# Photovoltaics as the innovative driving force of the energy transition – everywhere and for everyone

*Rutger Schlatmann*

*Head Solar Energy Division at Helmholtz Zentrum Berlin*

*Chair European Technology and Innovation Platform PV*

# Helmholtz-Zentrum Berlin für Materialien und Energie

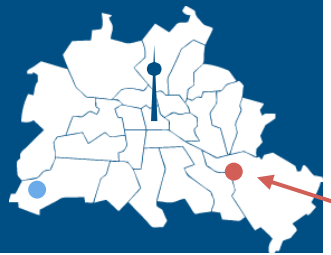
HZB Helmholtz Zentrum Berlin

Lise Meitner Campus

## Locations

Wannsee

Adlershof



Wilhelm Conrad Röntgen Campus

## ~ 1400 employees

~ 500 researchers
incl. 150 PhD students
~ 30 trainees
~ 10 young investigator groups

## ~ 3000 visits p.a. from guest researchers

>30 countries

## Funding

10 % State of Berlin
90 % federal government

Budget

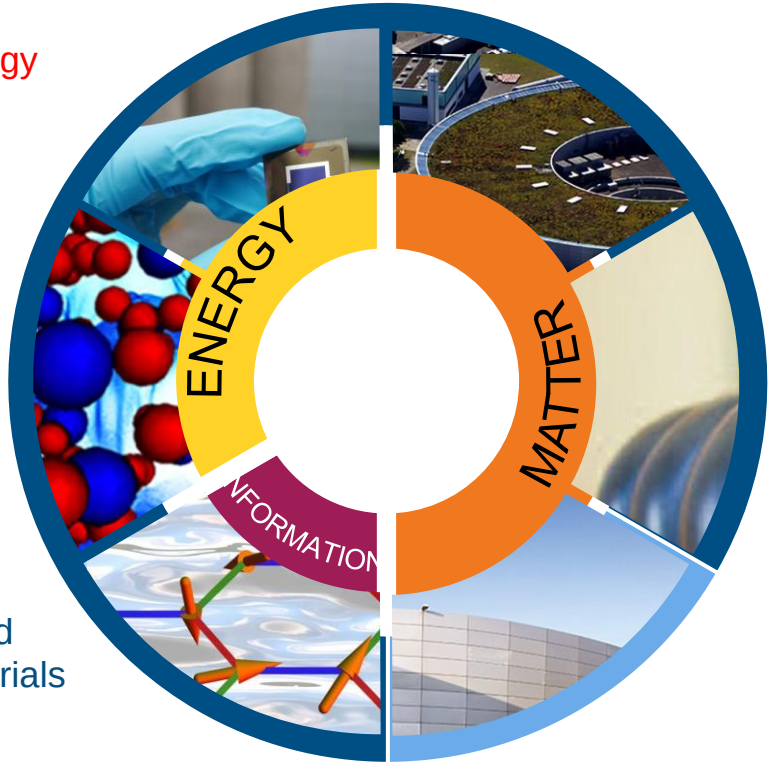
approx.
€ 200
million p.a.

# Helmholtz-Zentrum Berlin research themes

Solar Energy

Chemical Energy

Quantum and
Functional Materials



# Key messages of the ETIP PV vision

## By 2050 PV will

1. Provide 50% of final energy consumed in Europe
2. Be a central actor of the energy system stability
3. Support the global competitiveness of the European economy
4. Be at the heart of Europe's energy security and system resilience

# Key messages of the ETIP PV vision

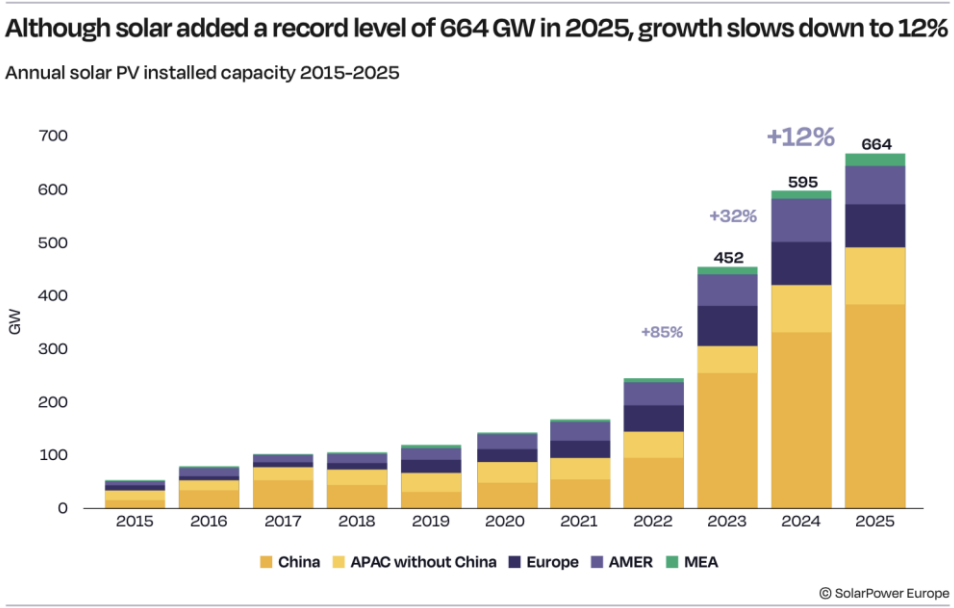
## Making European PV:

1. Policy defines the success of made in EU PV
2. Sustained competitiveness of EU PV manufacturing through innovation
3. Widespread digitalisation of PV's entire value chain
4. Reliability of PV technologies delivering energy security and cost efficiency.
5. Circularity along the value chain emerges as a core feature of PV in Europe

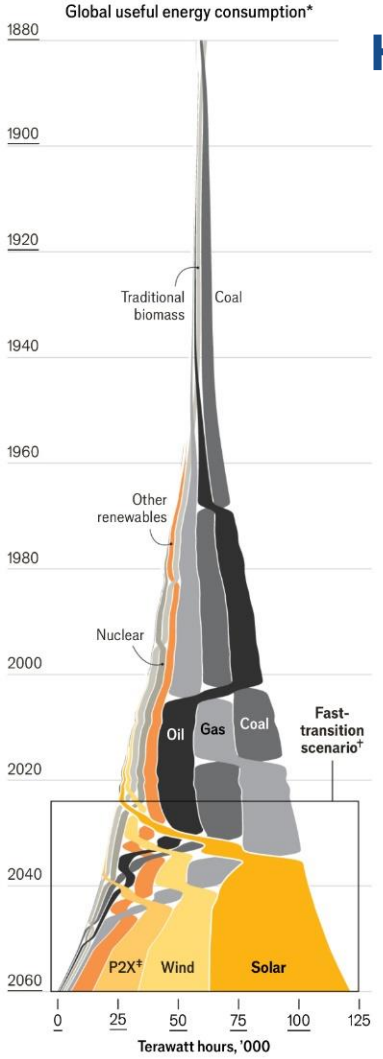
# Where are we now?

