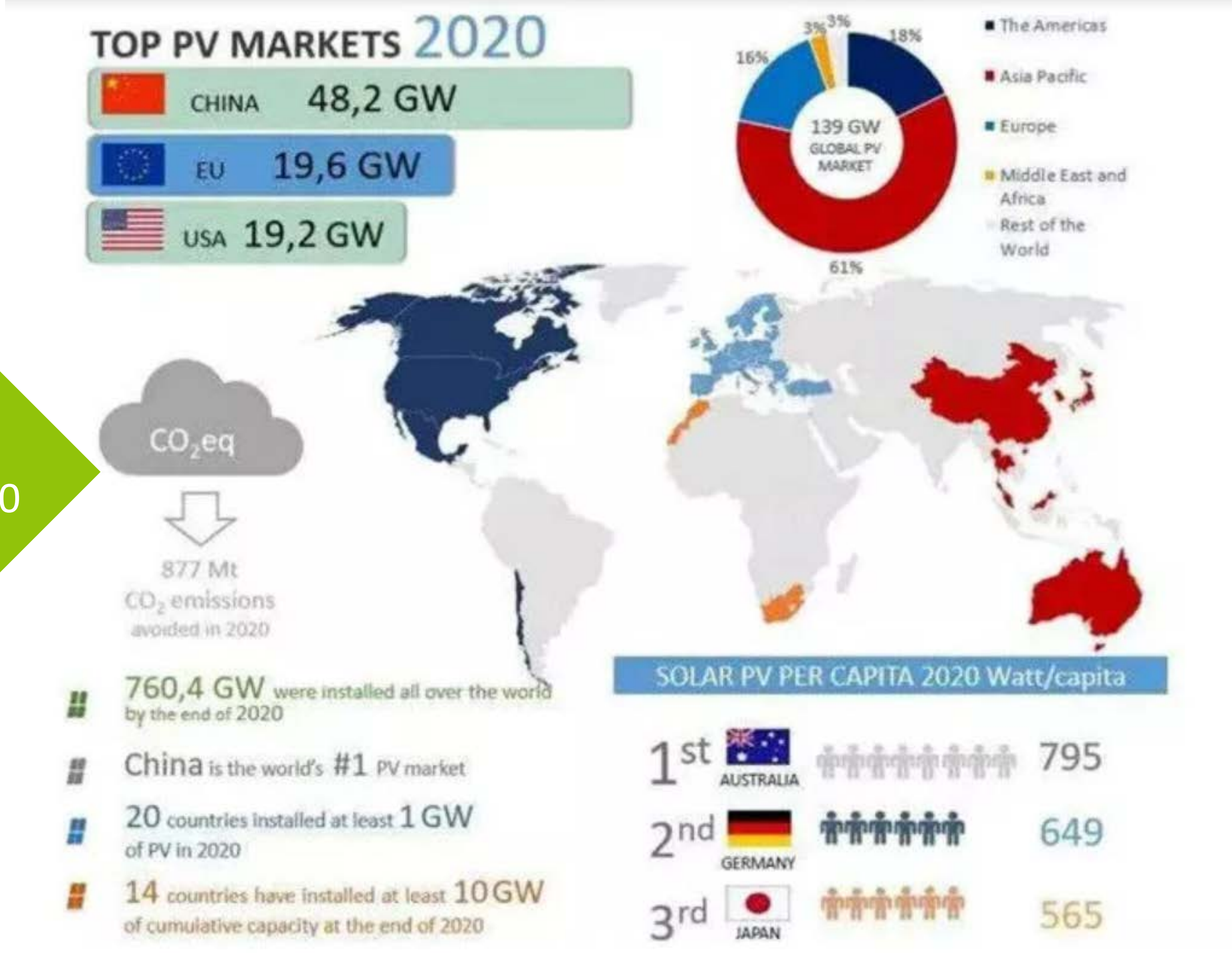
Figure ES-1. Summary of module MSPs for established PV technologies, 2020

https://www.nrel.gov/docs/fy22osti/78173.pdf

PHOTOVOLTAICS: CAPACITY AND INSTALLATION



30 years:
Production x 7600



Renewable Energy Snapshots 2009 Book
Office for Official Publications of the European Communities

