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Can we make PV modules that last 30+ years? Is the industry doing it?

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ZSW- Alumni-Tag
9. November2024

www.o-sole.eu

Outline

1. Modules that last 30+ years: a few examples

2. PV Market: 3 macro trends

   >>> Solar PV technology: **E**volution vs **RE**volution

3. Conclusions

NB: focus >> crystalline silicon (c-Si) wafer-based

PV module: service lifetime

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- PV module performance warranties: 25 to 30 years
- Warranties based on: assumptions, IEC testing, extended testing, ….
- IEC testing is «qualification» testing, not life-time testing (!!!)
- Arbitrary definition of «lifetime»: 80% of initial nameplate power

Can we make solar PV modules that last for 30+ years?

A few examples…

IEC: International Electrotechnical Commitee

PV system age: literature

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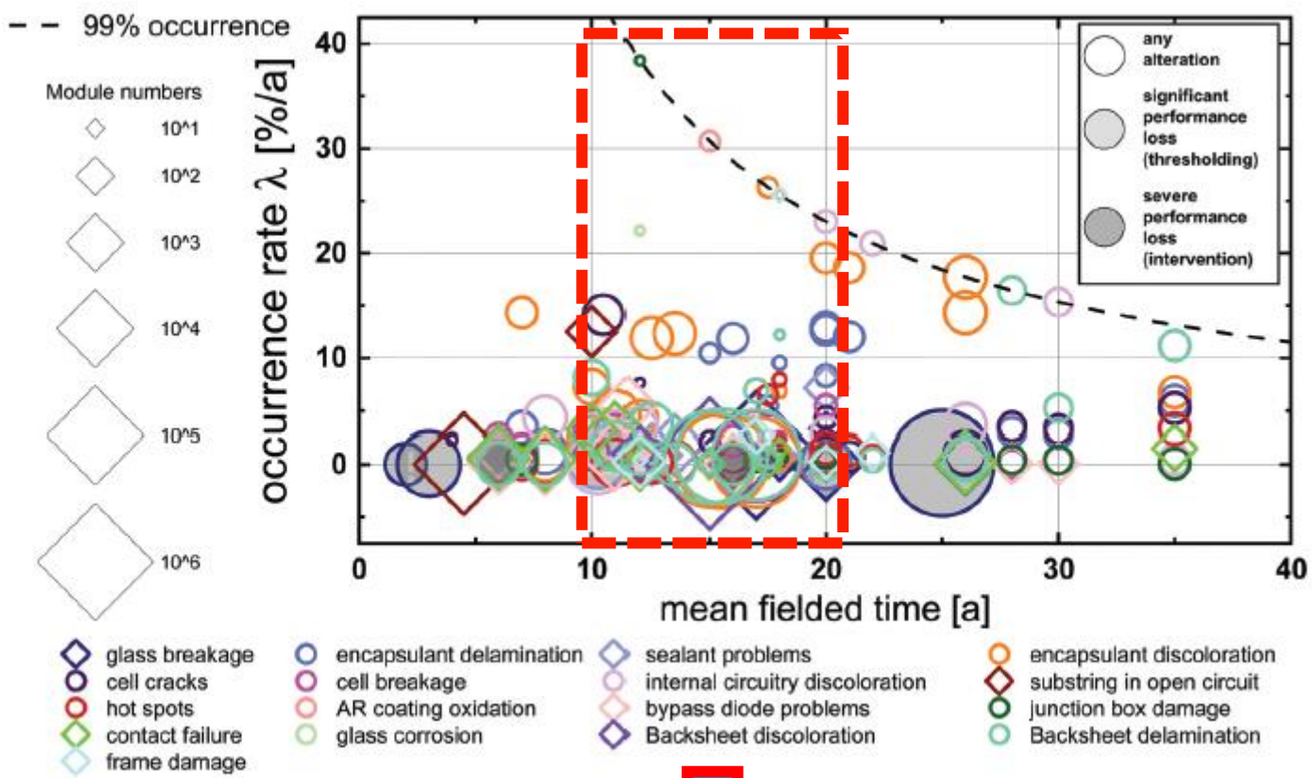
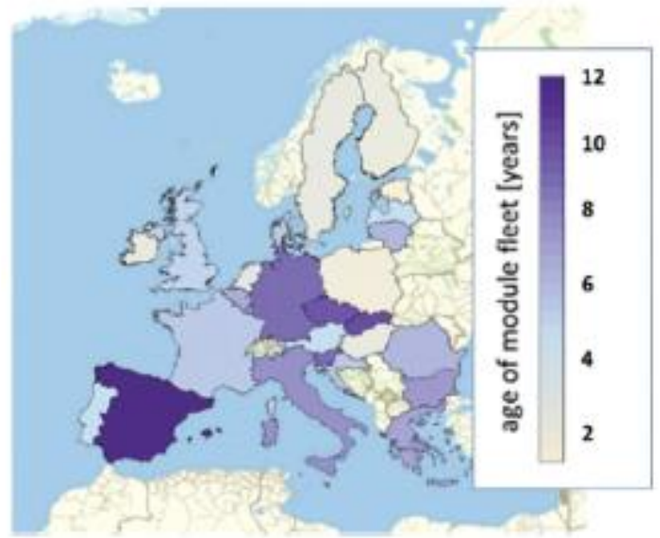
Occurrence rate of modules affected by various defects as calculated from literature sources ordered by the respective mean fielded time



Vast majority of data reported in the literature: 10 to 20 years
Few: 20 to 30 years
One or two: beyond 30 yrs

Denz, En.Env.Sci., 2022,
10.1039/d2ee00109h



Average module fleet age for various countries in Europe in the year 2019

35-years of PV: the TISO-10 kW plant

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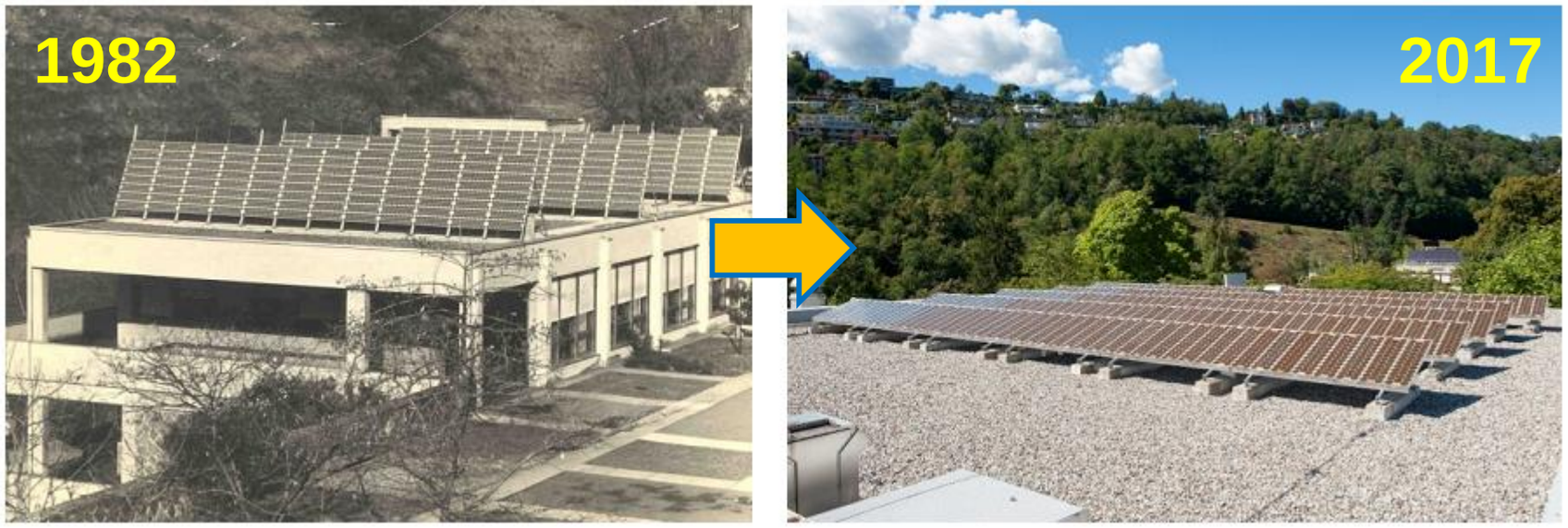
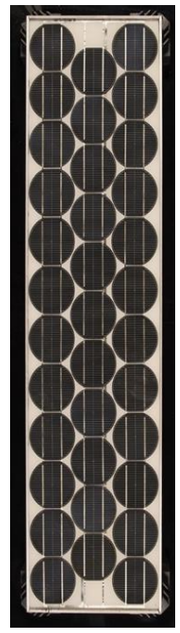
EXAMPLE (1)