# Market size and growth

## Annual Solar PV Installed Capacity 2015 - 2025




*Source: SolarPower Europe, Global Market Outlook, 2026*




*Source: The Economist, Sun Machines, 2024*

# PV has been the largest global “new electricity capacity” for the last seven years

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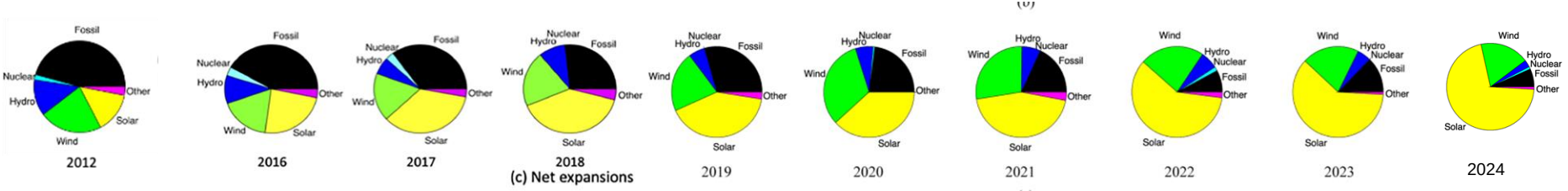
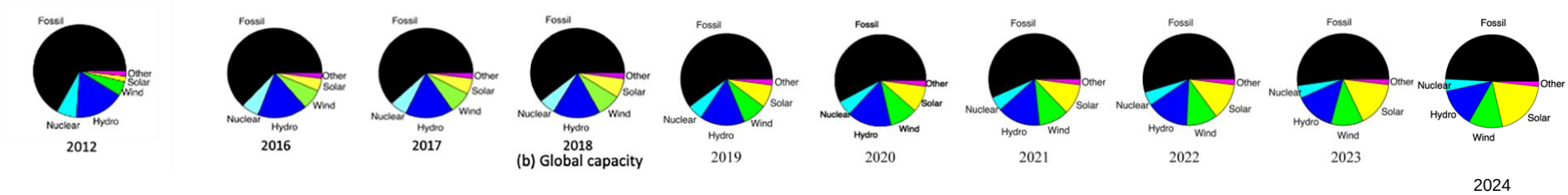
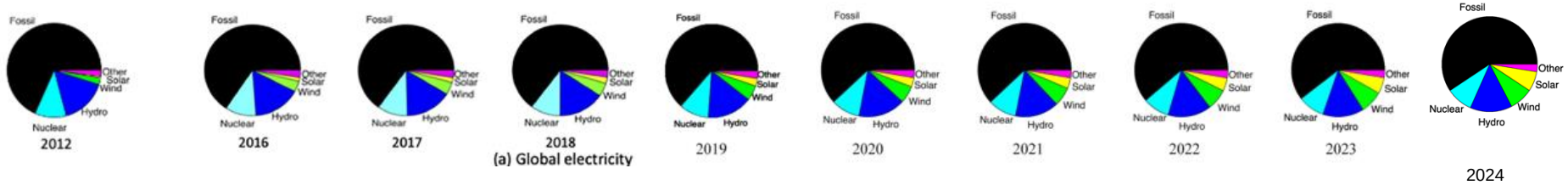
## Net capacity expansions per year




## Cumulative electricity generating capacity




## Electricity generation




*Haegel and Kurtz, IEEE Journal of Photovoltaics 2025* doi: 10.1109/JPHOTOV.2025.3604876

Example Khavda energy park, India

# Wind and Solar Power – the world-wide largest power plants

**30 $GW_p$ Wind and PV**

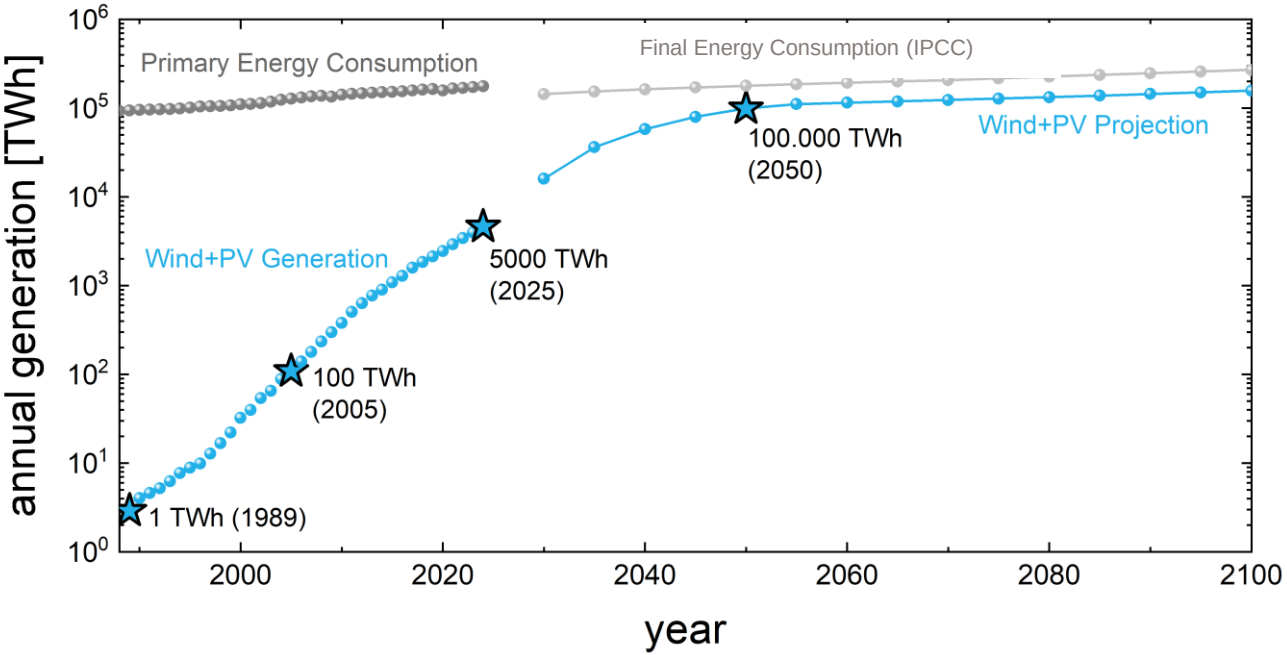
**80 TWh el. power /year**

**60 Mt $CO_2$ savings / year**

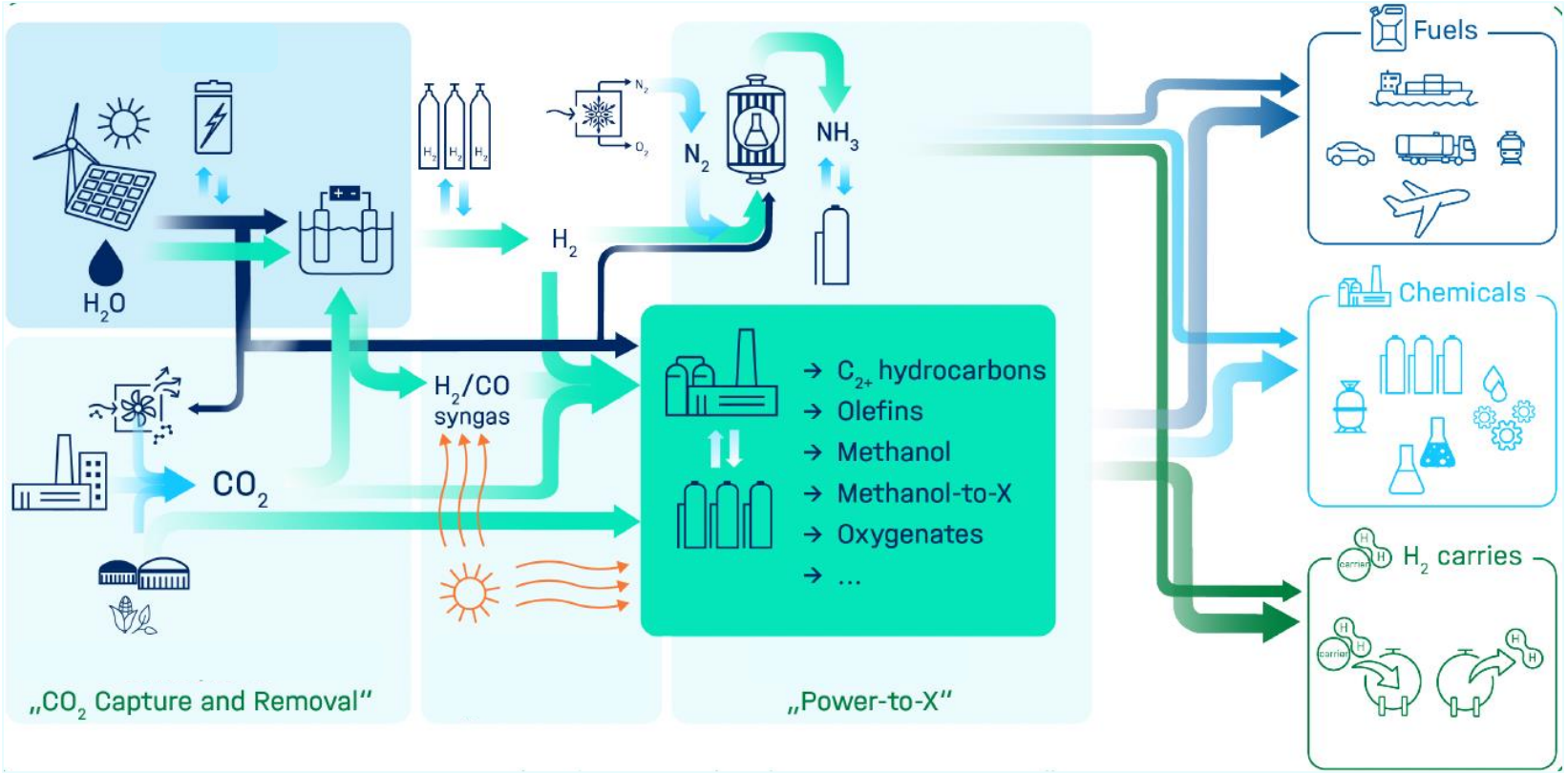

9

# PV and wind have become TW technologies

PV and wind generate 5000 TWh today. A constant growth rate yields 100.000 TWh in 2050.

