PV trends and "*trendy*" lightweight applications

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SOPHIA-workshop/webinar

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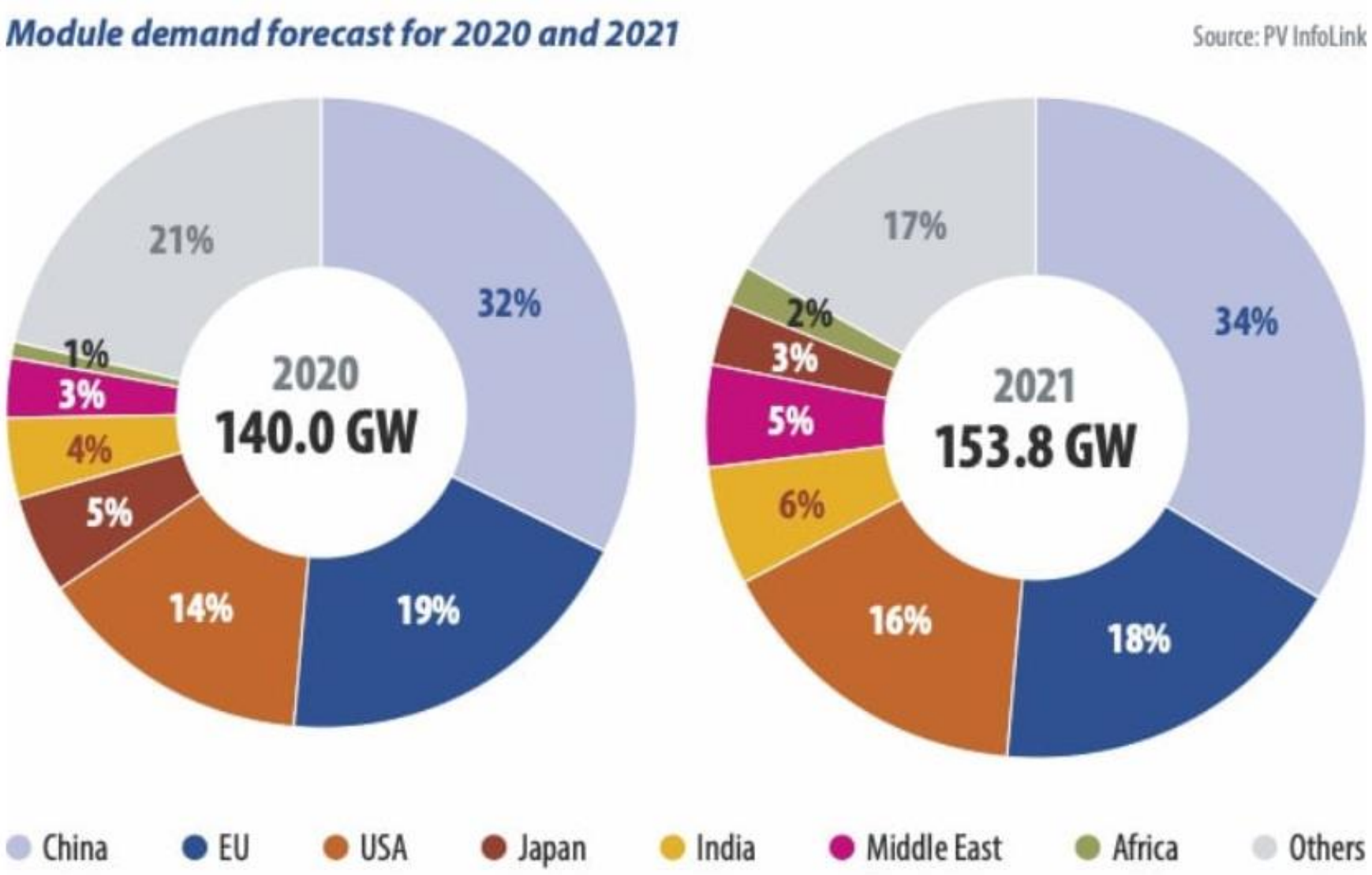
Outline