- First grid-connected PV-plant in Europe (Lugano/CH, temperate climate)
- PV plant's history very well documented
- A history of change: all has changed (site, inverter, monitoring system, …) with the exception of the 288 original PV modules
- Modules: ARCO Solar (36 W, c-Si 4» 330 um, PVB, backsheet: tedlar/steel/tedlar)





TISO-10
35 years of operation
(in a temperate climate)

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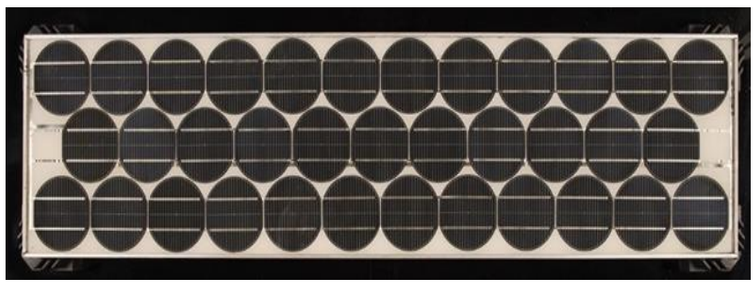
Main takeaways:

1. 70+% of modules would still statisfy a 35-yrs-long warranty set at 80% of the nominal power
2. The long-term performance was correlated to the encapsulant used
3. Changing one single component (e.g. encapsulant) may have a huge impact
4. **The BOM (bill-of-material) matters. A lot!**



RESEARCH ARTICLE

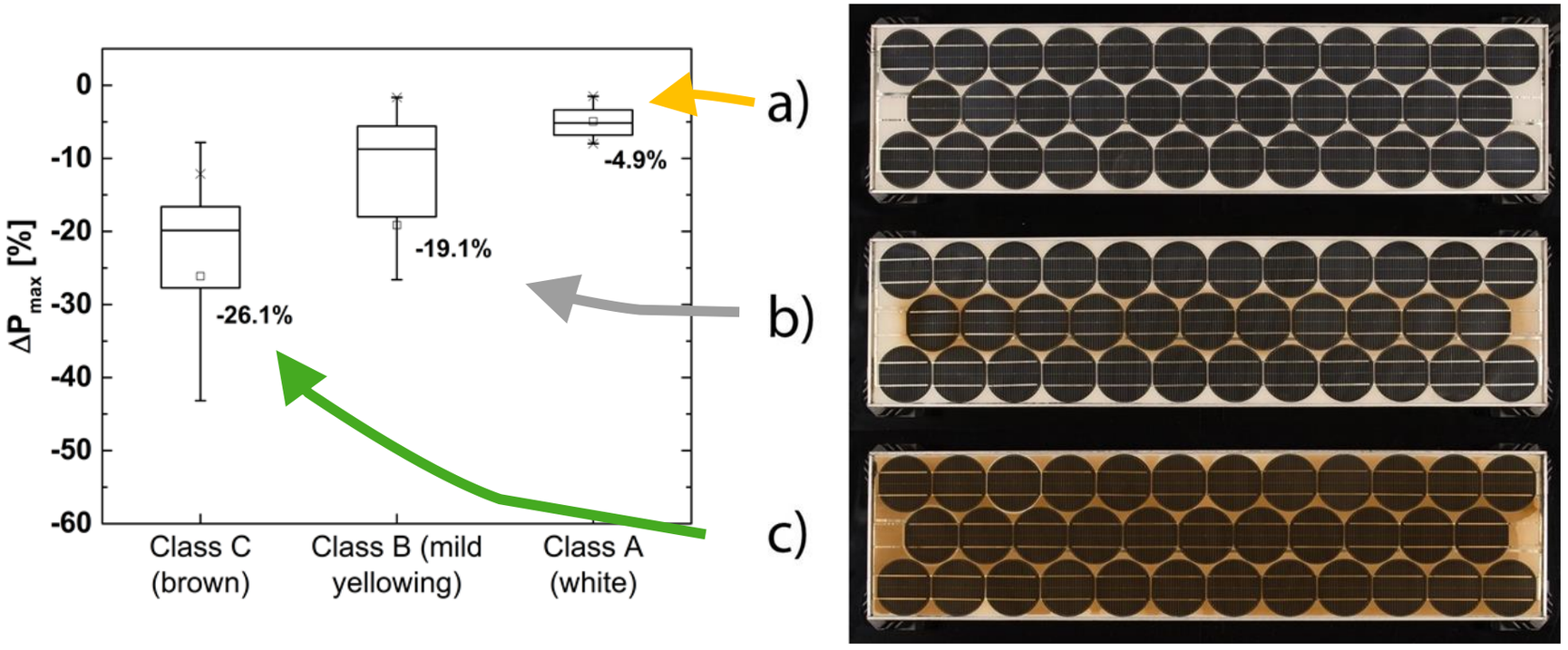
WILEY PROGRESS IN PHOTOVOLTAICS

35 years of photovoltaics: Analysis of the TISO-10-kW solar plant, lessons learnt in safety and performance—Part 1

Part 1: PiP 2019
Part 2: PiP 2019

Alessandro Virtuani[1] | Mauro Caccivio[2] | Eleonora Annigoni[1] | Gabi Friesen[2] | Domenico Chianese[2] | Christophe Ballif[1] | Tony Sample[3]

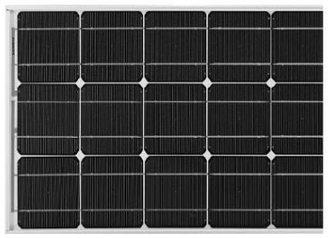
TISO-10 PV plant: module degradation after 35 years



1. Module power variation (2017 vs 1982): 3 classes
2. 3 different classes of modules based on encapsulant aging
3. 3 different encapsulant (PVB) suppliers were used at the time (1981) by the module manufacturer

Mont-Soleil PV system (500 kWp) EXAMPLE (2)

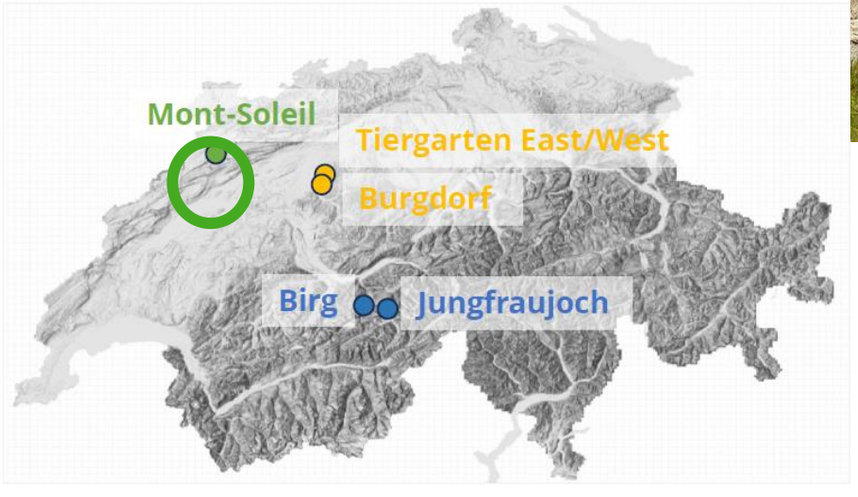
Quest et al., EUPVSEC 2024



Low altitude (< 1000)

Mid-altitude (1000-1500)

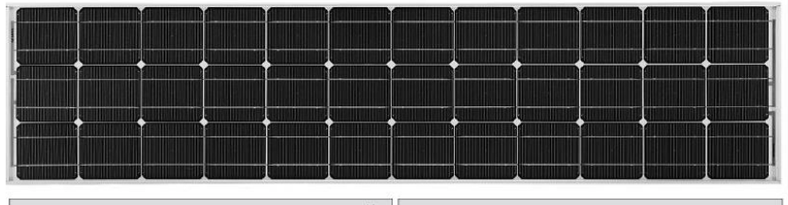
High altitude (> 1500)