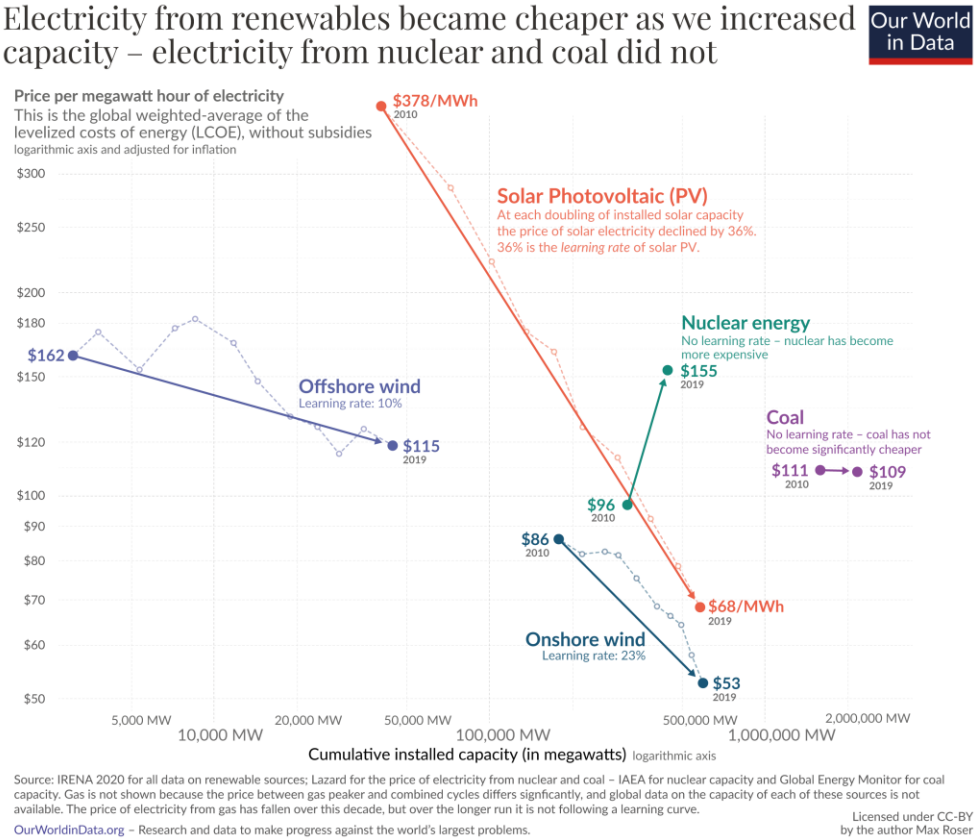


# Electrification of the energy system

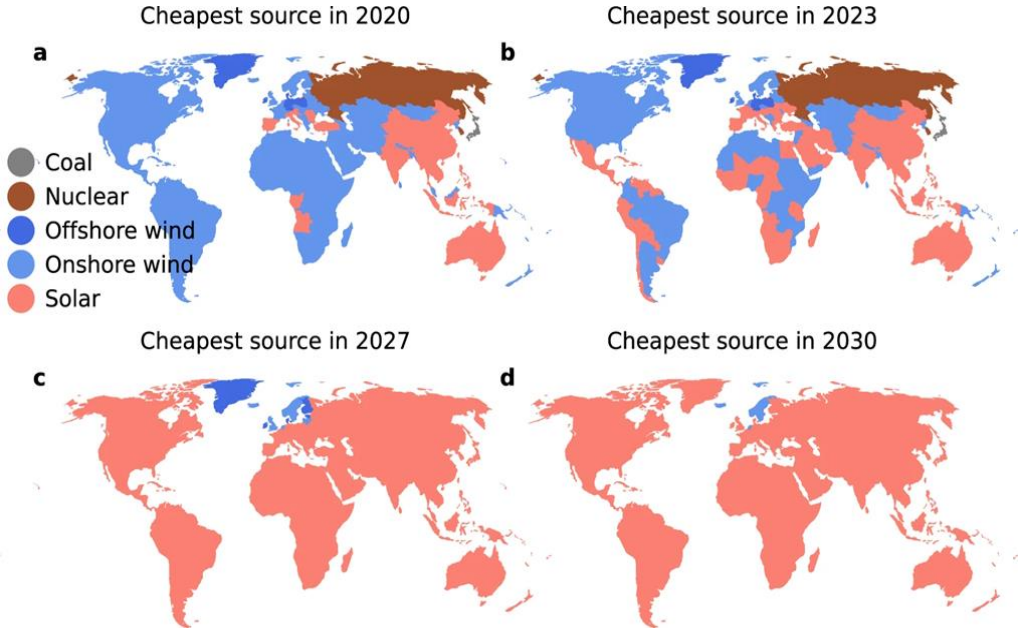


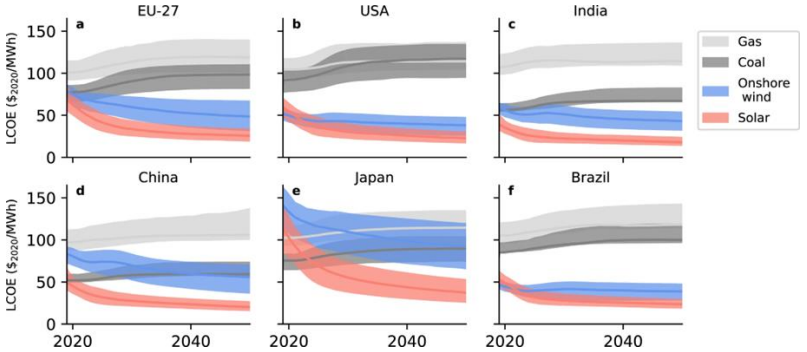
# What are the drivers?

# Spectacular cost reduction of PV



# The electricity market is not global, but PV cheapest source almost everywhere




*The momentum of the solar energy transition*
Femke J. M. M. Nijsse, Jean-Francois Mercure, Nadia Ameli, Francesca Larosa, Sumit Kothari, Jamie Rickman, Pim Vercoulen, and Hector Pollitt, Nature Communications **14,** 6542 (2023)