- State of art PV
- PV trends and "*trendy*" applications
- Our "*trendy*" application
- Conclusions

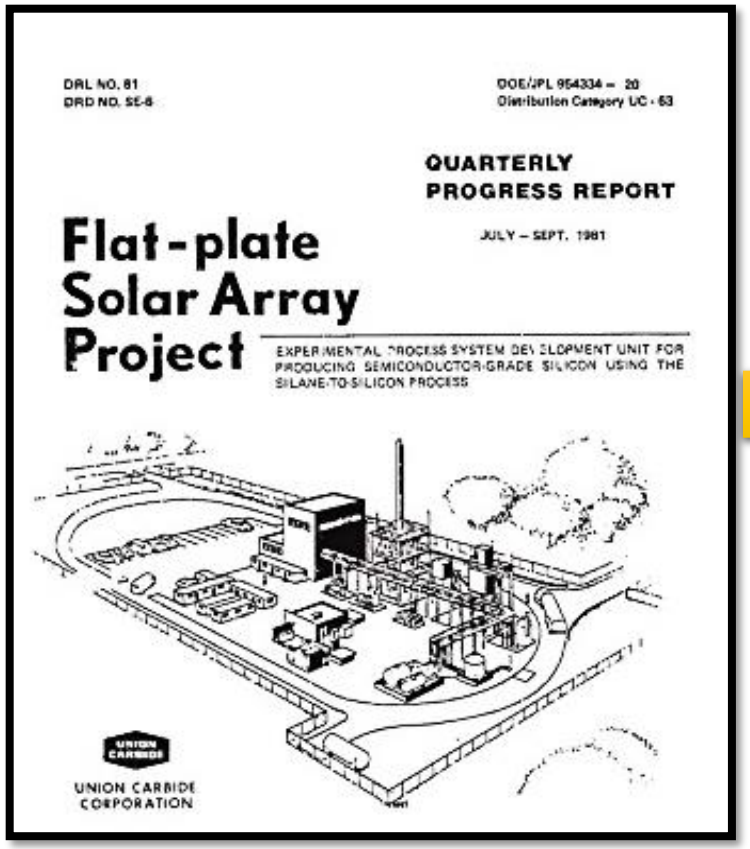
State of art PV



Overall, the global PV market crossed the 100 GW mark for the third year in a row!!

State of the art : PV module materials and technology

The general architecture of *modern c-Si wafer based PV modules* was developed in the late **1970s** and **early 1980s** within the **Flat-Plate Solar Array Project** and **<u>has not significantly changed since then</u>**.