Modules manufactured in 1991

BOM very «modern»:

glass-backsheet, EVA, mono-cSi



Siemens M55

- Mono-Si
- Textured cells
- EVA
- Backsheet

Maximum power rating P_{max}	$[W_p]$ 1)	55
Rated current I_{MPP}	[A]	3.15
Rated voltage V_{MPP}	[V]	17.4
Short circuit current I_{SC}	[A]	3.45
Open circuit voltage V_{OC}	[V]	21.7

BOM: Bill-of-Materials

Mt-Soleil: performance loss rates PLR

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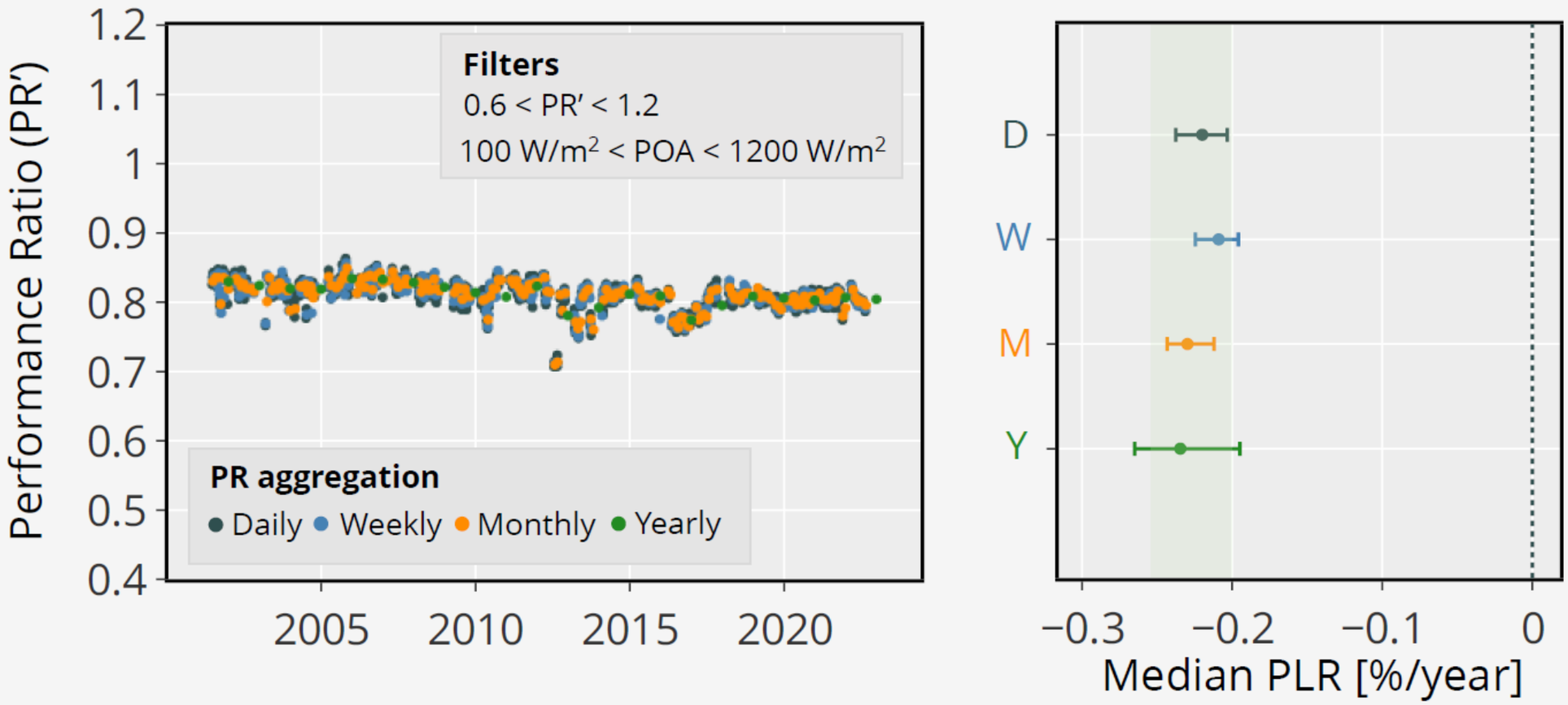
System metadata		
▪ **System capacity**	554.592 kWp	**Feb. 1992**
▪ **Tilt angle**	52°	
▪ **Orientation**	1st main field 20° East 2nd main field 35° East	
▪ **Inverter**	ABB central inverter	
▪ **Altitude**	1270 m.a.s.l.	

Main takeaways:

1. Connected to grid in 1992. Monitored since 2002.
2. PLR: -0.22%/y (very stable)
3. Power > 90% after 30+ yrs
4. BOM very «modern»: glass-backsheet, EVA, mono-cSi

Quest et al. (2024), 10.1002/pip.3855



PLR = -0.22 %/year, CI = [-0.24, -0.20]

Stable performance in the analysed period (2001 – 2022).

Compliant with warranty of **>90% nameplate power after 30+ years**.

PV module: service lifetime

Can we make solar PV modules that last for 30+ years?

YES

(at least in a temperate climate)

Is the industry doing it ?!?

IEC: International Electrotechnical Commitee

PV module: 3x macro trends

Post-covid

1. PV market: exponential growth (**CAGR-23/22: +88 %/y)**

2. Very sharp decline of PV module prices (-40 to -50% in 2023, continued in 2024)

3. PV module technology: Evolution vs REvolution
   - 1980 to 1990 (10 years): many changes
   - 1990 to ~2019 (30 years) Evolution.
   - **last 5 years: REvolution**