# Cost reduction of battery storage!

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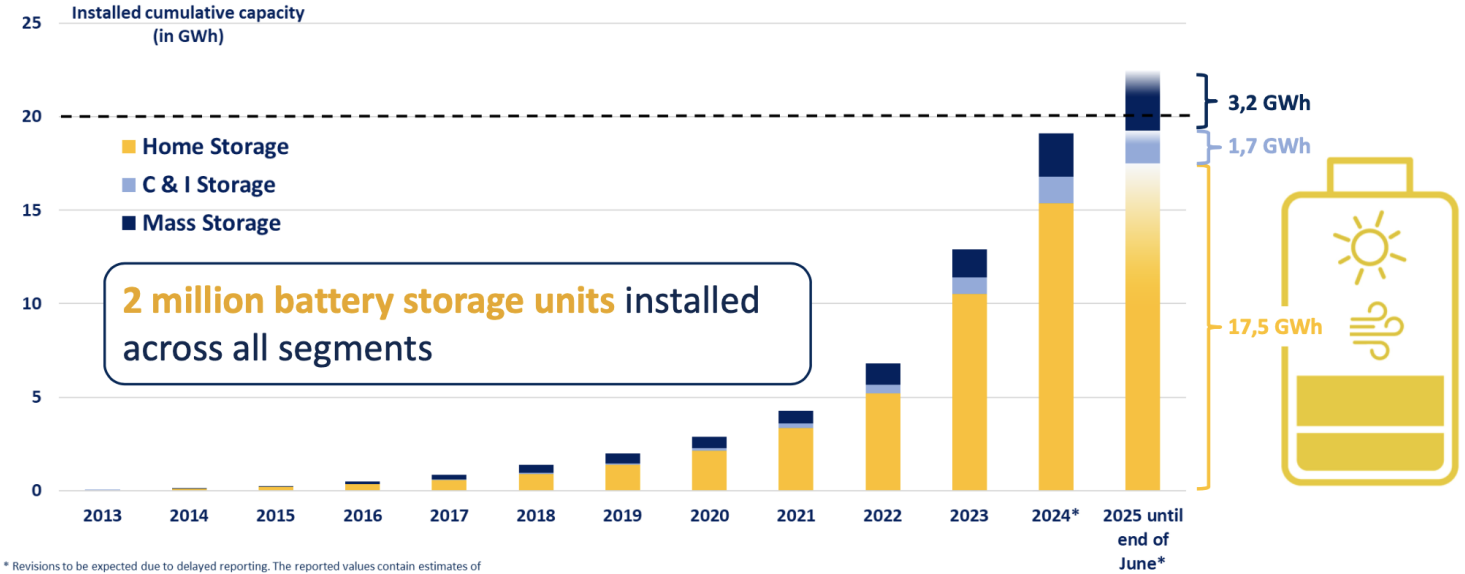
## Battery storage volume surpassed 20 Gigawatt hours in 2025

**2 Million battery systems** installed across all segments

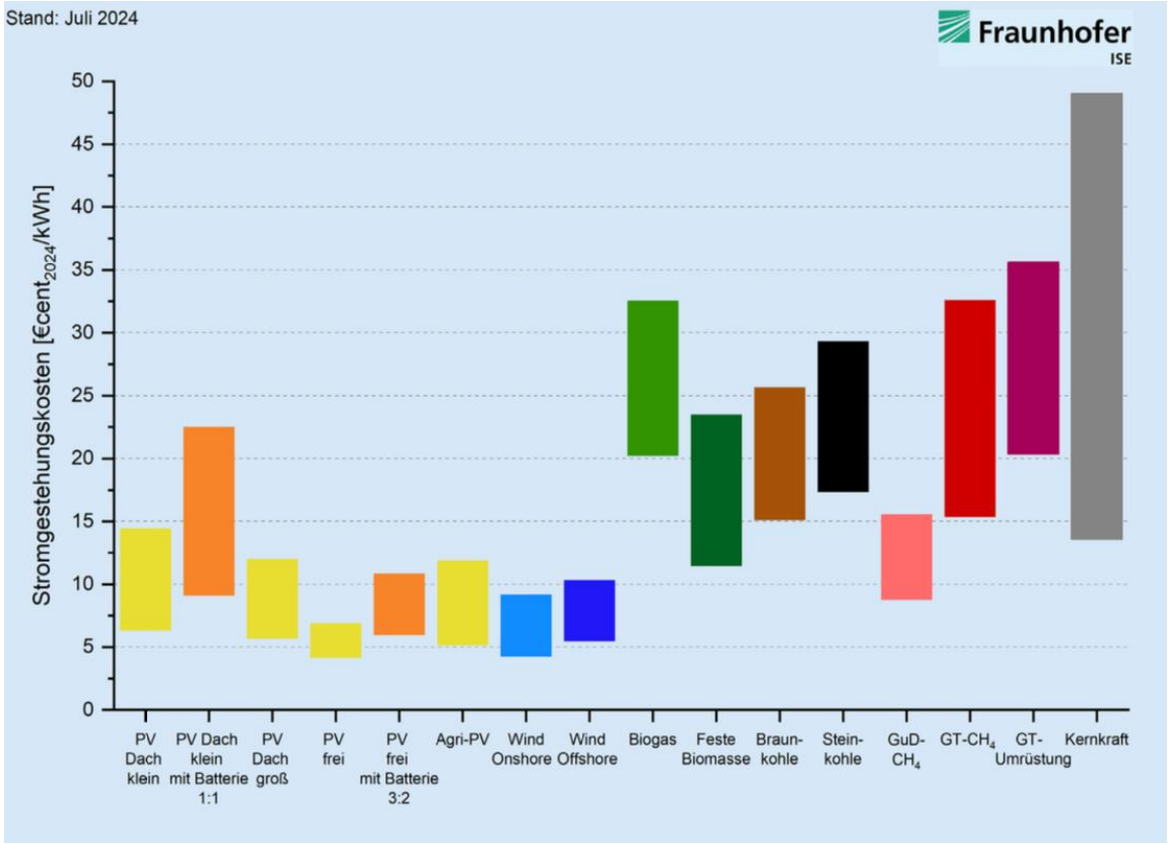
BSW SOLAR




* Revisions to be expected due to delayed reporting. The reported values contain estimates of (late) registrations to be expected until mid Aufust 2026 based on previous registration patterns.
Source: BSW, own estimates based on MaStR as of August, 12th, 2025.

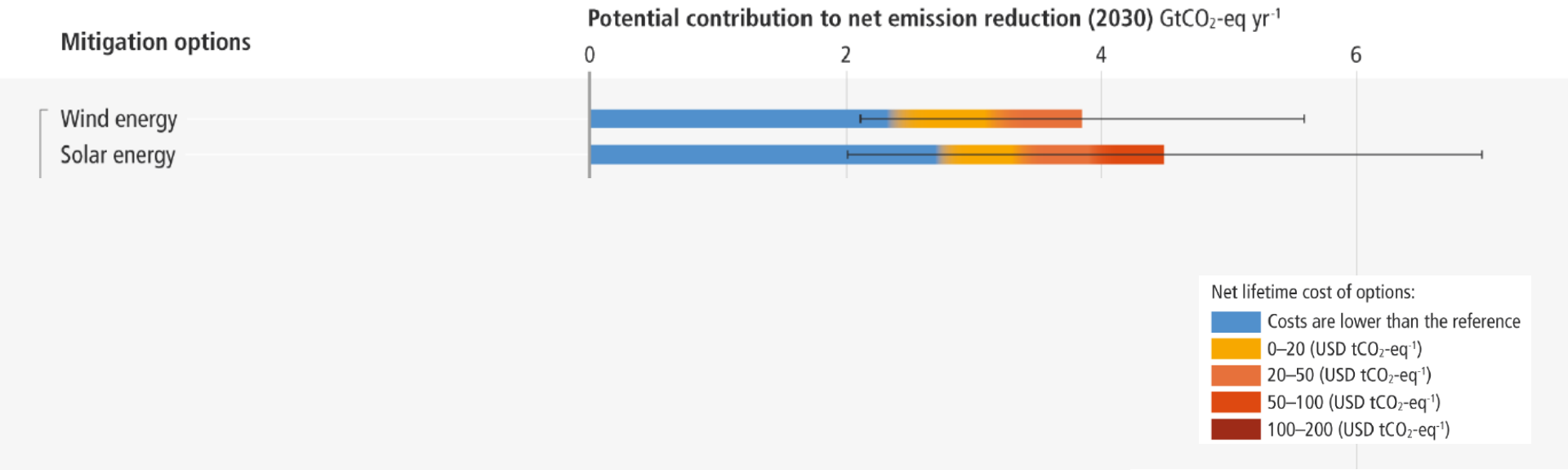
# Cost comparison for newly installed power plants