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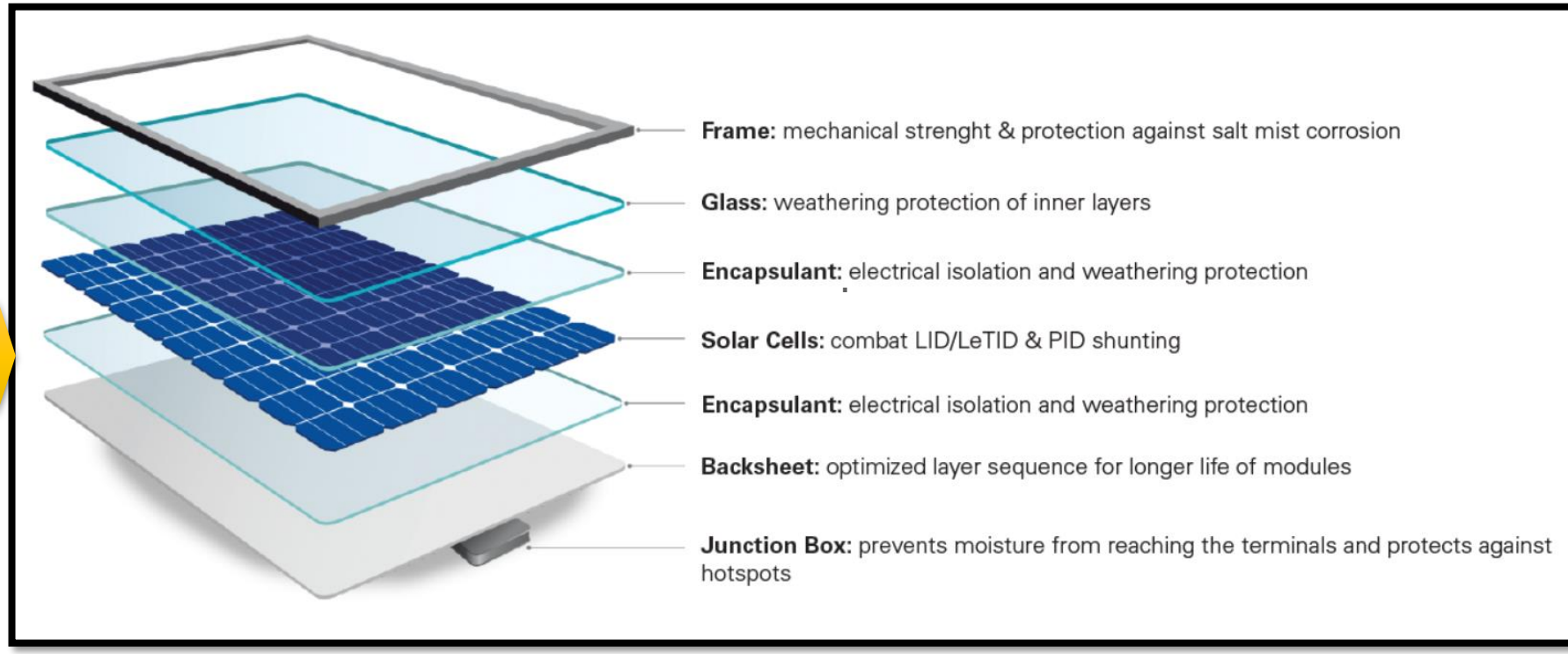
QUARTERLY PROGRESS REPORT

JULY – SEPT. 1981

Flat-plate Solar Array Project

EXPERIMENTAL PROCESS SYSTEM DEVELOPMENT UNIT FOR PRODUCING SEMICONDUCTOR-GRADE SILICON USING THE SILANE-TO-SILICON PROCESS

UNION CARBIDE CORPORATION



https://solarity.cz/blog/trends-for-pv-industry-in-2020/

A.Goetzberger, B. Voß, and J. Knobloch, Sonnenenergie: Photovoltaik: A.Physik und Technologie der Solarzelle, 2nd ed. Stuttgart: Teubner Verlag, 1997

ADVANCED MODULE TECHNOLOGIES

* Bifacial solar cell
* Half-cut , 1/3 cut cells or multi-cut solar cells
* Multi-busbars
* Shingled PV module technology
* Wafer sizes range from 156,75 x 156,75 mm^2 (M2) up to 210 x 210 mm^2 (M12).

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Decrease of LCOE: cost reduction and performance improvement

- ✓ ***New module designs***
- ✓ *Reduction* and *replacement* of ***expensive materials***
- ✓ *Acceleration* of ***manufacturing processes***
- ✓ ***Performance*** *increase*
- ✓ ***Production related cost*** *decrease*
- ✓ ***Sustainability*** and ***legal regulations***
- ✓ **New requirements for standardization**

In addition to the ground and roof PV systems**,**

where is the potential market of photovoltaic development in the future?

Five *trendy* PV Applications in the Future

1. *Floating photovoltaic power station & floating photovoltaic solution (FPV)*

Due to the *cooling effect of water*, FPV can:
*provide ***higher power generation efficiency*** *and* ***power generation capacity*** (can increase up to 10%).
****reduce water evaporation*****,**
****prevent the generation of harmful algae*** *and*
****reduce the cost of water treatment*** → ***Floatovoltaic – FloatPhotovoltaic***.

- In ***2008***, the ***first commercial 175kWh floating plate PV system*** was installed at one winery in Napa Valley, California.