Global PV market

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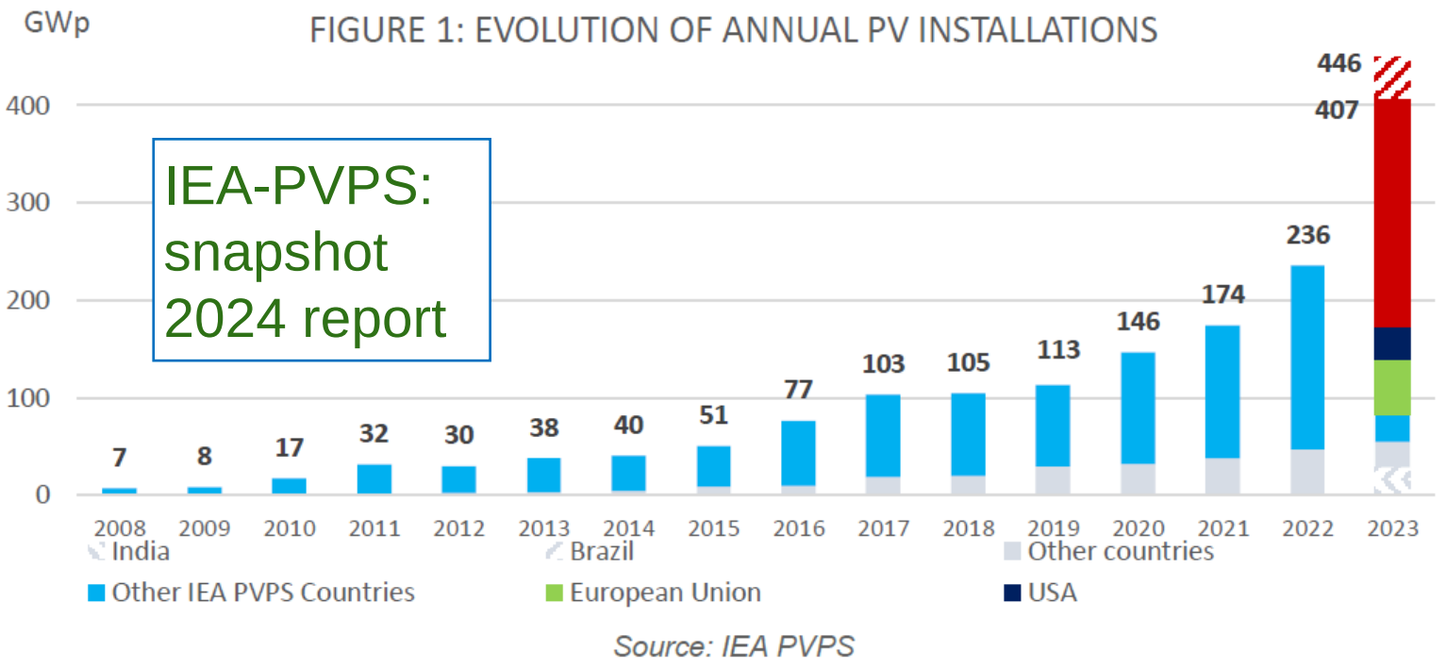
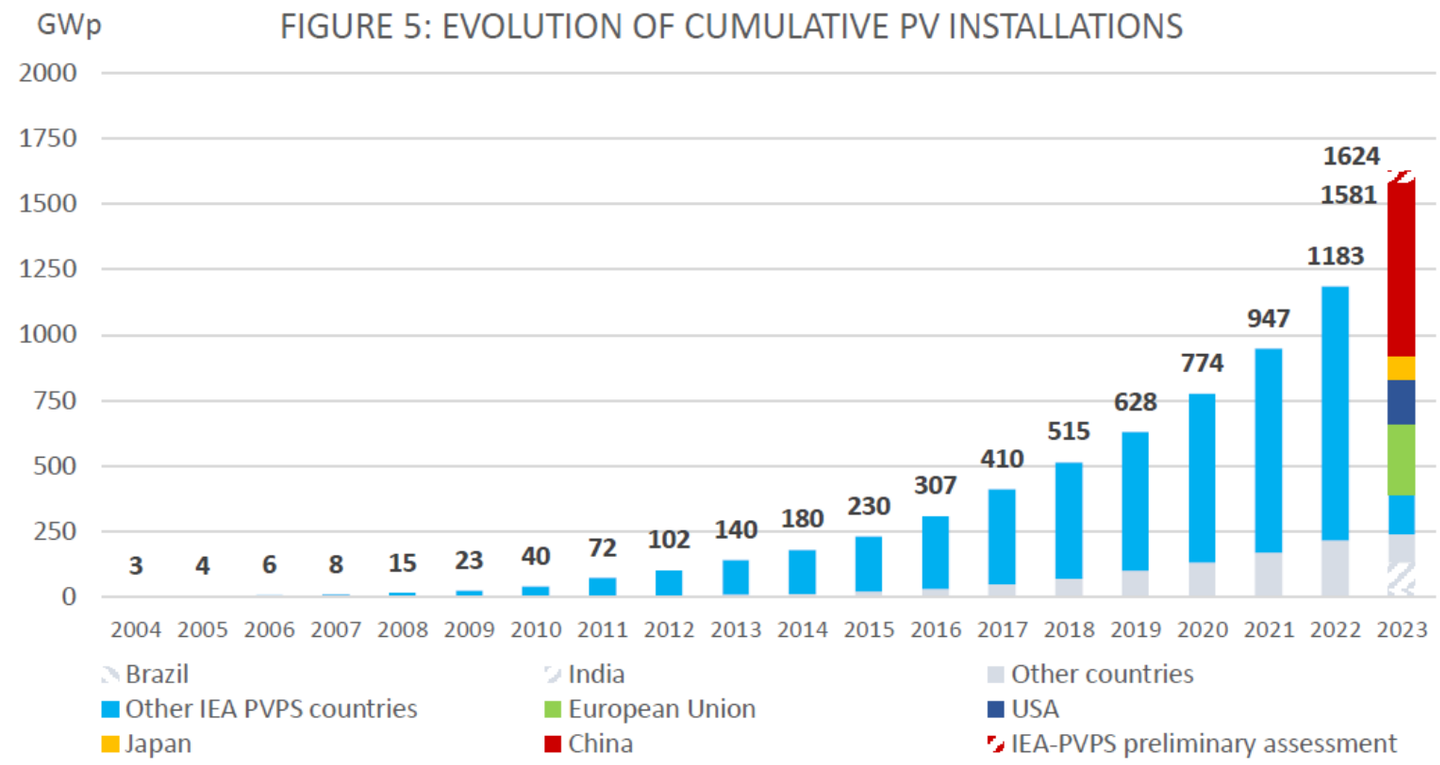


Source: IEA PVPS

2023: newly added
PV installation: + ~450 GWp

CAGR-22/21: +35%/y
CAGR-23/22: +88%/y



2023: cumulative capacity
~1.6 TWh

Dominant PV technology:
c-Si wafer-based

95+ % of new additions
95++ % of cumulative capacity

PV module prices

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Very sharp decline of PV module prices (-40 to -50% in 2023, continued in 2024)

2023

ITRPV says solar module prices fell 50% in 2023

The new edition of the International Technology Roadmap for Photovoltaic (ITRPV), published this week, reveals that the world's installed PV capacity reached 1.6 TW at the end of last year. The learning curve, which reflects average module prices relative to cumulative shipments, is 24.9% for the period from 1976 to 2023.

JUNE 5, 2024 SANDRA ENKHARDT

MARKETS | MODULES & UPSTREAM MANUFACTURING | TECHNOLOGY AND R&D | WORLD

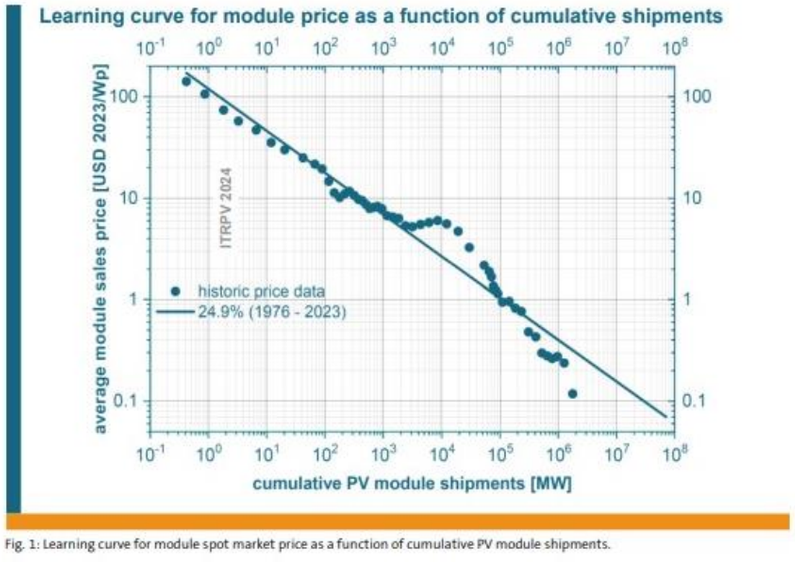
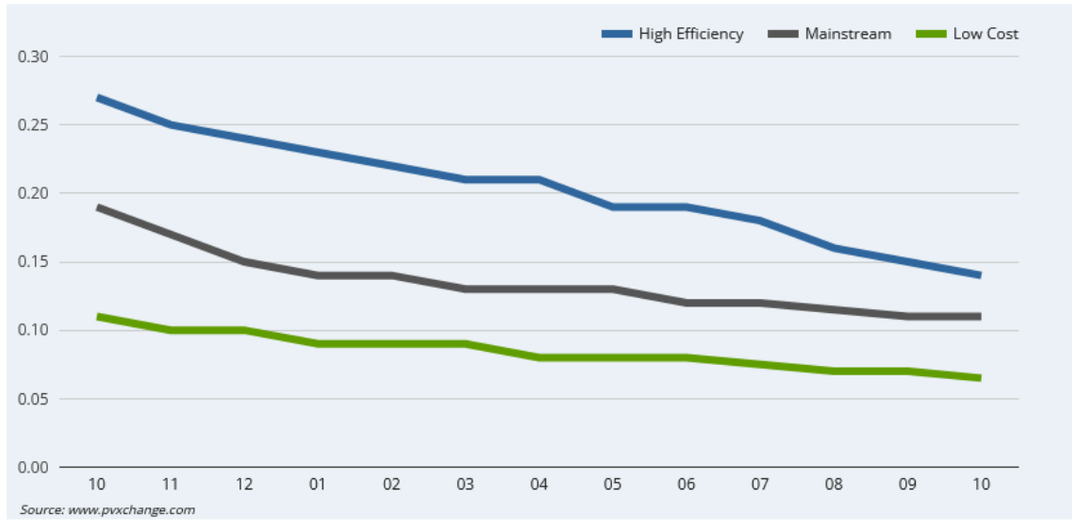


Fig. 1: Learning curve for module spot market price as a function of cumulative PV module shipments.