PHOTOVOLTAICS: CAPACITY AND INSTALLATION

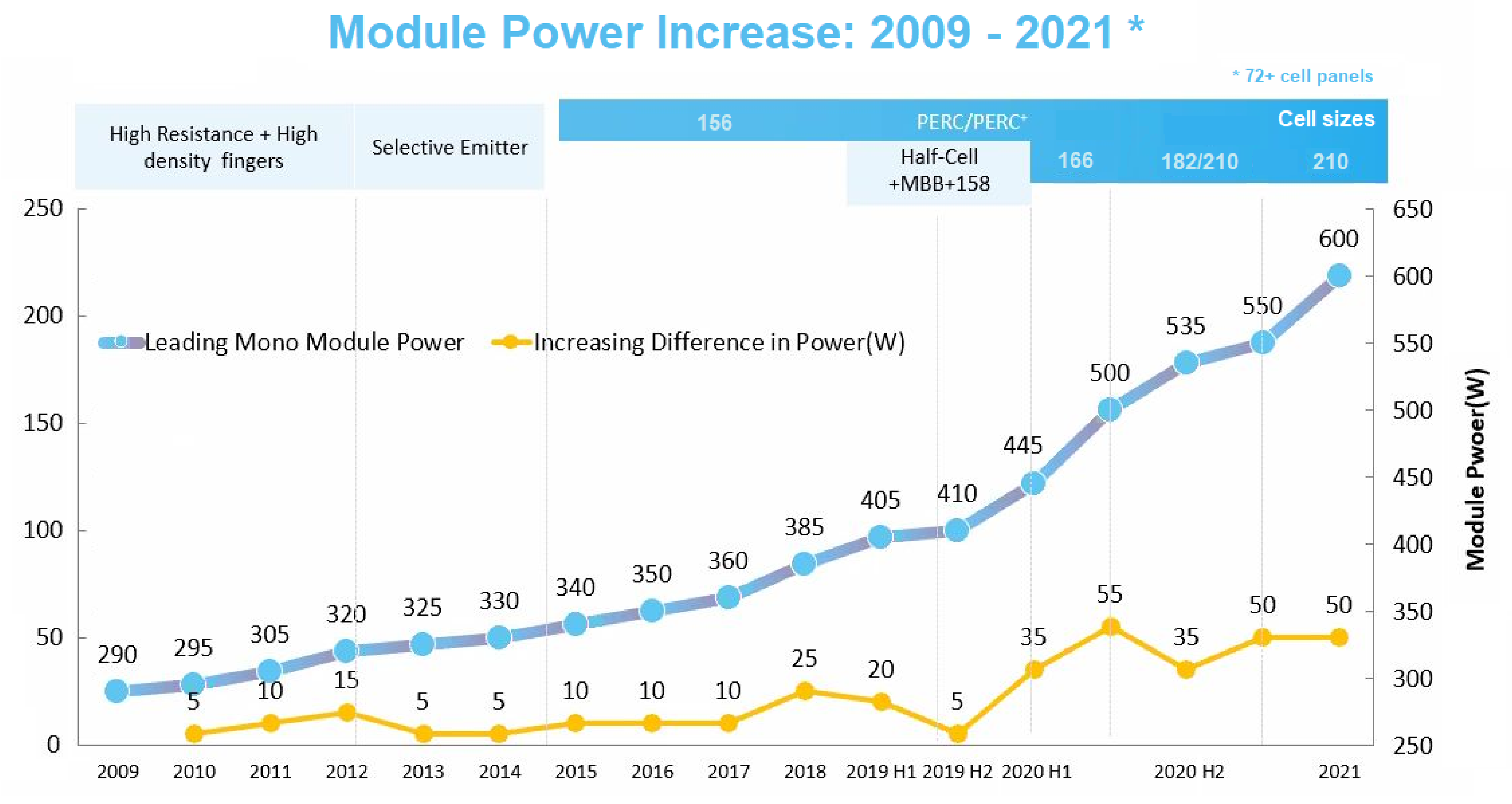
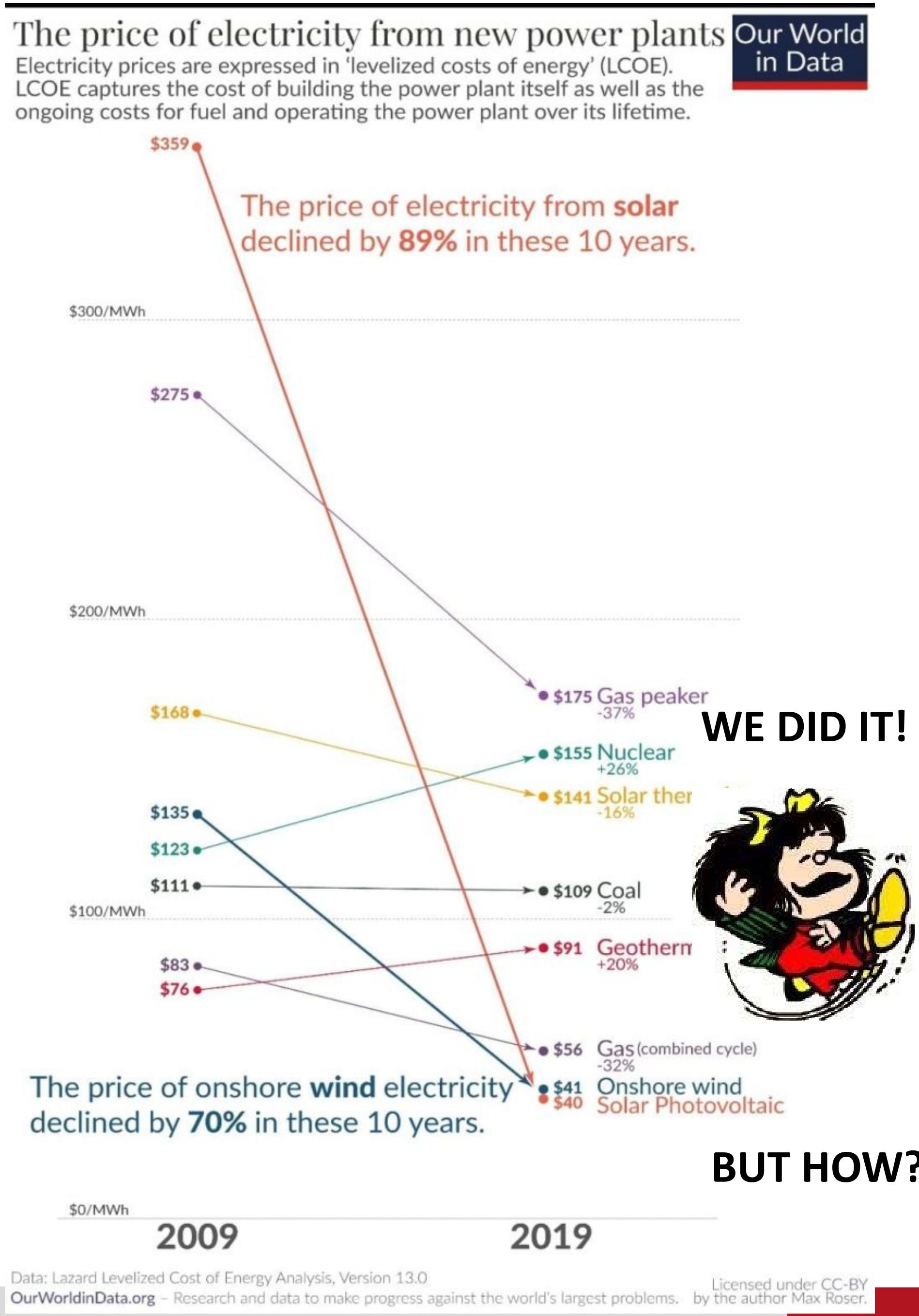


Image credit: Trina Solar

STATUS IN 2020

- Production mainly in Asia (>90%)
- Mostly solar cell PERC technology (>90%)
- Monofacial systems (Glass-Backsheet)
- Same technology for almost all systems
- Reliability around 20 years
- Standard systems: fixed and 1 axe tracker
- Competitive Price of epectricity!
- Production capacity and value chain for manufacturing
- Module power achieves 400W



WE DID IT!

BUT HOW?