- In ***2016***, the largest **single floating photovoltaic power station** on the water surface in the world was

Huainan 20MW project of sunshine power construction

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Five *trendy* PV Applications in the Future

2: Solar skin

New PV technology: integrates *customized design* into the *solar panel system* as the **shell of buildings**, **cars**, **toys** and other items.

- *Solar skin technology does not need solar mountings*.
- It can cling to the substrate, has a smooth appearance, hides all metal parts.

- The *disadvantage* of solar skin is ***its cost***, which is about ***10% more than the price of traditional panels***.

A comparison of a standard solar panel installation (L) and solar skins on top (R).

Image Credits: Massachusetts Institute of Technology (MIT)

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La Monarca at the San Antonio Zoo. (Photograph by Penelope Boyer).
Sistine Solar makes a film—SolarSkin—onto which any graphic image can be printed. The special film allows almost all of the light through to the solar cells to generate electricity.

The product was developed at *MIT* by the company's founders, and has been marketed as a way to disguise solar panels on rooftops by printing a full-scale image of the surrounding roof shingle pattern, color, and texture.

Five *trendy* PV Applications in the Future

3: Solar Fabric

Imagine that the electricity can be generated on ***your clothes*** and ***backpacks***!!!
Solar fibers can be **embedded** in **your T-shirt, winter coat or any other clothing to help keep you warm**, ***power your phone***, and power other needs on your journey.

Hanergy

The combination of solar fabrics and solar panels may include:
Solar Fabric Canopies
Awning: it can light up the street lamp.
Curtain: it can open and close by itself.
Solar household clothing

4: PV Noise Banner

If the noise control can be combined with sustainable power generation, it will bring not only social benefits, but also economic benefits.

→ in the United States, the potential for solar energy production from these Barriers could be about ***400 gigawatt hours (GWh) per year***. That's about *37, 000 households' annual electricity consumption*.

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Five *trendy* PV Applications in the Future

5: BIPV - photovoltaic building integration

In the form of **roof, canopy, curtain wall, facade** and **skylight system**.

- BIPV is attractive in ***architectural aesthetics***, rather than a simple renovation of architectural design.

- In addition to the ***building's beauty***, the ***economy*** *is also important* to the owners. The BIPV system can not only save the cost of building materials and electricity, but also realize the *models of low-carbon* or *zero carbon buildings*. It helps owners apply for **various government subsidies and awards.**

- *Market strategy of BIPV PV suppliers*: the ***BIPV is not sold as PV, but as a new building material***.

  Improving energy efficiency
  High thermal insulation and sound insulation
  Clean and free solar output
  Reduce operation and maintenance costs

Tesla Solar Roof tiles

Weight of PV modules is *an obstacle* → broader fields of application for ***lightweight PV modules***.

Kaleo in Neuchâtel, Switzerland has a version of a printed film that is applied to the face of a solar module.

The solar module making electricity behind is completely invisible, obscured by the beauty of the artwork.

London Kingsgate House
Designed by Horden Cherry Lee using LOF solar cells (2014).

Solar Graffiti project
at Gomez Farias outside of Mexico City. © Leonardo Medina Ruiz (2018);

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- Vehicle integrated PV (***VIPV***), **Aerospace** and **custom** applications

SolarStratos, a project to send the first manned solar plane to the stratosphere, only powered by solar means, thus, establishing a new altitude world record for this flight mode.

https://www.solarstratos.com/en/2017/02/newsletter-014-en/

Flisom offers development, testing and manufacturing expertise to customize flexible solar films for high altitude drones, electric helicopters, airships, hot air balloons and satellites.