# What about, …., climate change?

# Solar & wind energy have largest potential to reduce $CO_2$ emissions



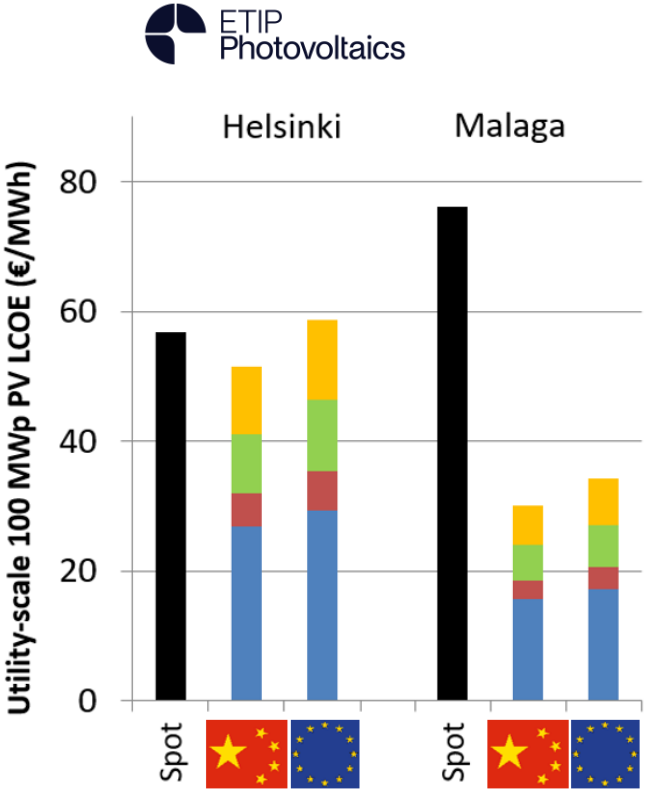

IPCC AR6, Working Group III, 2022

# What about, …, EU resilience and strategic autonomy?

# Politics: national, EU, and global

- **REPowerEU**
- **EU Green Deal**
- **Green Deal Industrial Plan**
  - **Net-Zero Industry Act**: “Strategic net-zero technologies manufacturing capacity in the EU approaches or reaches at least ***40% of annual deployment needs by 2030.***”
- **2025:Clean Industrial Act**
- **2026: Industrial Acceleration Act**
- **Strong ambition for local PV manufacturing, but little tangible effect so far**

- Manufacturing in China is ~50% cheaper than in the EU, but ***the effect on LCOE is not very pronounced!***



# Innovation opportunities!

- Reliability of PV technologies delivering energy security and cost efficiency
- Circularity along the value chain emerges as a core feature of PV in Europe
- Widespread digitalisation of PV's entire value chain (including grid services, energy communities, new business models)
- Multi-benefit integration of high efficiency PV

# Land use for a 100.000 TWh scenario

Urban Landscapes

Agriculture

Mobility

Society

**Multi-benefit integration reduces conflicts**

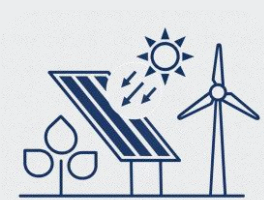
- In 5000 years, we have created 800.000 $km^2$ of manmade structures on earth
- Until 2050, we globally need about 1.5 Mio $km^2$ for the total renewable energy area
- In Germany, this will require ca **16.000 $km^2$ for 400 $GW_p$ PV (**and 160 $GW_p$ wind)

**MISSION: Achieve highest efficiency for "multi-benefit" integrable technologies**

# Land use for a 100.000 TWh scenario

**Technical Potential (D)**
**~ 1 $TW_p$**

**Urban Landscapes**



**Technical Potential (D)**
**~ 5 $TW_p$**

**Agriculture**

**Technical Potential)**
**~ 0,3 $TW_p$**

**Mobility**

**Acceptable, Efficient, Sustainable**

**Society**

**Multi-benefit integration reduces conflicts**

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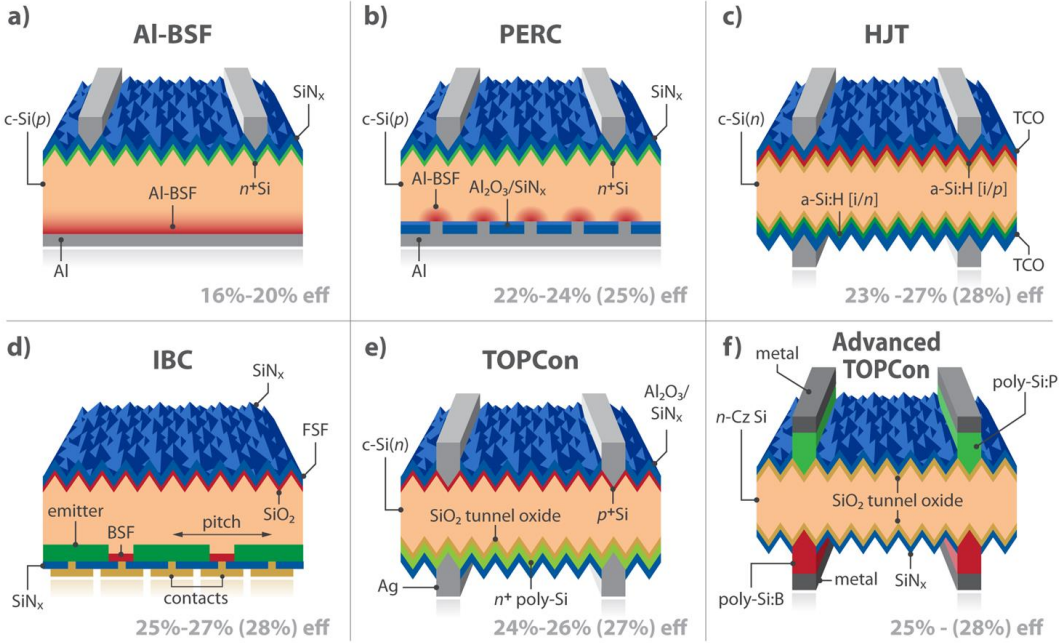
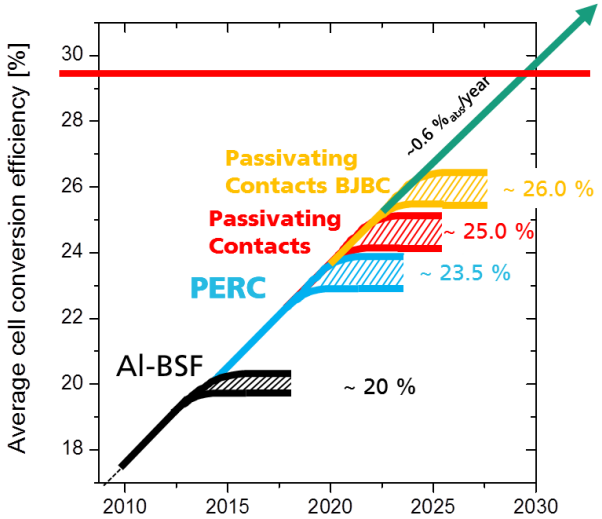
**MISSION: Achieve highest efficiency for "multi-benefit" integrable technologies**

# Pushing efficiency, generations of Silicon solar cells

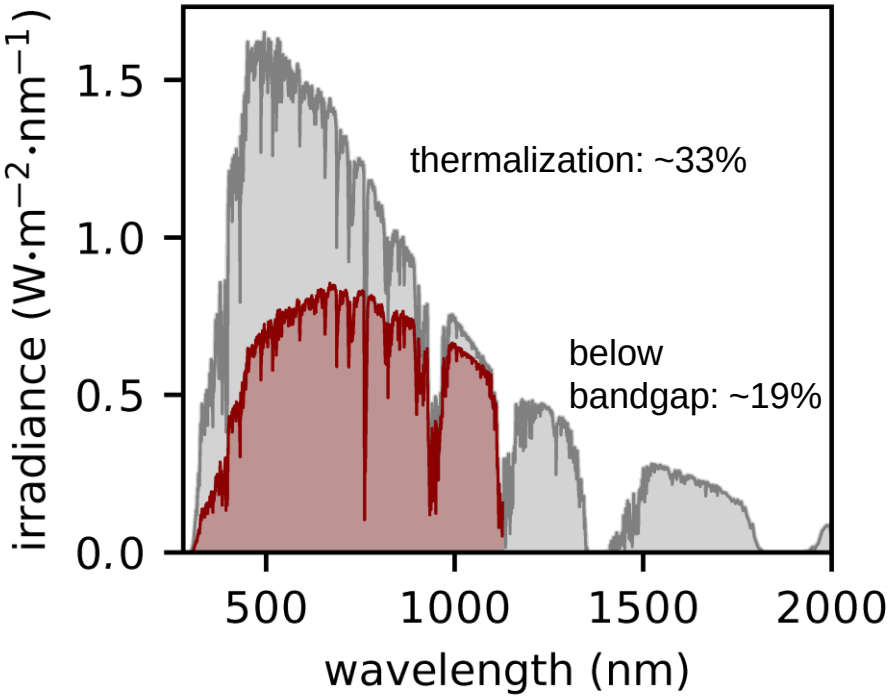


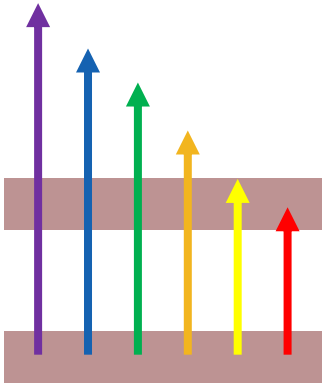




Verlinden et. al., Device **1**, 2023.