PHOTOVOLTAICS: AFTER 2020 PRESENT

New keywords appearing into the PV ecosystem

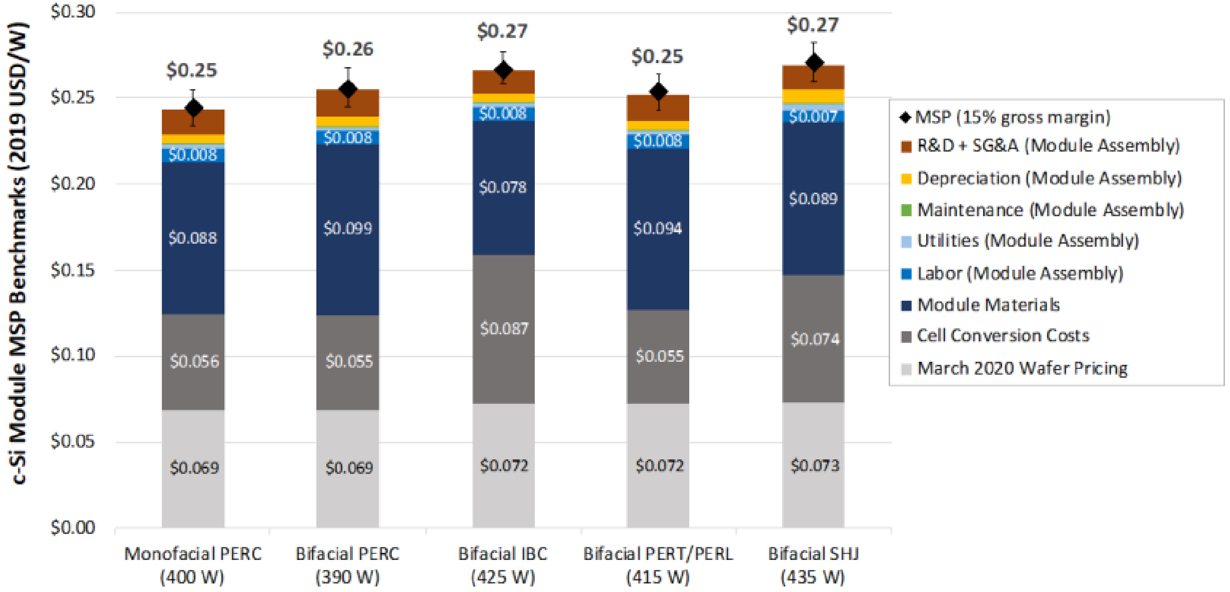
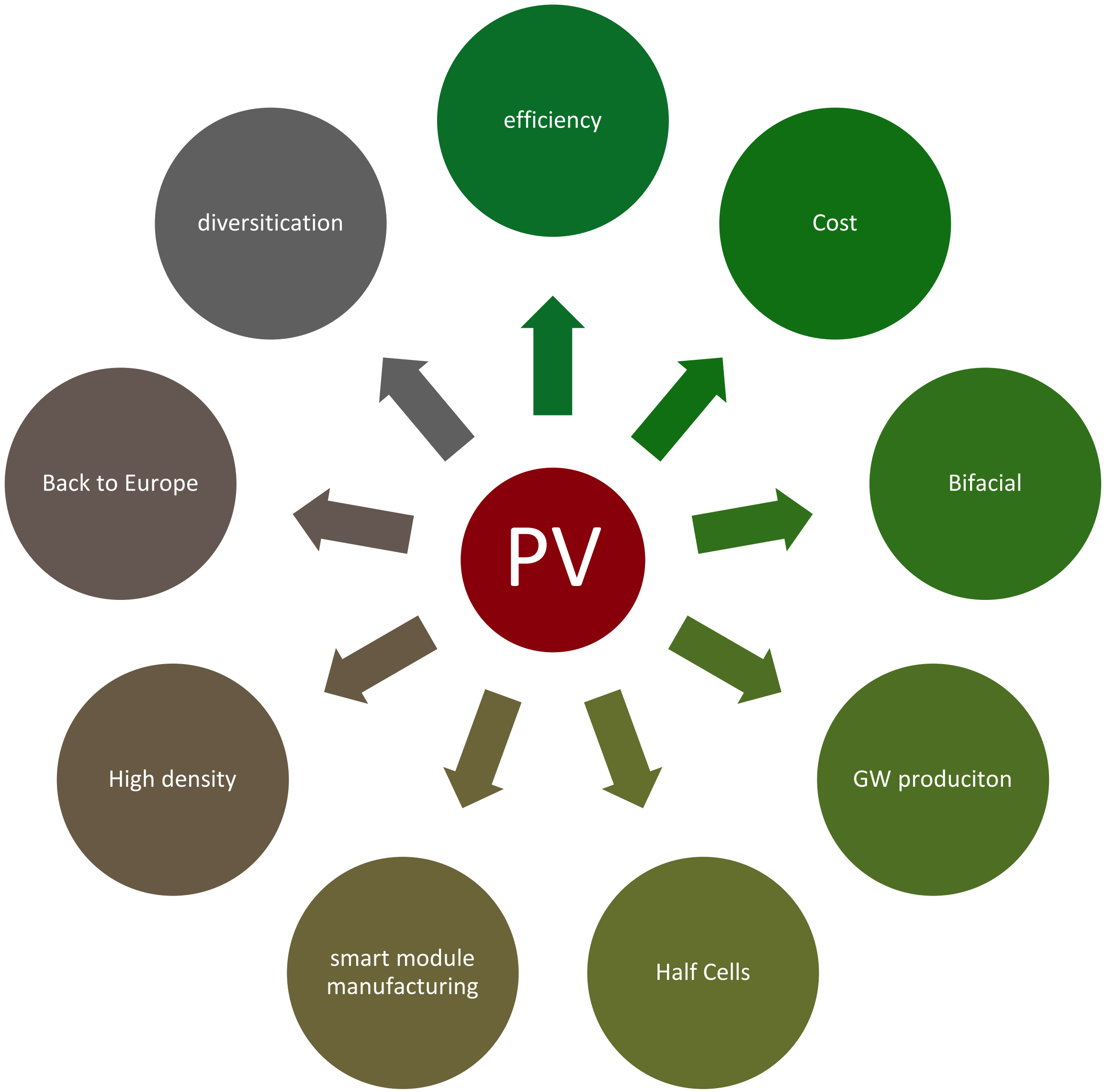
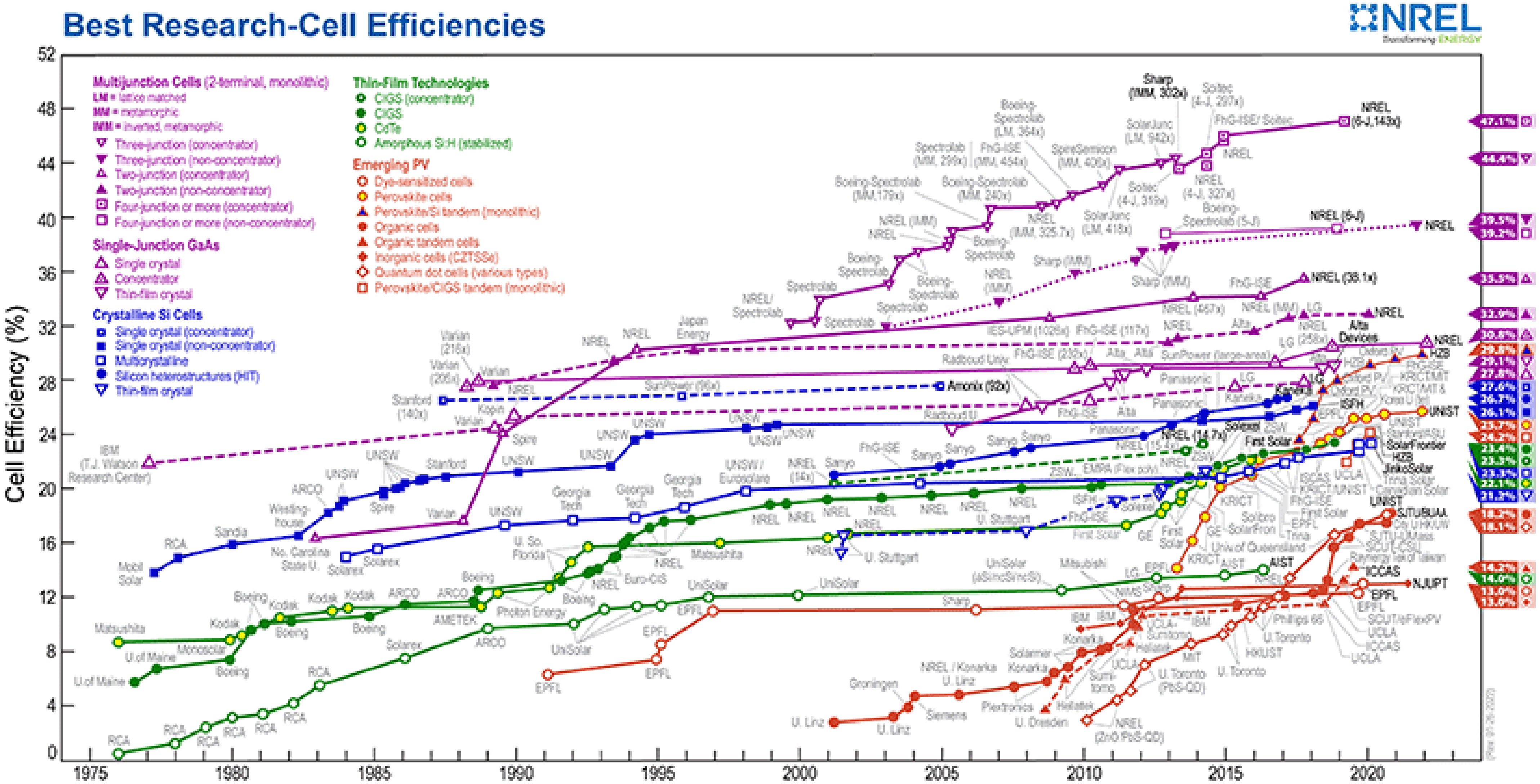