Electric car 26-year world record broken by **Australian solar racing team, 2014**

A new speed record by the Sunswift Australian solar racing team for the fastest electric vehicle over a distance of 500 km has been officially recognized. Their vehicle eVe can achieve more than 100 km/h.

https://www.rt.com/news/196568-electric-car-speed-record/

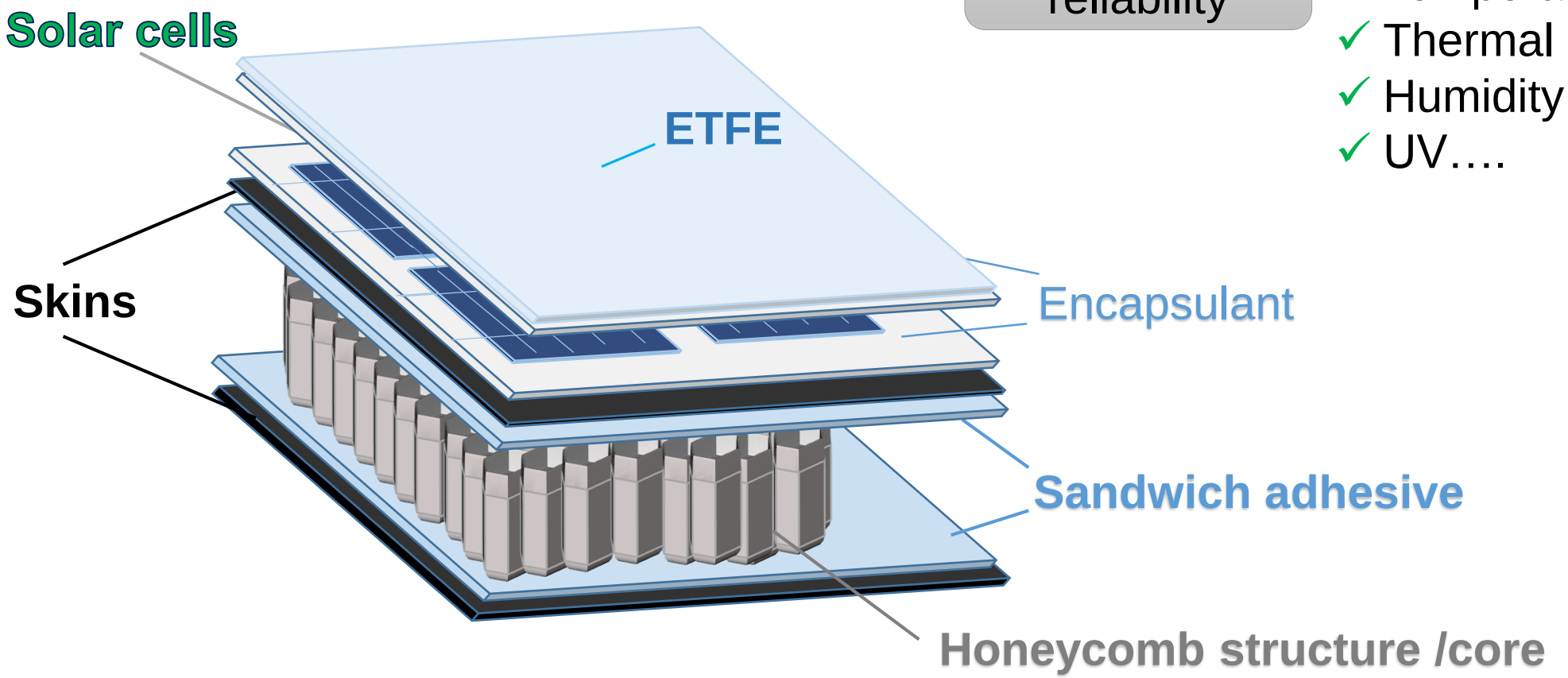
Lightweight PV design

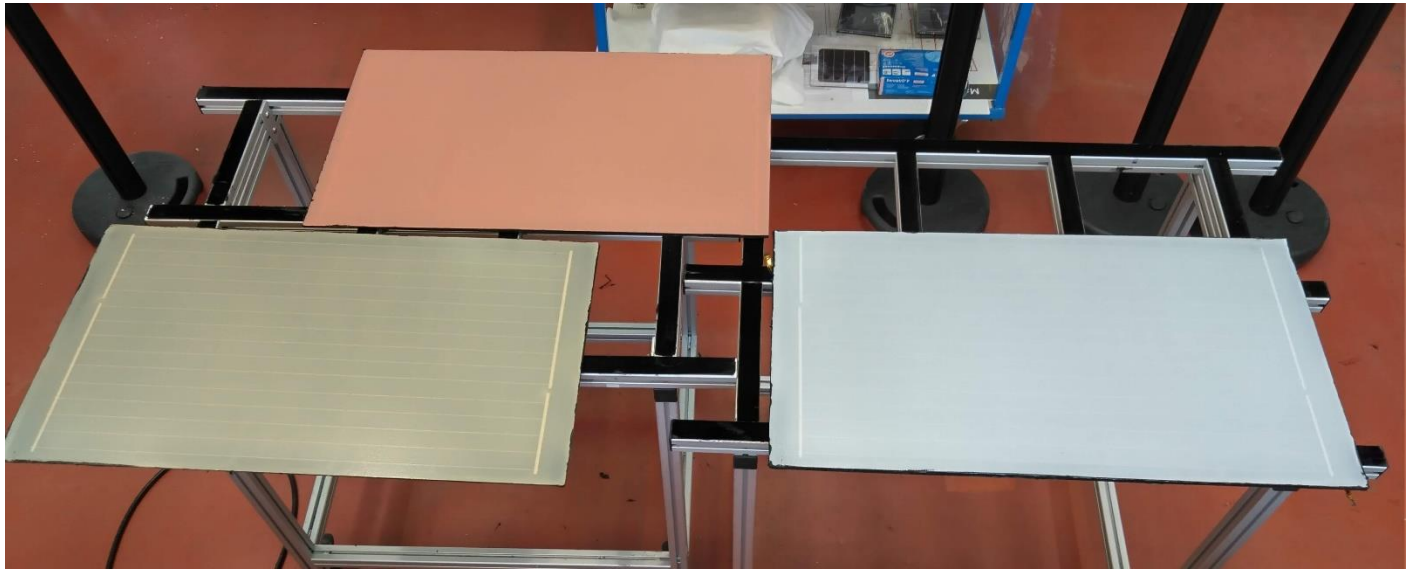
What about us???

Design and manufacturing → Performance and Durability → Mechanical stability / Environmental reliability

Mechanical stability
- ✓ Impact resistance
- ✓ Load resistance

Environmental reliability
- ✓ High Temperature
- ✓ Thermal Cycles
- ✓ Humidity
- ✓ UV….





Lightweight PV modules with a **weight of 5-6Kg/m²** (compared to 15-20Kg for conventional BIPV products) are **manufactured by EPFL**.
CSEM and **EPFL** are currently **combining their technologies** to develop ***Ligthweight/coloured BIPV products*.**
Aging, life-time and certification aspects are carried on by EPFL.

Preliminary view of demo PV systems

Case Study 1
Corby (UK)

Case Study 2
Technical University of Cluj-Napoca (Romania)

Extended testing sequences to cope with the harsher operating conditions (e.g. higher temperatures, dynamic wind loads, shading, etc.) experienced by BIPV products (compared to free-rack standing modules) will be developed and provide the basis to:

1. increase the ***understanding of potential failure mechanisms*** experienced by BIPV products and the colouring solutions;

2. implement mitigation strategies to prevent degradation;