PV-magazine: 06.2024

2024

Price trend for solar modules by month from **October 2023 to October 2024** per category (the prices shown reflect the average offer prices for duty paid goods on the European spot market):



Overview by technology of different price points in **October 2024**, including the changes over the previous month:

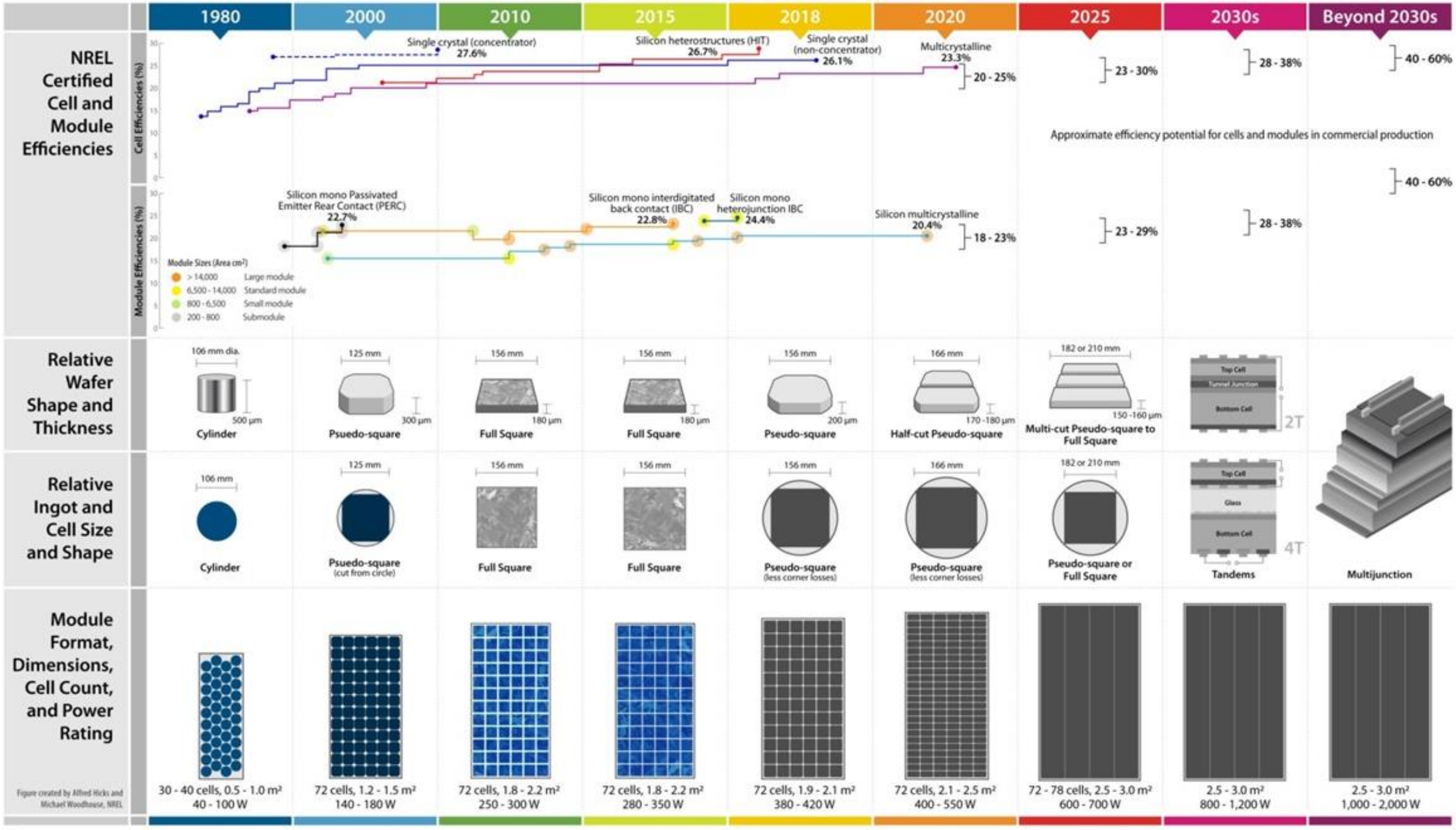
Module class	€/Wp	Trend since September 2024	Trend since January 2024	Description
Crystalline modules				
High Efficiency	0.14	- 6.7 % ↘	- 39.1 % ↘	Crystalline modules with mono- or bifacial HJT, N-type/ TOPCon or IBC (Back Contact) cells and combinations thereof, which have efficiencies higher than 22 percent.
Mainstream	0.11	0.0 % →	- 21.4 % ↘	Standard modules, typically with monocrystalline cells (also TOPCon), which are mainly used in commercial PV systems and which have an efficiency of up to 22 percent.
Low Cost	0.065	- 7.1 % ↘	- 27.8 % ↘	Stock lasts, factory seconds, insolvency goods, used or low-output modules (crystalline), products with limited or no warranty, wich usually also have no bankability.

Source: www.pvxchange.com

www.pvxchange.com

PV module technology

Alfred Hicks & Michael Woodhouse (NREL): ITRPV 2021: web seminar



- 1980 to 1990 (10 years): many changes
  - 1990 to ~2019 (30 years) Evolution.
  - **last 5 years: REvolution**

PAST: Technology EVOLUTION

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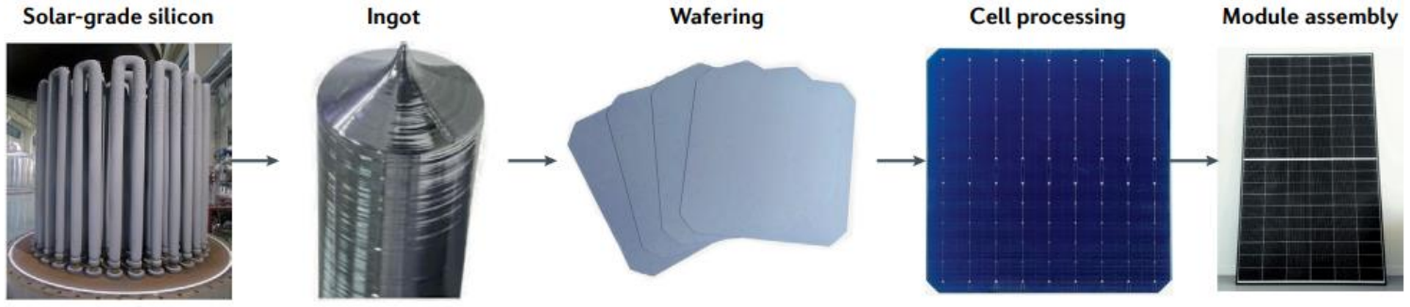
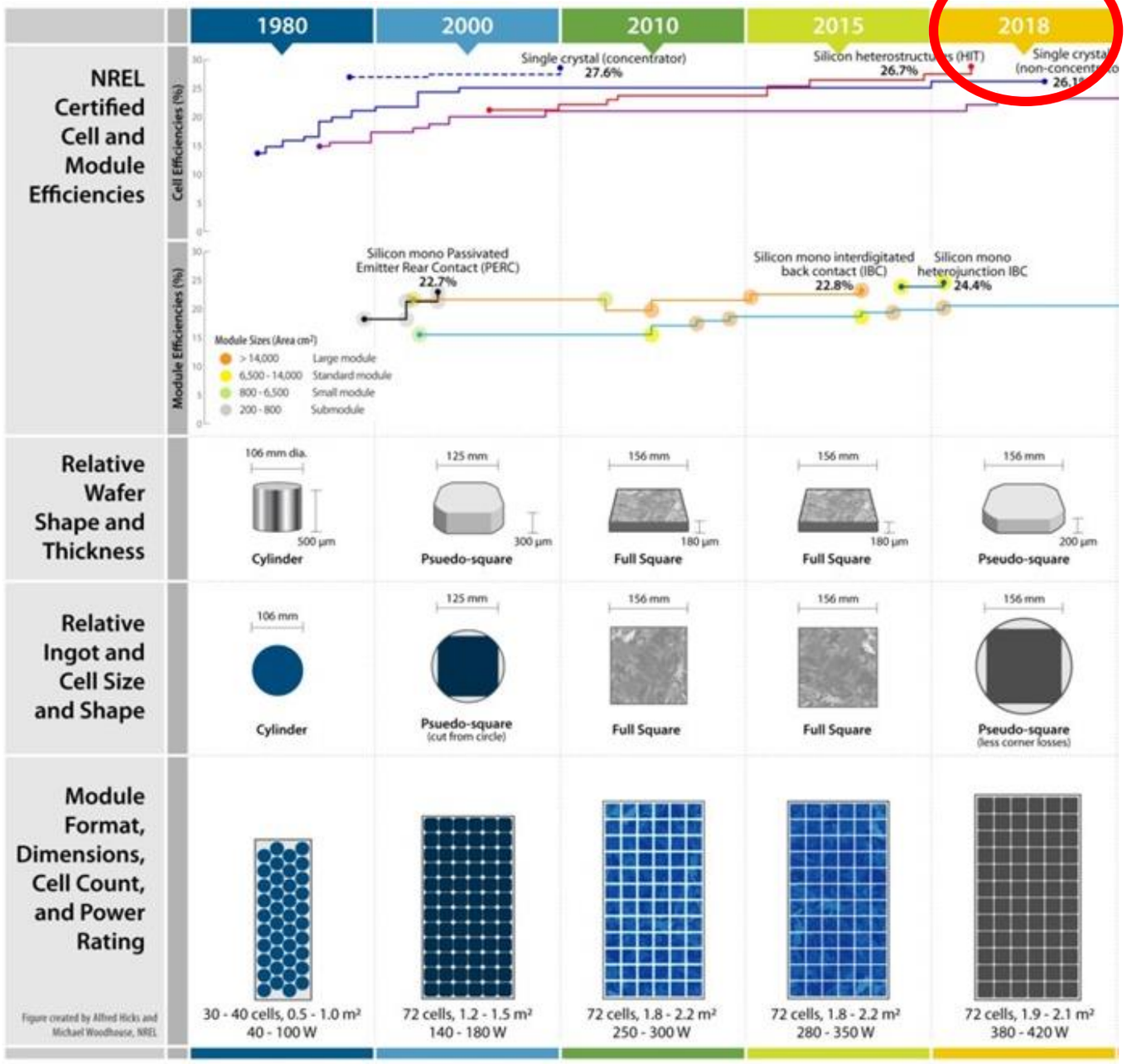