Figure 12. c-Si PV module MSP benchmarks by cell technology, 2020



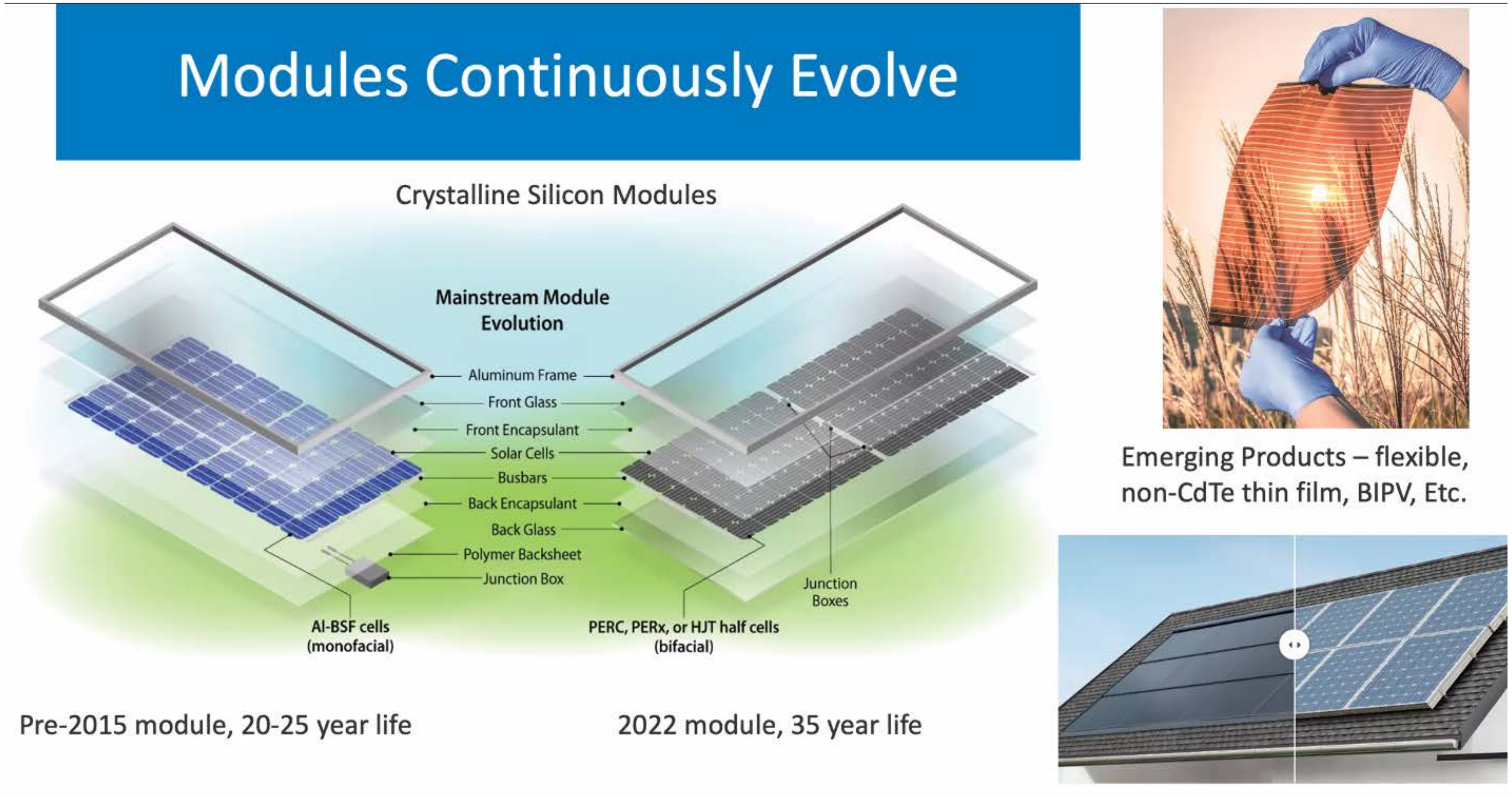
PHOTOVOLTAICS: AFTER 2020 PRESENT

ALWAYS IMPROVING, DIFFERENT TECHNOLOGIES



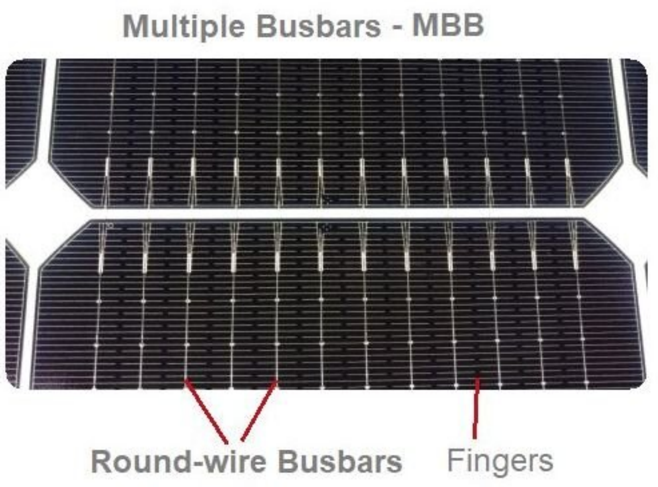
PHOTOVOLTAICS: AFTER 2020 PRESENT

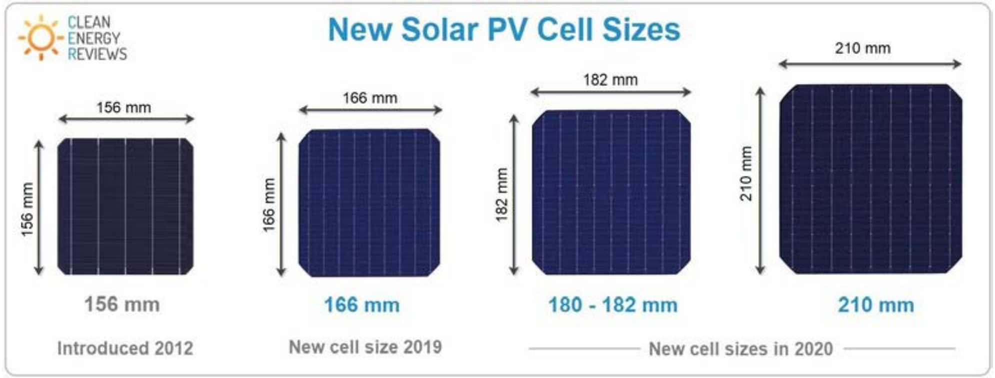
- New bifacial modules improving reliability, flexible, starting diversitication