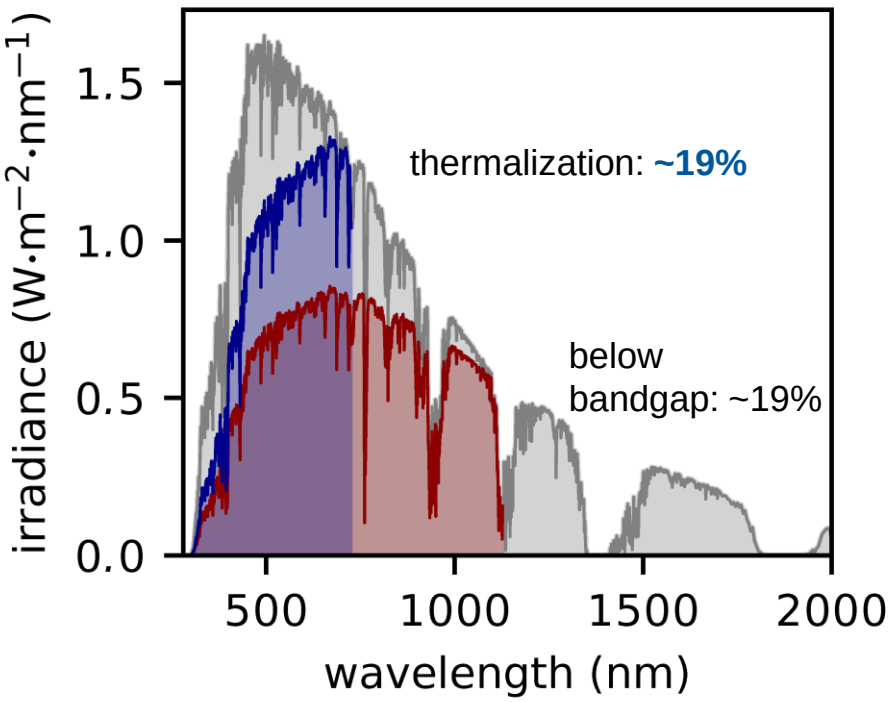
M. Hermle ETIP 2017

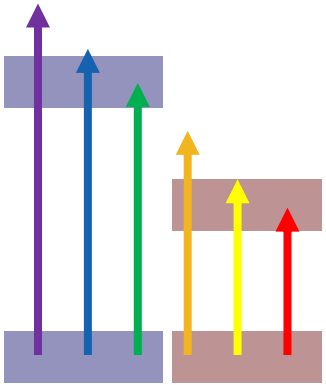
# Limits to solar cell efficiency based on silicon (or any absorber)



# In multijunction solar cells, sunlight can be used more efficiently.



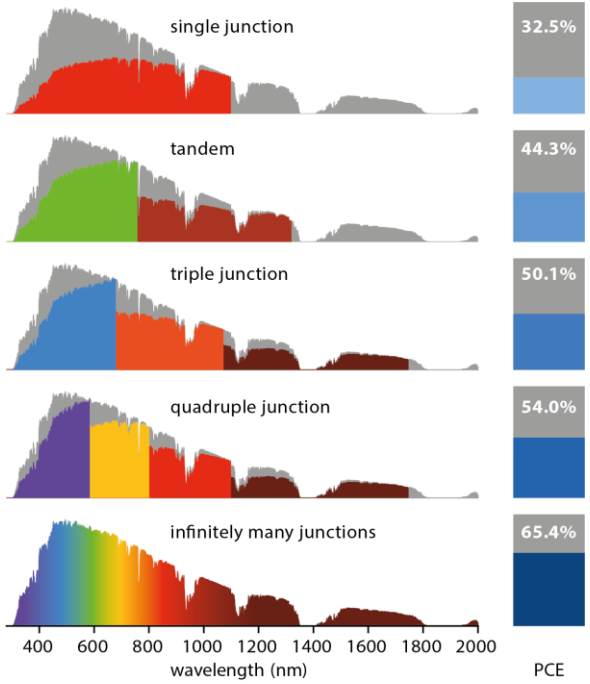
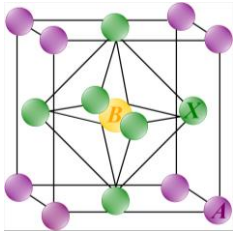
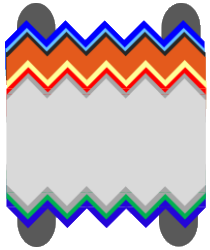


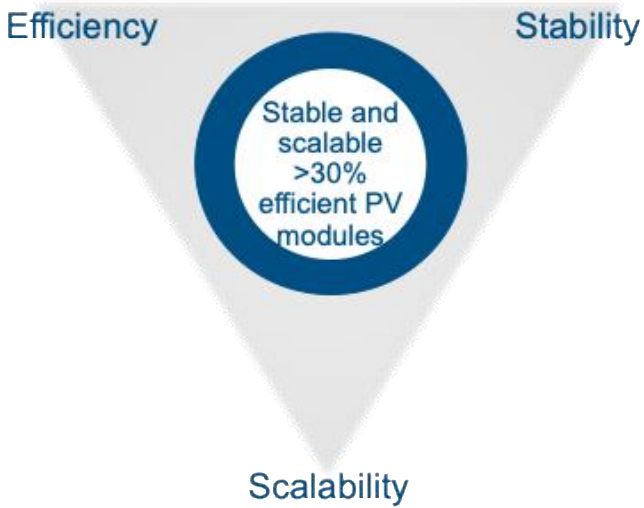

*Image courtesy: Klaus Jäger (HZB), Values from Marti et al., DOI: 10.1016/0927-0248(96)00015-3*