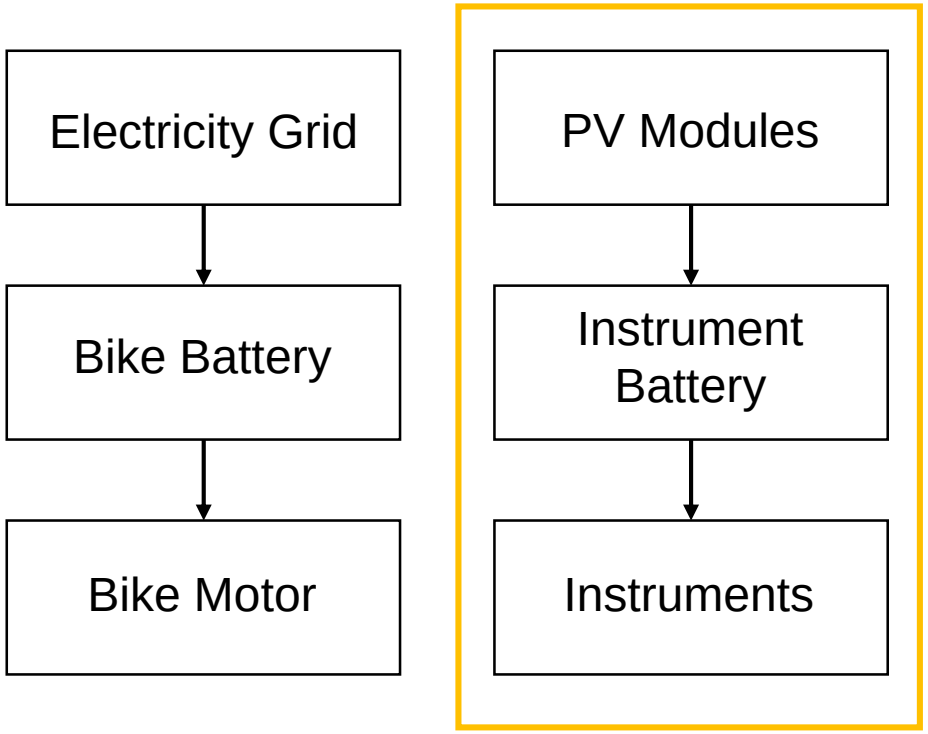
3. align and extend life-time of BIPV solutions to service life-time of other building products (35+ years).

CBB : cargo bike band project

- Band on electrical cargo bikes with electrical instruments

Future System

- Bike battery charged before travel
- Instrument battery charged during travel by PV modules