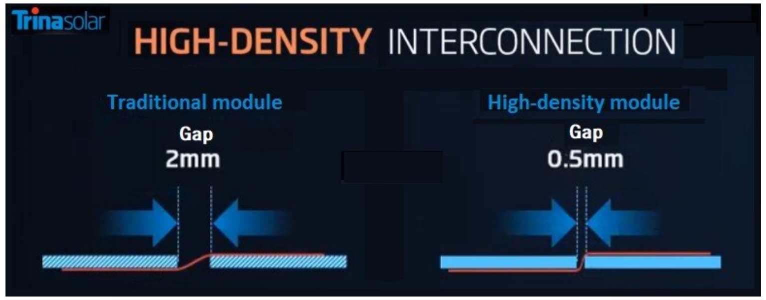


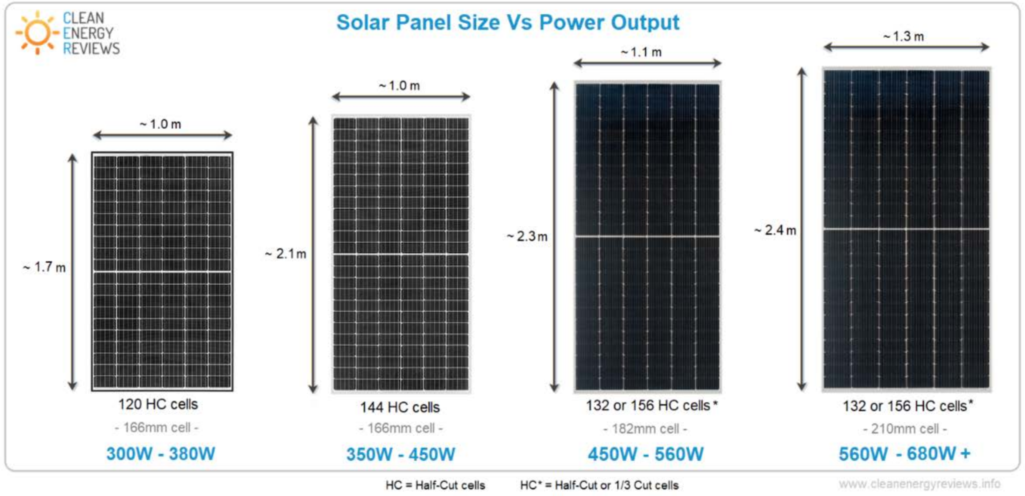
PHOTOVOLTAICS: AFTER 2020 PRESENT

New interconnection, densification, high density new size









PHOTOVOLTAICS: AFTER 2020 PRESENT

GW production back to Europe

Enel Green Power ("EGP") and the European Commission signed the grant agreement[1], under the framework of the EU's first Innovation Fund call for large-scale projects, that will contribute to the development of TANGO (*iTaliAN pv Giga factOry*), an industrial-scale production facility for the manufacturing of innovative, sustainable and high-performance photovoltaic (PV) modules at EGP's 3Sun solar panel factory in Catania, Sicily. In line with the deal, the factory's expansion is set to result in a 15-fold increase in its production capacity to 3 GW per year from the current 200 MW. The **3 GW production** facility is expected to be fully commissioned by July 2024, after starting with the first 400 MW in September 2023, making 3Sun Europe's largest gigawatt-scale factory producing high-performance bifacial PV modules.

Meyer Burger operates a heterojunction cell production facility in Bitterfeld-Wolfen and a highly automated module factory in Freiberg, Germany. Production at both sites is expected to begin by the end of May. The first modules could then be delivered to customers from July. The initial annual capacity of both factories is 400 MW each, which the manufacturer wants to increase to **5 GW by 2026**.

Enel secures EU funds to scale up Italian heterojunction PV module factory to 3 GW

An unspecified sum is being provided by the European Union to help Enel become a large-scale PV panel manufacturer. The Italian company secured the funds through the Innovation Fund

NOVEMBER 17, 2021 EMILIANO BELLINI

HIGHLIGHTS | MARKETS | MODULES & UPSTREAM MANUFACTURING | ITALY

Meyer Burger unveils 400 W heterojunction solar module

The solar module will be available in three versions – white, black, and glass-glass. The products have an output of up to 400 W, but when the bifacial effect is optimally used, the output of the glass-glass module can reach up to 430 W. Both the white and black modules weigh less than 20 kg

APRIL 28, 2021 SANDRA ENKHARDT AND EMILIANO BELLINI

COMMERCIAL & INDUSTRIAL PV | MODULES & UPSTREAM MANUFACTURING | RESIDENTIAL PV | GERMANY | SWITZERLAND

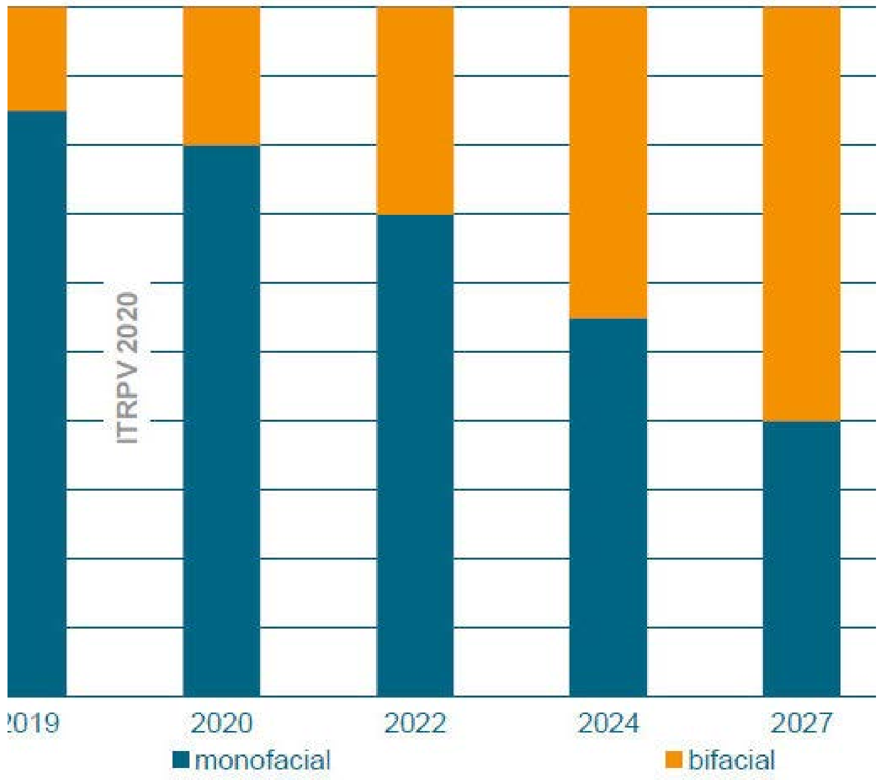
PHOTOVOLTAICS: PRESENT UTILITY SCALE UP TO THE GW

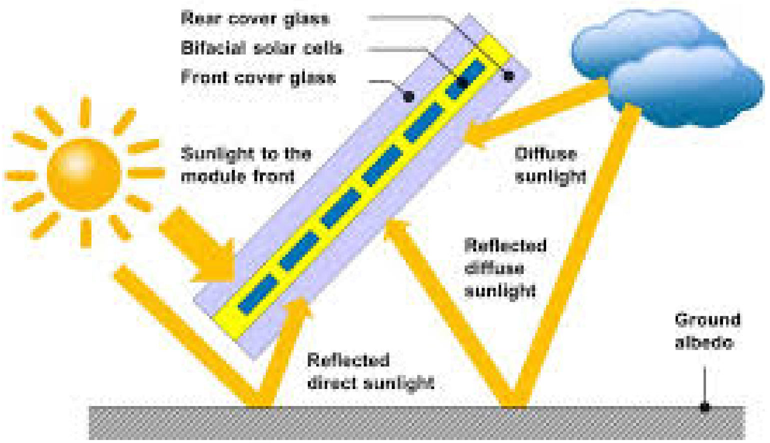
Longyangxia solar park has a capacity of 850MW.
Credit: USGS/NASA Landsat

With 2,300,000 PV modules, Enel's Villanueva project is currently the largest solar plant in the Americas.
Image: Secretaría de Energía/Gobierno de México

PHOTOVOLTAICS: PRESENT

- Bifacial is the mainstream





PHOTOVOLTAICS: PRESENT NEW PILOT SYSTEMS FOR DEDICATED APPLICATIONS

Mallemort expérimente un nouveau type de serre photovoltaïque

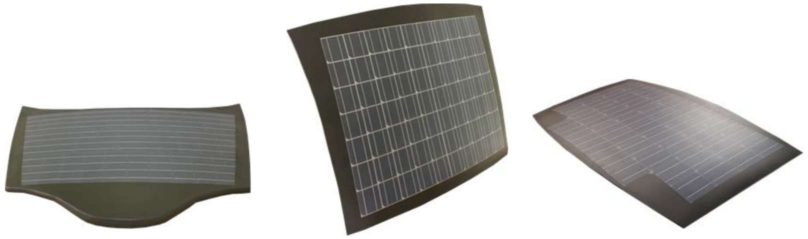
Christiane Wanaverbecq (Bureau de Marseille du Moniteur), Caroline Garcia et Mathieu Dejeu | le 26/10/2017 | Technique, Bâtiment, Bouches-du-Rhône, Energies renouvelables

Europe's largest floating solar system, located in Piolenc (France), powered by 17MW of Trina Solar PV modules. | Photo: Akuo Energy

Fig. 2. Photo of PV panels installed on the greenhouse (left) and their detail (right). (Source: own elaboration).