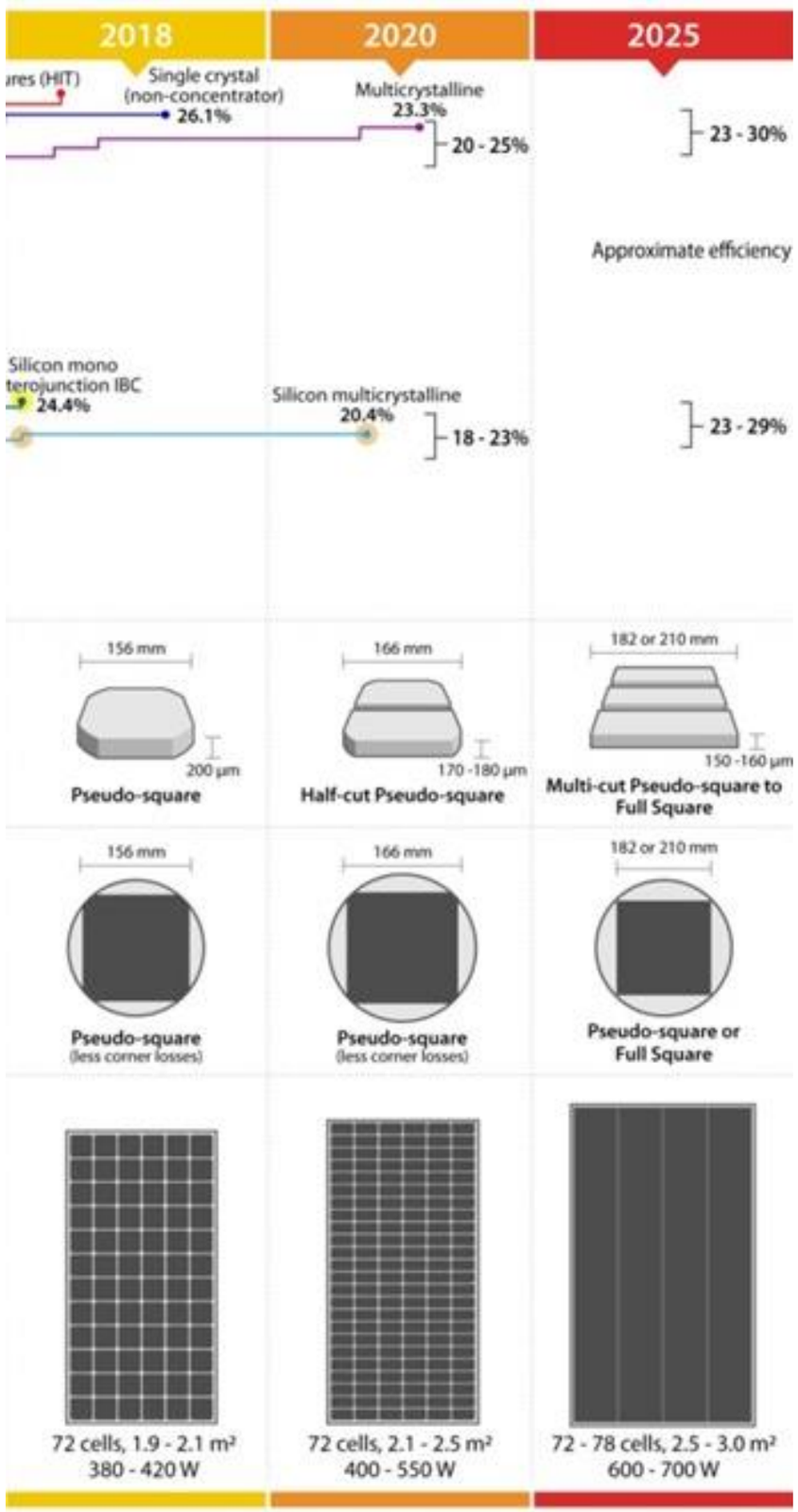
Ca. 1990 to 2020

Crystalline-silicon (c-Si):

1. Cell: Al-BSF
2. Interconnects: 3-4 bus-bars (BBs) + soldered ribbons
3. Encapsulant: EVA
4. Module structure: glass/foil

***Idem* ITRPV 2021: web seminar**

PRESENT: Technology R-EVOLUTION



Why?

Main drivers:
cost-reduction & increased conversion efficiency

What is changing?

1. New cell concepts: PERC, SHJ, **TopCon**, half-cells, 1/3-cells, bifacial cells…
2. Doping: Ga-doping, n-type cells, ..
3. Larger cells/modules >> higher powers
4. Interconnects: multi bus-bars, wires, shingled, overlap, …
5. Non-soldering interconnection techniques & low T processes
6. Glass/glass modules: thinner glass, untempered glass
7. New encapsulants: polyolefins (POE, TPOs, …), backsheet foils..
8. Module structure: glass/foil vs glass/glass
9. Higher-system voltages (1500 V vs 1000 V): a comeback for PID?
10. Module-integrated electronics
11. ……

PV module: service lifetime

Can we make solar PV modules that last for 30+ years?

YES

Is the industry doing it ?!?

Mhhh

IEC: International Electrotechnical Commitee

Conclusions

Solar PV has earned a **well-deserved good reputation** (over 40 years). This reputation is now at stake.

> If we change more than 1 parameter at the time (module technology), we stop understanding.

> We install new technology without any trackrecord.

> If we do this in a exponentially-growing («out-of-control») market and companies need to cut cost to remain competitive the situation is even worse.

Thank you for your attention !

Questions ?