# Perovskite absorbers: superior material properties and ideal silicon partner

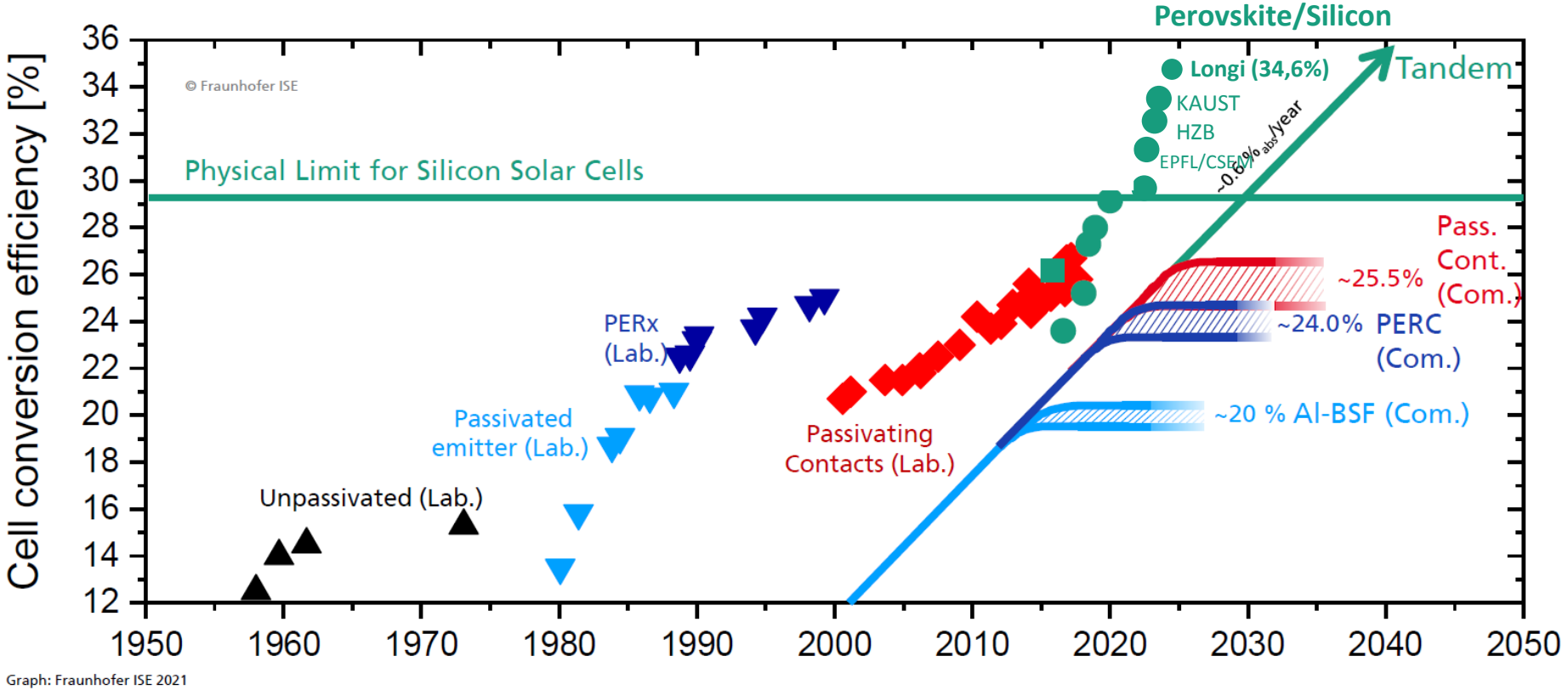
- Tunable Bandgap, ideal for multijunctions
- Very high electro-optical quality
- Low cost deposition
- Stability not yet sufficiently proven?



