The rise of PV: Economic and Technological Perspectives

Empa
Materials Science and Technology

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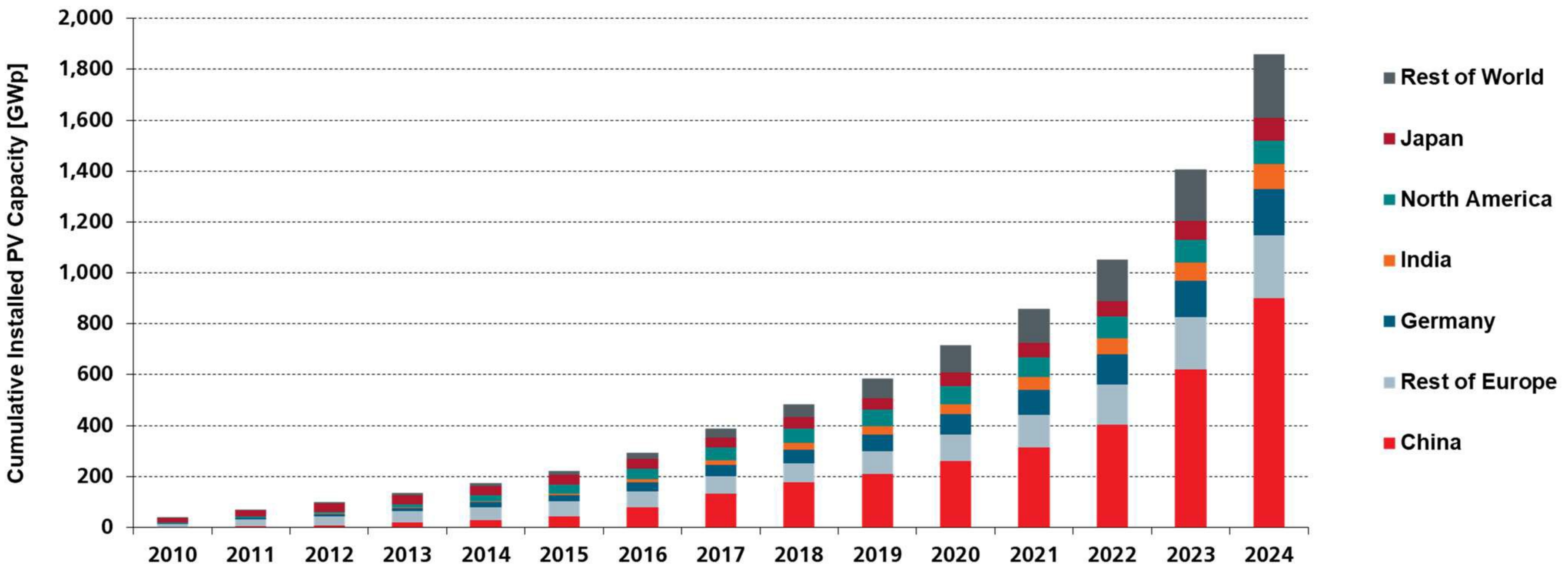
Key Facts and Achievements About Solar Photovoltaics

- Solar PV is expanding faster than total electricity demand, with solar alone covering 83% of the rise in global demand in the first half of 2025.
- Solar's share in the global electricity mix rose from 6.9% in 2024 to 8.8% in the first half of 2025.
- In the first half of 2025, renewables, led by solar, overtook coal-fired generation for the first time.
- Solar PV has been on a long-term trajectory of rapid cost decline and deployment growth, and there’s nothing about the underlying physics, economics or politics that suggests that trend will suddenly stop.