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Solar cells technologies

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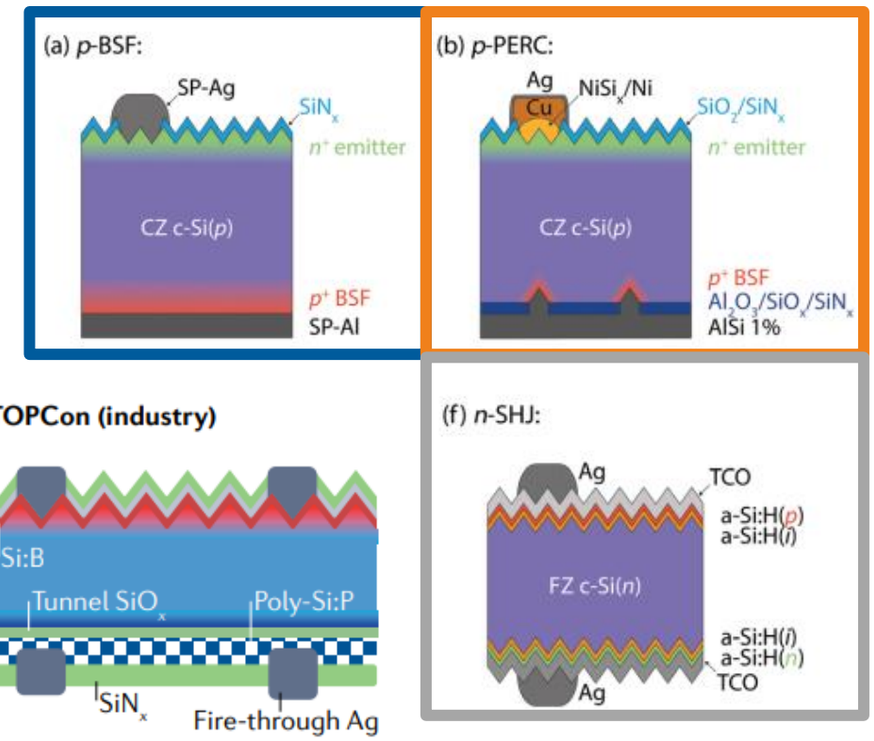
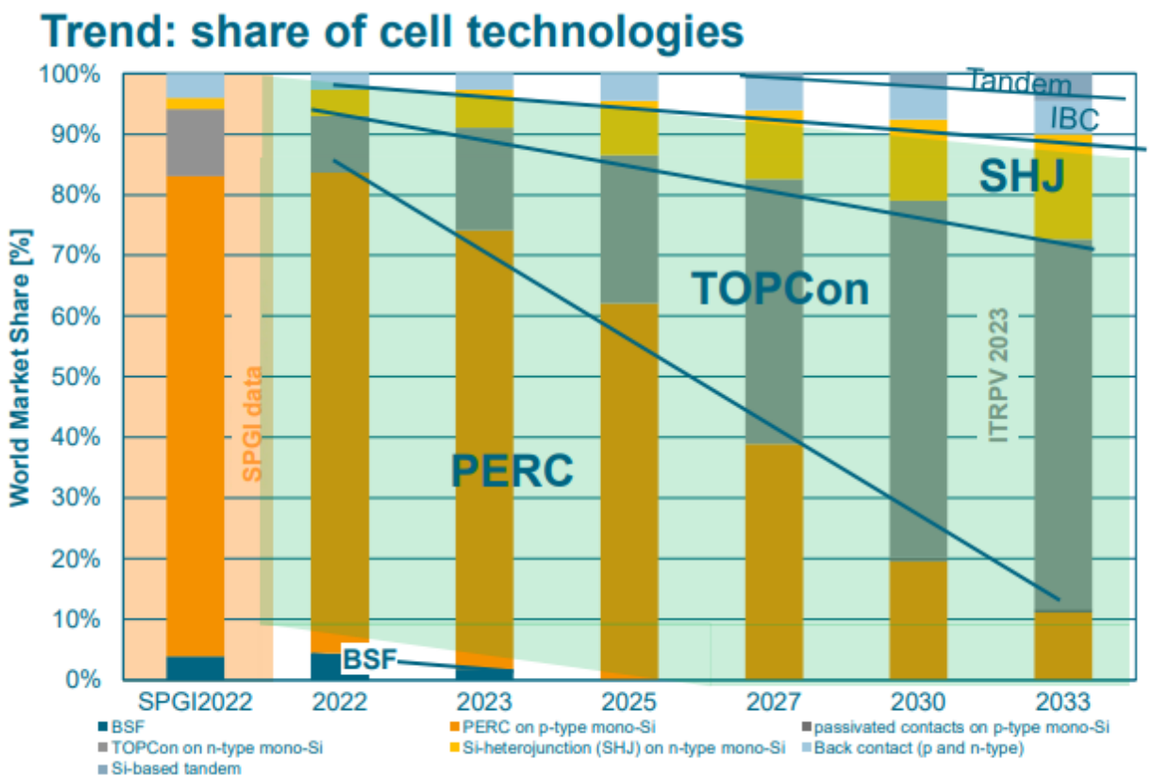
1. Thin Film (TF) PV now marginalized (CdTe resists, CIGS for special applications)
2. Crystalline silicon (c-Si) is the dominant technology
3. c-Si: until 2018 **BSF** (Back-Surface-Field), from 2018 onwards rapid transition to **PERC** (Passivated-Emitter-Rear-Contact)
4. Rapid transition from **poli** (~BSF) to **mono** (~PERC) + **Ga-doping** in place of B-doping (for p-type)
5. Coming now/next: Si n-doped wafers, **SHJ** (Si-Hetero-Junction), **TOPCON** (Tunnel Oxide Passivated Contacts)
6. Most cells are today made **bifacial**



J. Hascke et al. En. Env. Sci. 2017



ITRPV 2023

If reliability matters….

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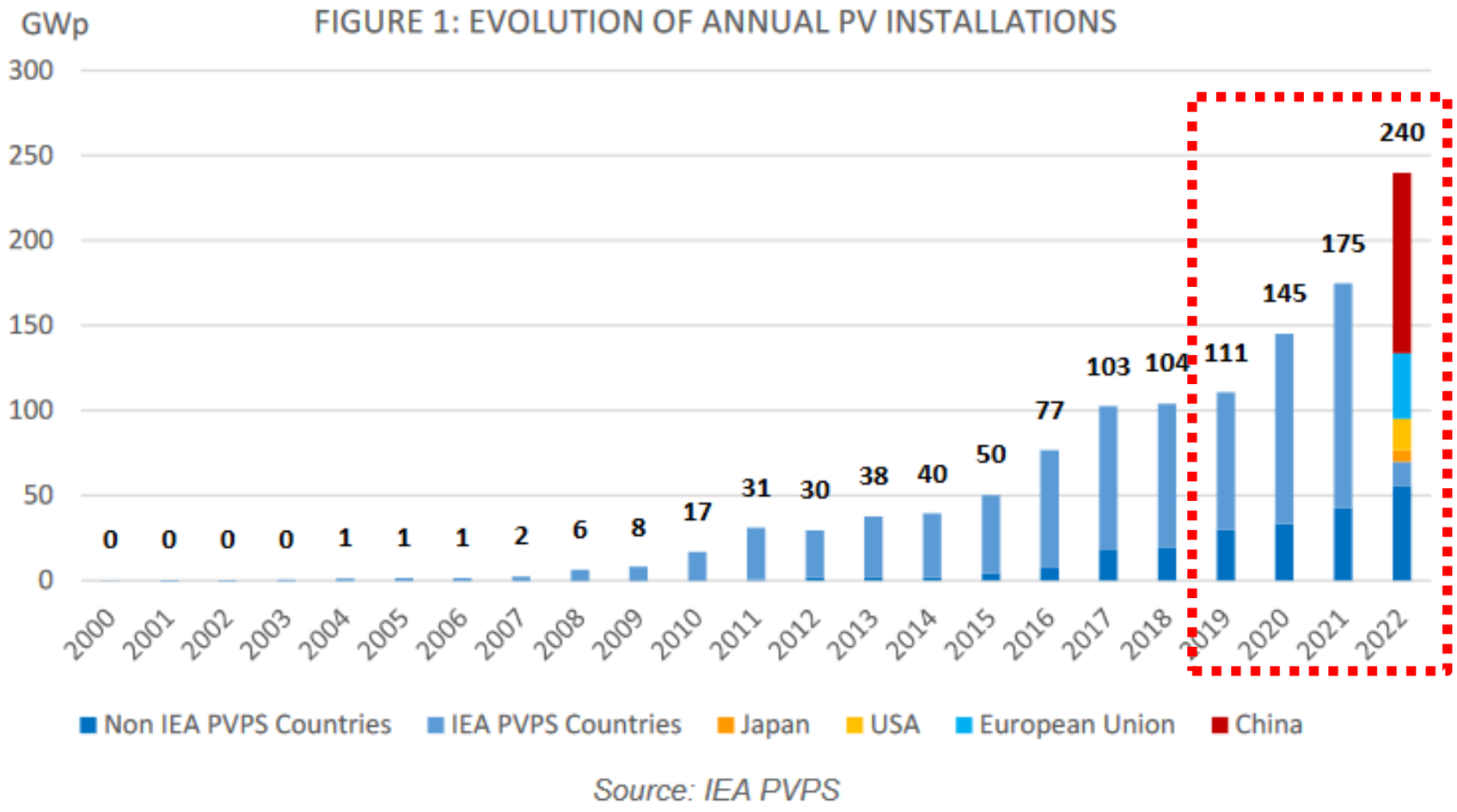