PHOTOVOLTAICS: PRESENT NEW PILOT SYSTEMS FOR DEDICATED APPLICATIONS

➢ **First Vehicle-Integrated PV demonstration on Courb C-Zen electric vehicle @CEA Tech**



	Hood	Front roof	Back roof
Cells	33 x ½	70 x ¼	40 x ¼
Vmp	18.3 V	38.7 V	25.4 V
Imp	4.6 A	2.3 A	2.4 A
Pmp	84.6 W	89.7 W	59.0 W

Type	Quadricycle – 2 seats
Weight	650 kg
Motor	Asynchronous – 15 kW
Battery	Li-ion 96 V – 12.1 kWh
Autonomy	~ 120 km
Vmax	110 kph
Hood surface	0.60 m²
Front roof surface	0.65 m²
Back roof surface	0.45 m²

EM PROJECT

TECHNOPOLYS

➢ **Static estimation of the energy harvested by the VIPV system, based on PVGIS 5 radiation data:**

✓ **annual average = 6 km per day (607 Wh/day) in Le Bourget-Du-Lac (38% from hood, 37% from front roof, 25% from back roof)**

PHOTOVOLTAICS: AFTER 2020 PRESENT

New questions:

Module is not the final product: the final product is ENERGY

from KWp to KWh

There are different technologies in function of the application

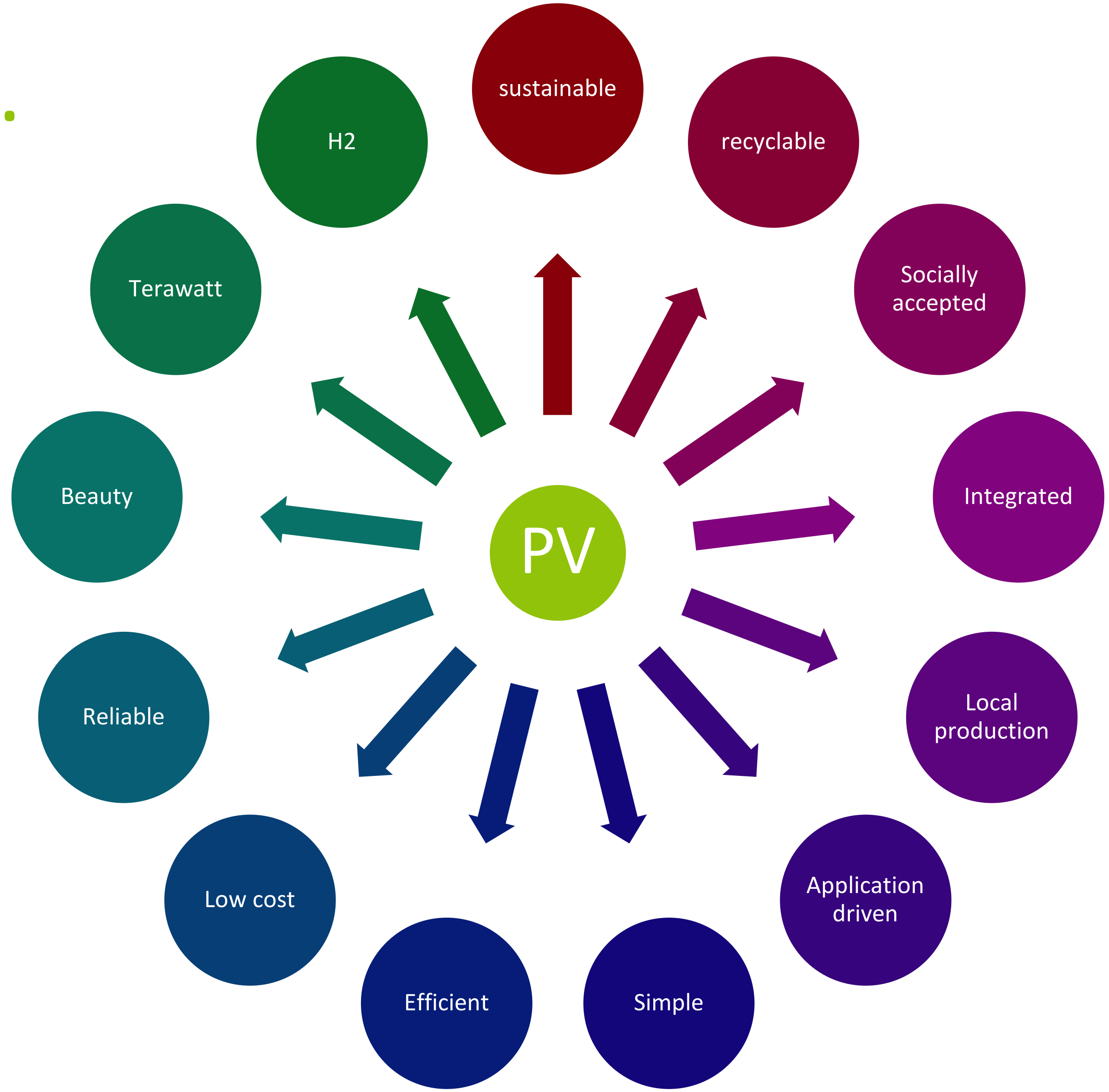
Not everything is for everywhere

What about sustainability for the Terawatt ERA

Is technology ready for a global deployement of PV

FUTURE OF PHOTOVOLTAICS IS…

More and more challenges!