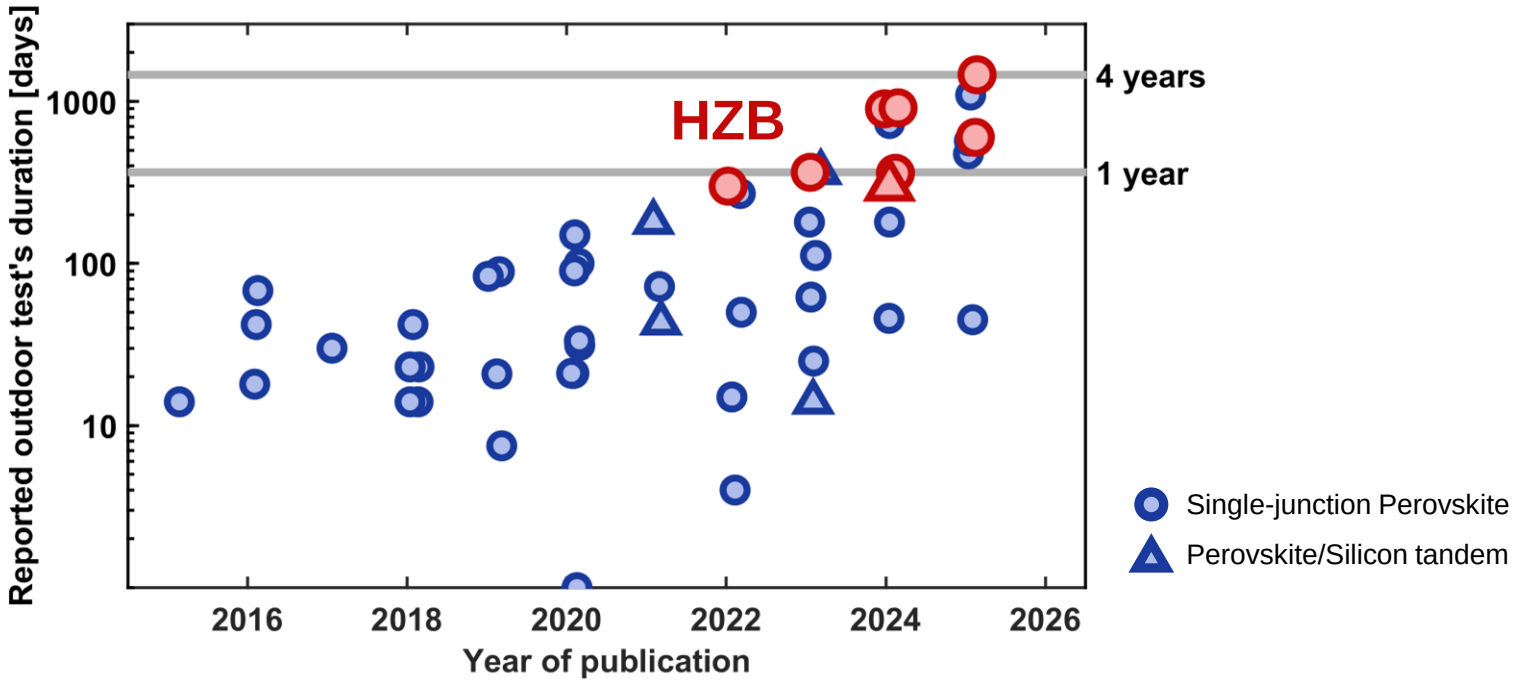



# Extending the efficiency development

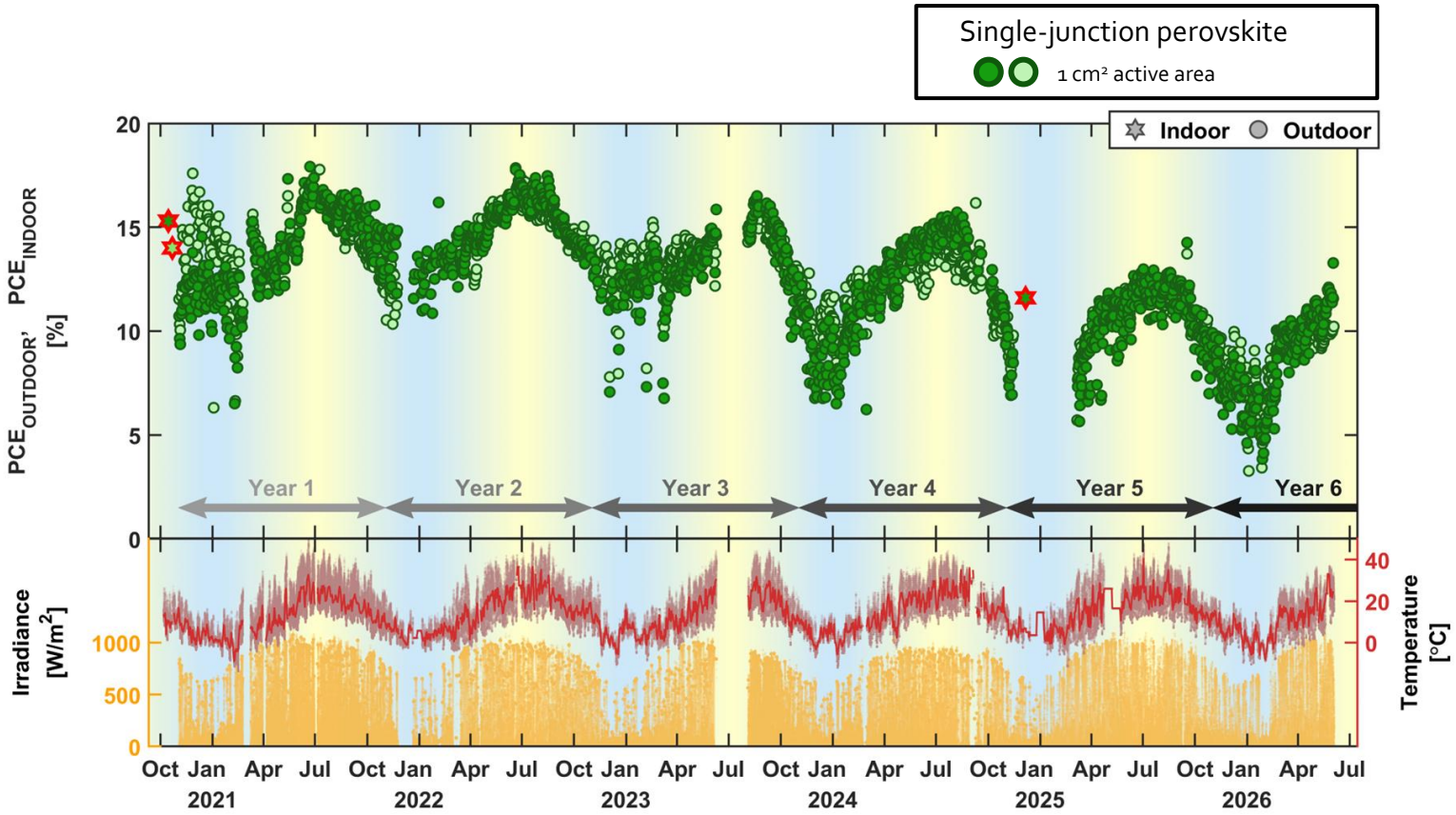



adapted from „ISE photovoltaics report 2022“, www.ise.fraunhofer.de

# Stability: Steady progress in reported outdoor experiments

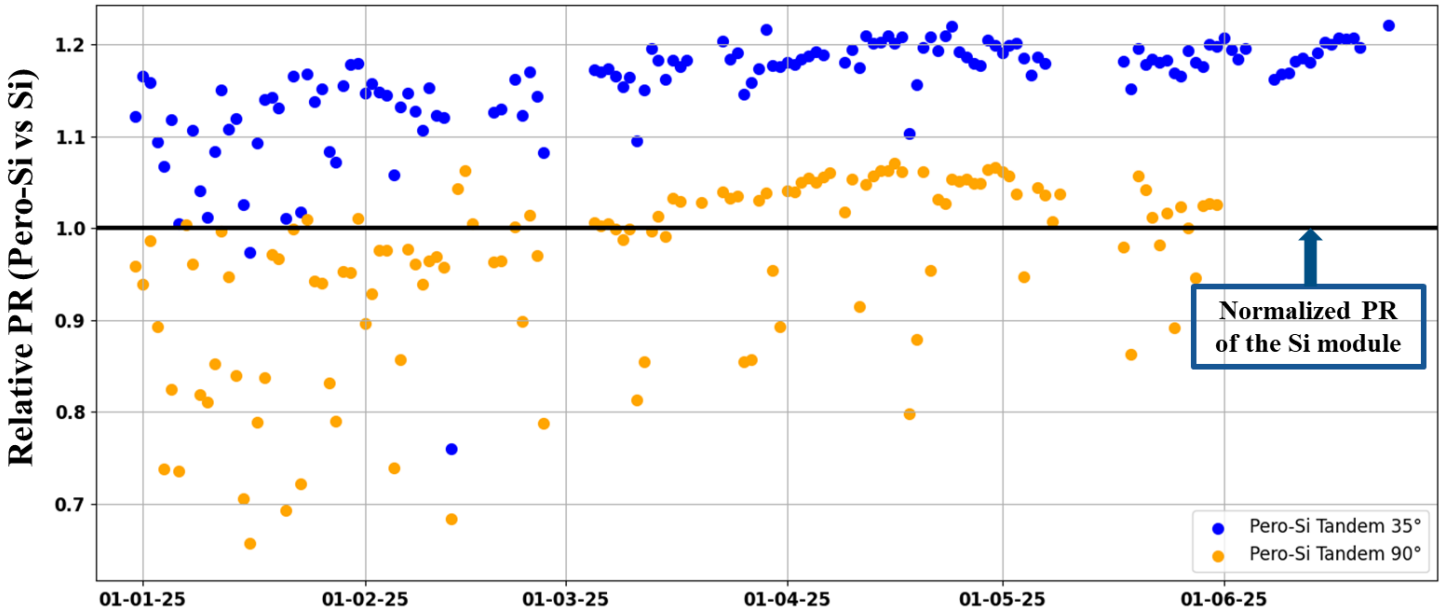


# Perovskite stability, a complex scientific and technological issue




M. Remec et al., "Seasonality in Perovskite Solar Cells: Insights from 4 Years of Outdoor Data," Advanced Energy Materials, 2025, doi: 10.1002/aenm.202501906.

# Sneak preview: full industrial size Si-Pero Tandem modules outdoor




- Full size industrial Perovskite-Silicon tandem module compared to the Silicon technologies
- The tandem outperforms all siilcon-based modules, so far

Ulbrich et al., to be published

# Device concepts beyond silicon-perovskite tandems

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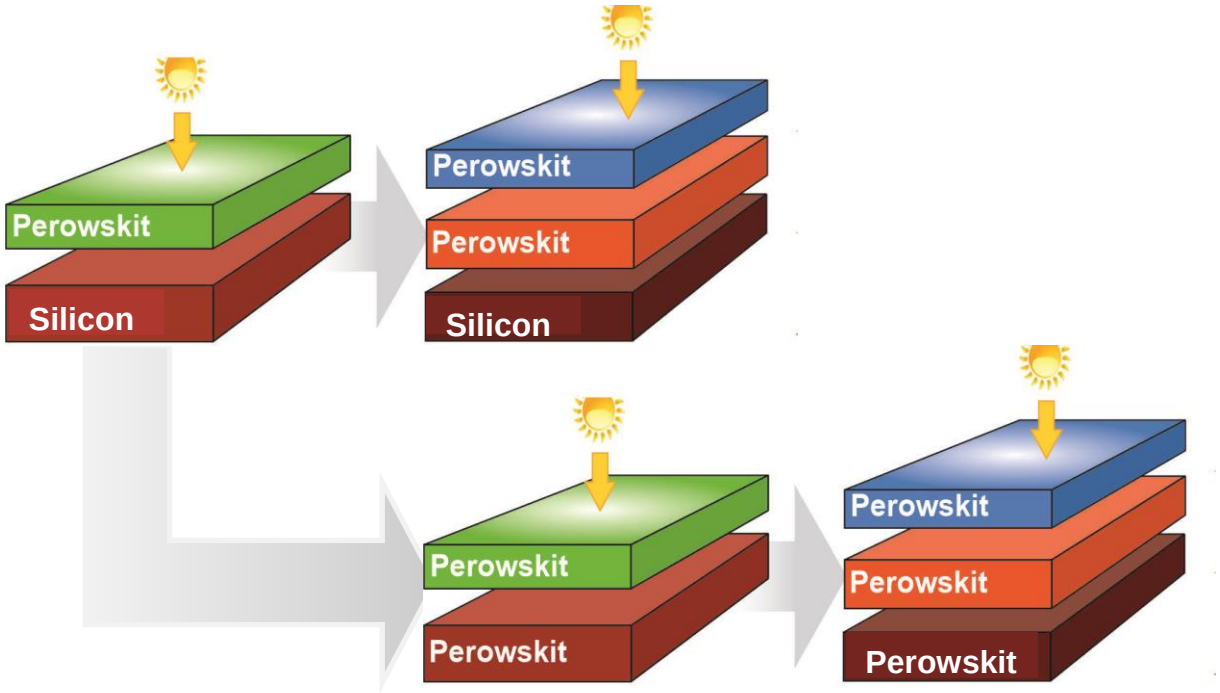


- Many further combinations possible
- Very high efficiency potential

# Some conclusions

- Techno-economic developments for PV have been spectacular and will open up new avenues for clean electrification and power-to-molecules
- Ambitious EU policies, but big gap between ambition and reality for regional production.
- Consumer LCOE effect of higher local production costs small!
- ETIP PV funnels Europe´s combined industrial and academic PV R&I (Co-programmed Partnership for PV)
- The opportunity for further innovation is enormous (system, grid, storage, PV modules, and PV integration)
- Conversion efficiency strongest technological lever for further PV module development
- Demonstrated high-efficiency potential for perovskite-based tandems, Silicon-Perovskite closest to market
- Outdoor stability of perovskites is complex but steadily better understood and is still futher improved

# *Thank you for your attention!*

**Thank you to all colleagues at HZB, ETIP PV and to our partners!**

Federal Ministry of Research, Technology and Space

Federal Ministry for Economic Affairs and Energy