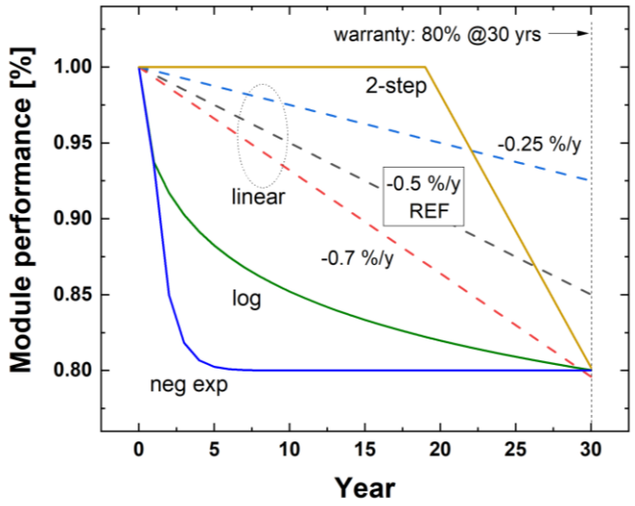
50% of global capacity installed in last 4 yrs !!!

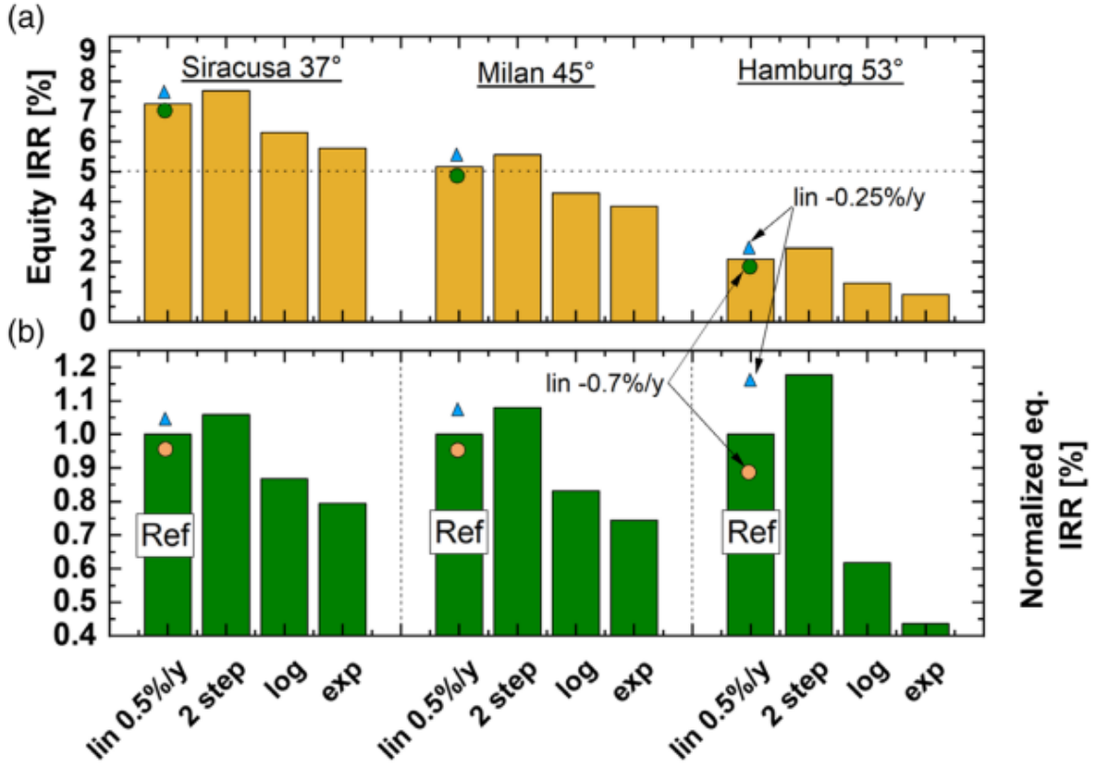
IEA-PVPS: snapshot 2023 report

1. Next TW of PV will be installed in 4 years
2. Market introduction of new concepts/materials is too fast
3. There’s a high reliability risk
4. There’s a high risk of loosing understanding of aging behaviors

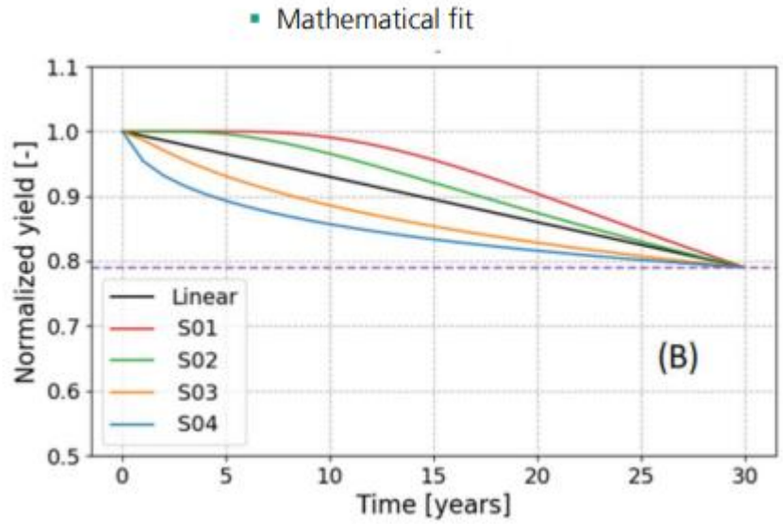
SOPHIA European Research Infrastructure

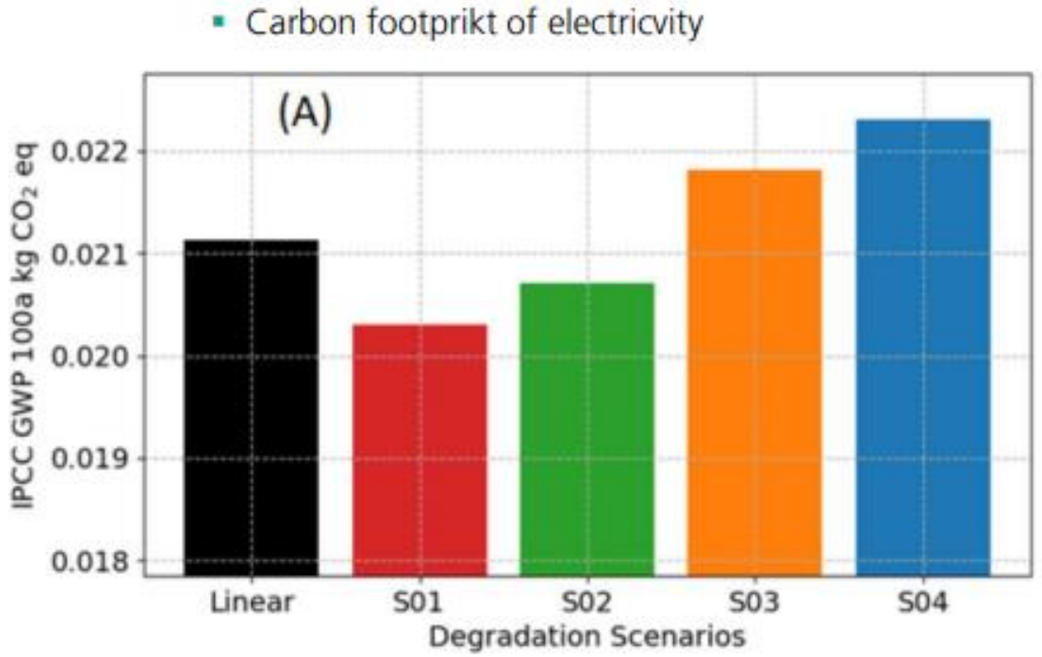
Why does reliability matter?





Virtuani et al. Solar RRL 2022





S. Herceg et al. Sustainability 2022

Reliability impacts the **profitability** of solar projects and the **overall** sustainability of PV.