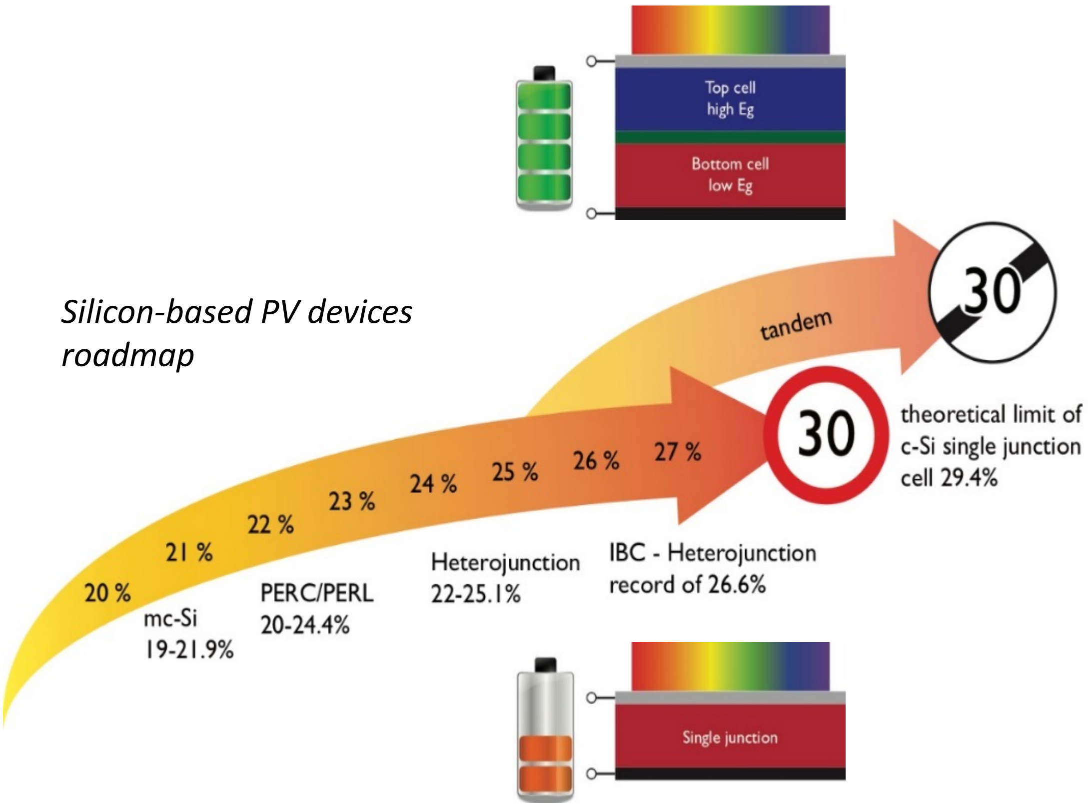


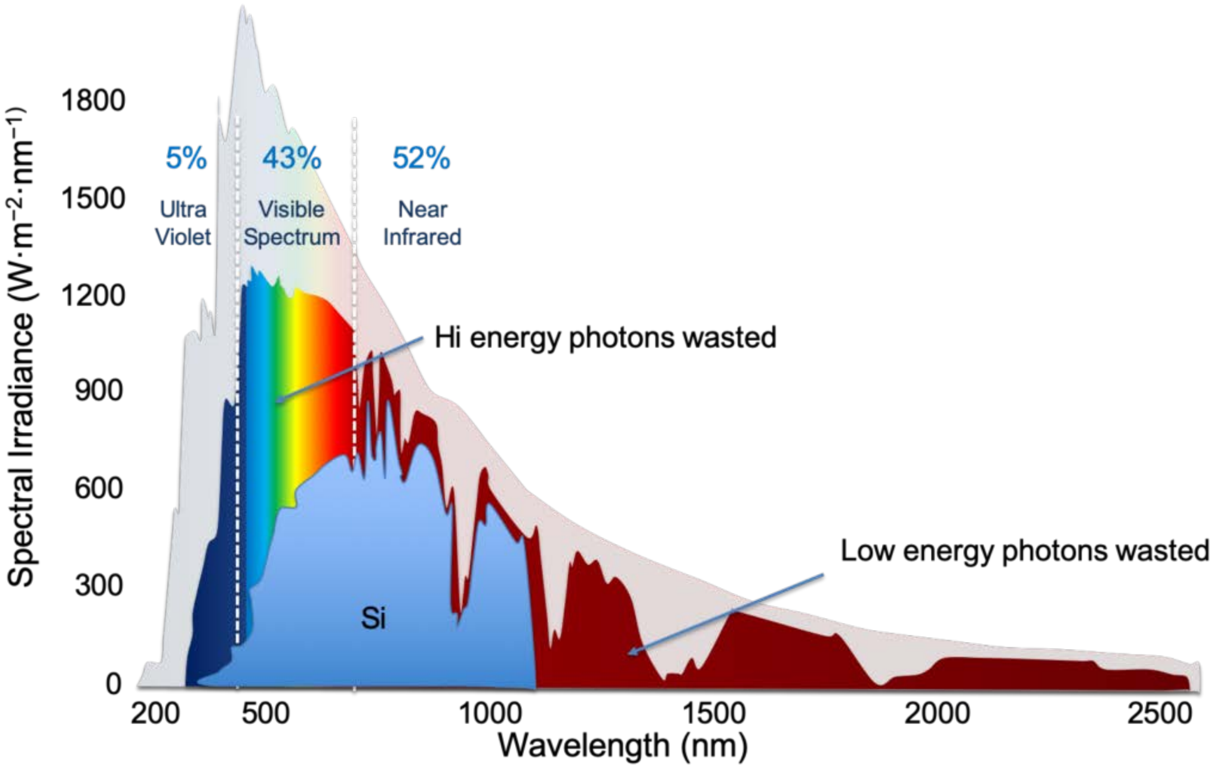
FUTURE OF PHOTOVOLTAICS IS…

MORE AND MORE EFFICIENT

MOVING TO TANDEM CONCEPTS: PUSHING THE LIMITS OF MATERIALS AND LIMITING LOOSES

Silicon-based PV devices roadmap





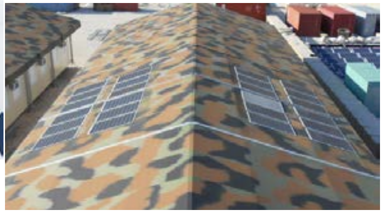
FUTURE OF PHOTOVOLTAICS IS…

MULTIFUNCTION: COMPLETELY VERSATILE

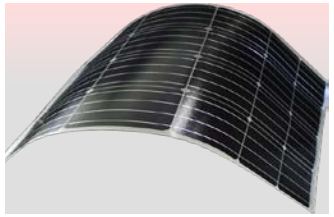
Solar Road
8 kg/m²

Solight
6 kg/m²

Energy Observer
3.5 - 6 kg/m²



Opérasol
4 kg/m²



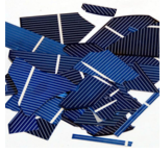
Stratobus
<800 g/m²

FUTURE OF PHOTOVOLTAICS IS…
CIRCULAR

Circular Economy of PV system

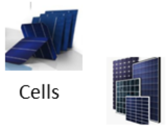
Recycling & Valorisation

- New profitable recycling processes
- Increase the recovery of materials for second use
- Performances tests of the ReUse PV modules



Eco-design

- Location of PV components (Elec mix)
- Increasing the rate of recycled silicon
- Reducing kerf loss
- Reducing Elec consumption by process



- New alternatives to replace/reduce raw materials
- Pb Free PV module
- New alternatives with recyclable materials
- High efficiency with competitive cost

Responsible consumption

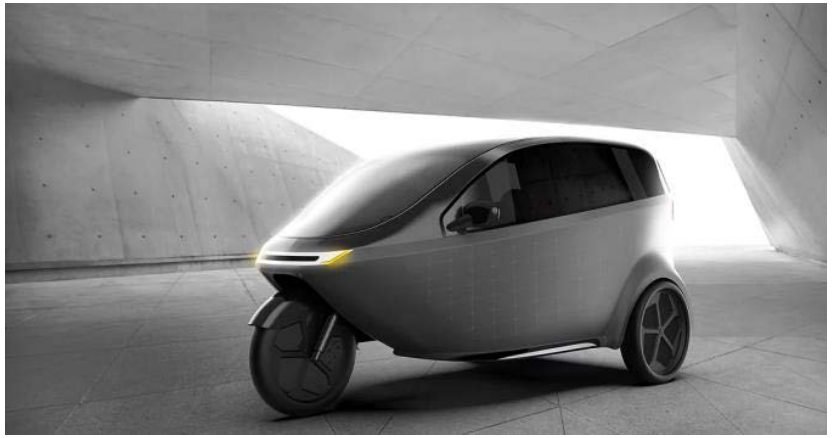
- New alternatives to reduce the raw material consumption in the mounting system
- New applications of PV module (VIPV, BIPV…)

Durability of use

- Optimisation to an efficient integration of PV into the grid (smart grid…)
- PV+ storage (test & diagnostic of Batteries, PV technology…)