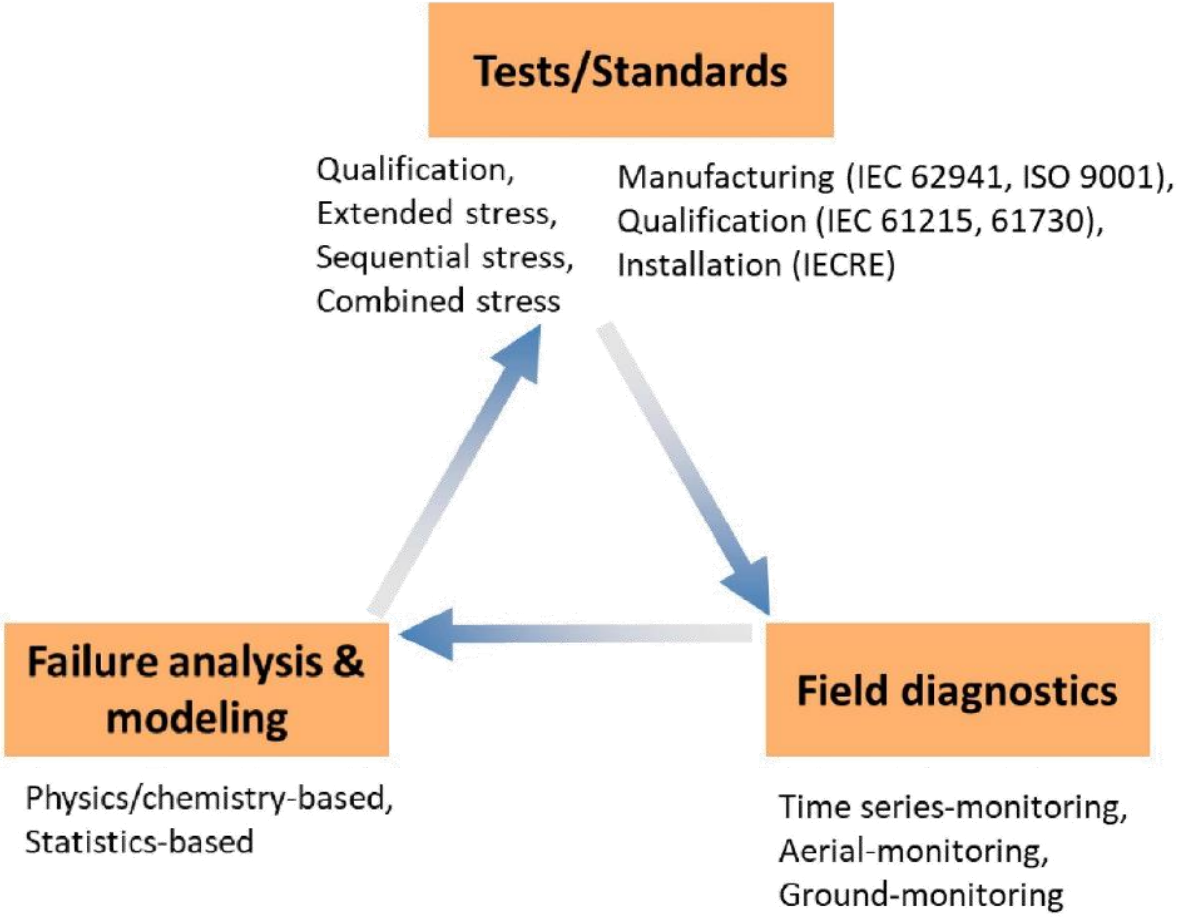


..Food for thoughts..

Two macro-trends have dominated the PV industry throughout its existence:

- *increase* ***performance*** and/or **lifetime of the modules** or
- *decrease the* ***cost*** to produce new module designs **without a long-term understanding** about the **performance** and **reliability** *of these new materials*. This presents a technology risk for the industry!!

- **Non-standard PV modules exists**, where the reliability requirements may differ, and often be *lower* than for long-term outdoor applications in PV power systems.
- Work on a standard for PV consumer products was started– *depending on applications* – (easing some of the module type qualification tests, and add others, e.g. a drop test..)
- **Consumers** and **manufacturers** rely on **constant** *adaptation and development* of international standards



J. Phys. D: Appl. Phys. 53 (2020) 493001

Unfortunately, the *length of each learning cycle (years) is considerably longer than the product development cycle (months)*.

Improving PV reliability depends on reducing the reliability learning cycle.

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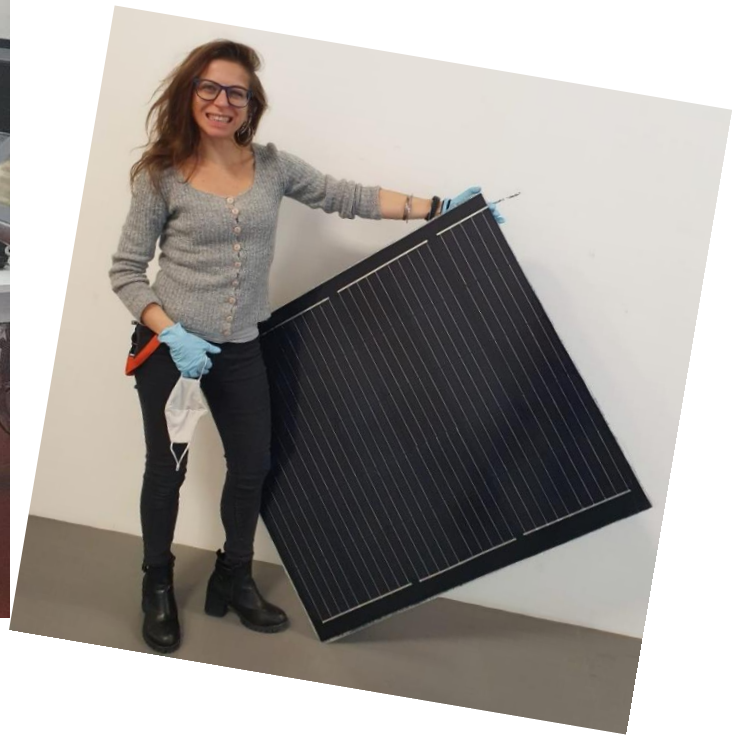
EPFL

..and…what about a Human PV?!

Open Conclusions



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