FUTURE OF PHOTOVOLTAICS IS…

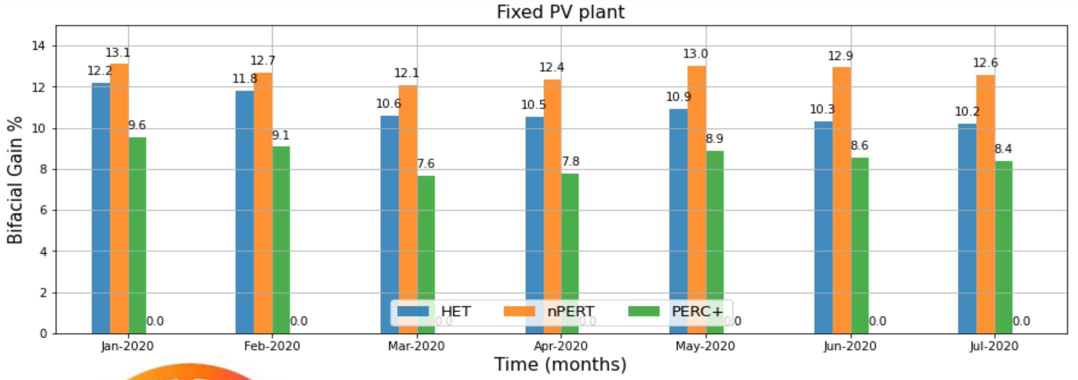
FULLY INTEGRATED: DESIGN CHALLENGES



Images from CSEM, CEA, exasun, Imefficiency, Energy Observer, ISSol

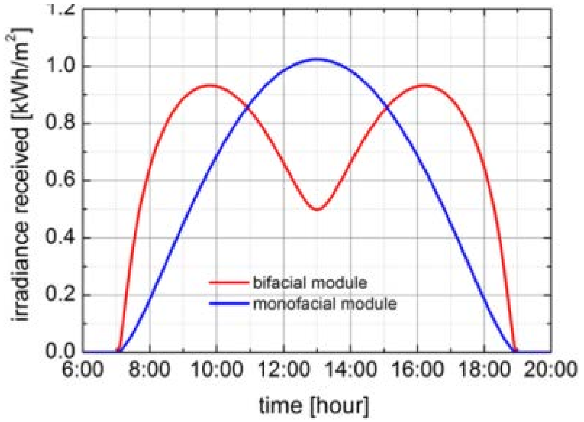
FUTURE OF PHOTOVOLTAICS IS…

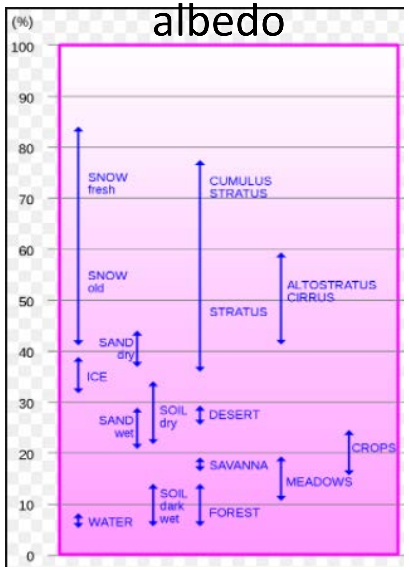
CLIMATE ADAPTED

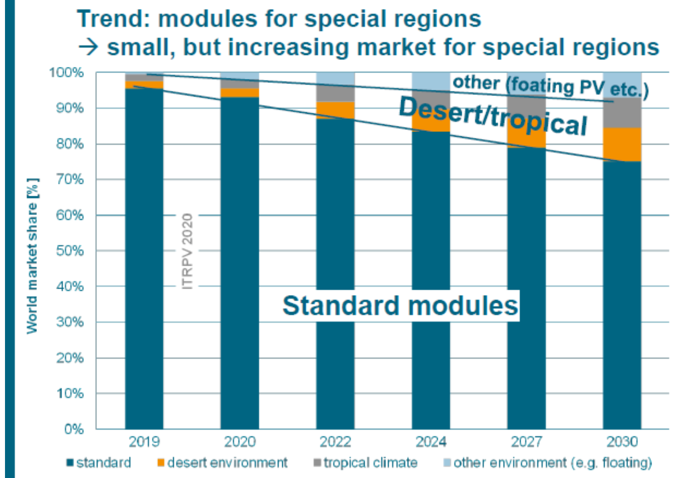


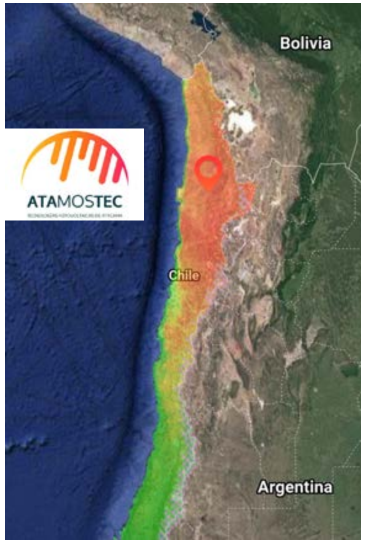
ATAMOSTEC
TECNOLOGÍAS FOTOVOLTAICAS DE ATACAMA

Ganancia Bifacial Promedio
nPERT: 12.7 %
HET: 10.9%
PERC+: 8.6 %









ATAMOSTEC ATACAMA DESERT

GHI:
>2500 kWh/m2/y
6 – 9 kWh/m2/d

UVA:
300-630 Wh/m2/d
171.4 kWh/m2/y
UVB: 65% over EU std
4-20 Wh/m2/d
4.6 kWh/m2/y

Sun hours:
>4000 sunshine h/y

Temperature:
T < 30º avg in summer

Driest place o earth:
2mm rain avg year

Bifaciality
Production tuning, Generation when is needed

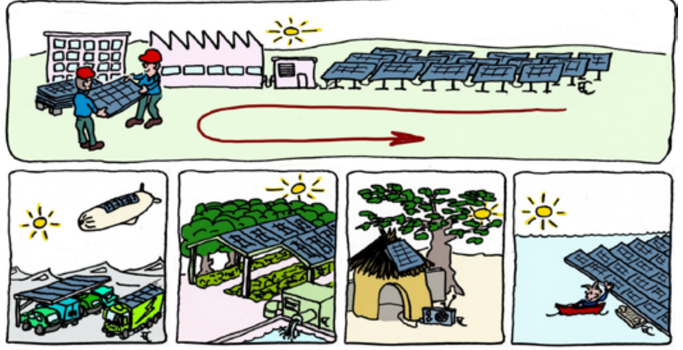
280 GW potential in the Global High Radiation Sun Belt 2020-2030

FUTURE OF PHOTOVOLTAICS IS…
WHAT ABOUT PORTS?

Photovoltaics can be installed in all areas where there is no shadowing with a DUAL use:

- noise barriers
- Solar road /bikes with light
- Overhead
- Roofs and facades
- Floating



EN CONCLUSIÓN…

- La energía fotovoltaica esta lista para ser uno de los vectores de producción de energía renovable a escala mundial y responder a las necesidades de la sociedad

- La instalación fotovoltaica es hoy en día más y más versátil, integrada, eficiente, sustentable

- La energia fotovoltaica es distribuida, lo cual favorece el acceso a la energía, pero necesita un cambio de paradigma de producción, distribución y consumo, que viene de la mano de grandes inversiones, y cambios sociales.

- La energía solar fotovoltaica habilita vectores nuevos, como el hidrógeno verde, o la electromobilidad masiva que solventan, a su vez necesitades de almacenamiento y transporte de la energía.

- La descarbonización pasa por una reducción del consumo, un uso inteligente de la energía, una apuesta por las energías renovables locales sustentables a nivel global.

MUCHAS GRACIAS POR LA ATENCIÓN

Gracias a todos los equipos de CEA -INES

Empresas participantes:

AMARRADORES VALENCIA

Lifting Global Trade. APM TERMINALS

BALEARIA

BOLUDA TOWAGE SPAIN

CENTRO PORTUARIO DE EMPLEO DE VALENCIA

CSP Spain The Ports for ALL

Fertiberia

galp

Grupo Torres DESDE 1915

INFOPORT

ist Intersagunto Terminales

msc TERMINAL VALENCIA S.A.U.

RECICLAMÁS seroil

TEPSA Flexible tanking. Certified. RUBIS TERMINAL

VALENCIA TERMINAL EUROPA

vareser

VELAS LLUCH

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