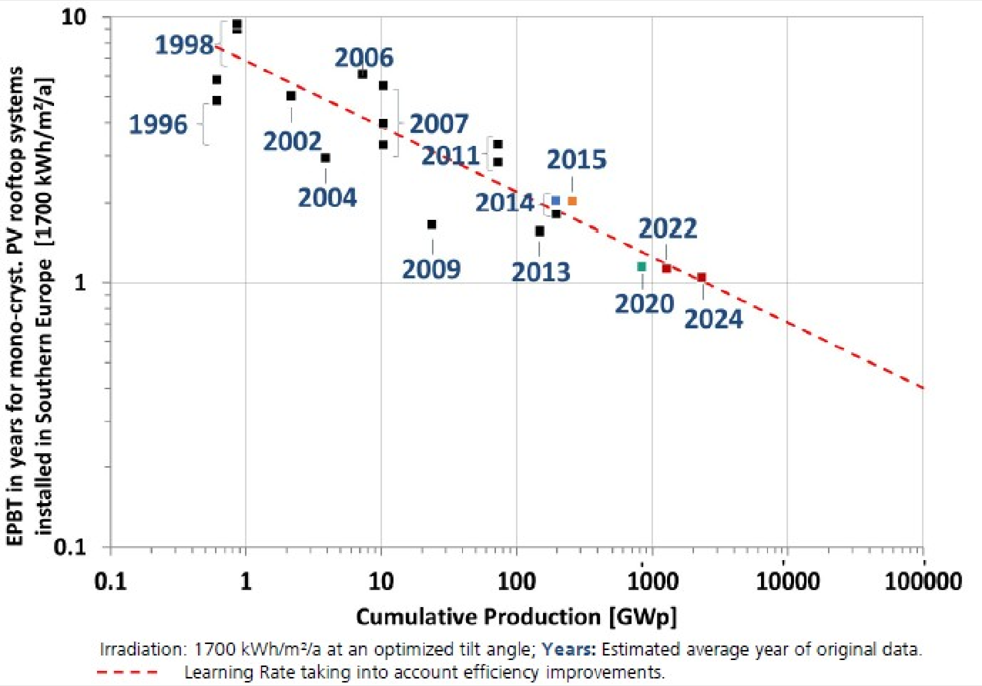
International Energy Agency IEA, Global Energy Review 2026

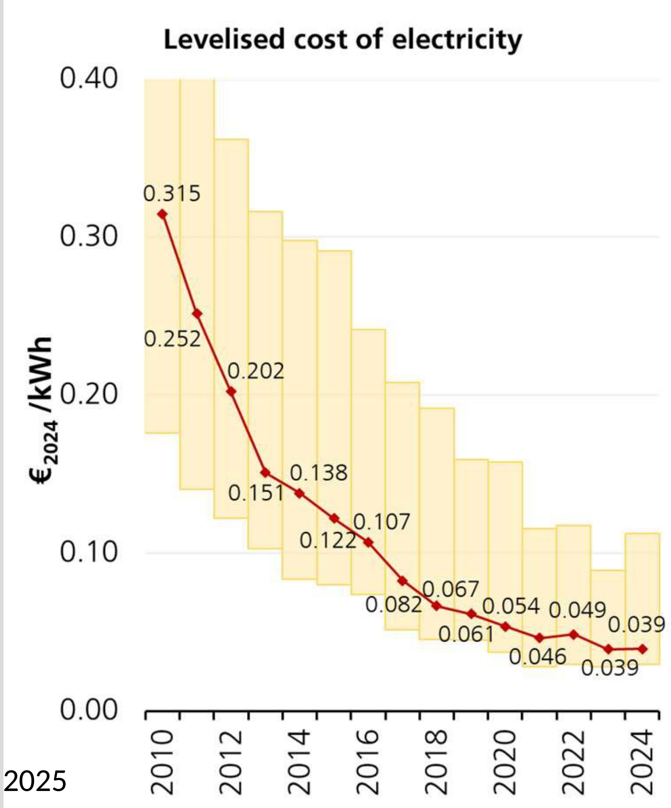
Global Growth of Solar Power Deployment



IRENA 2025. Graph: PSE Projects GmbH 2025. Date of data: 24.03.2025

Energy Pay Back Time and global weighted average Levelized Costs of Electricity for large PV systems



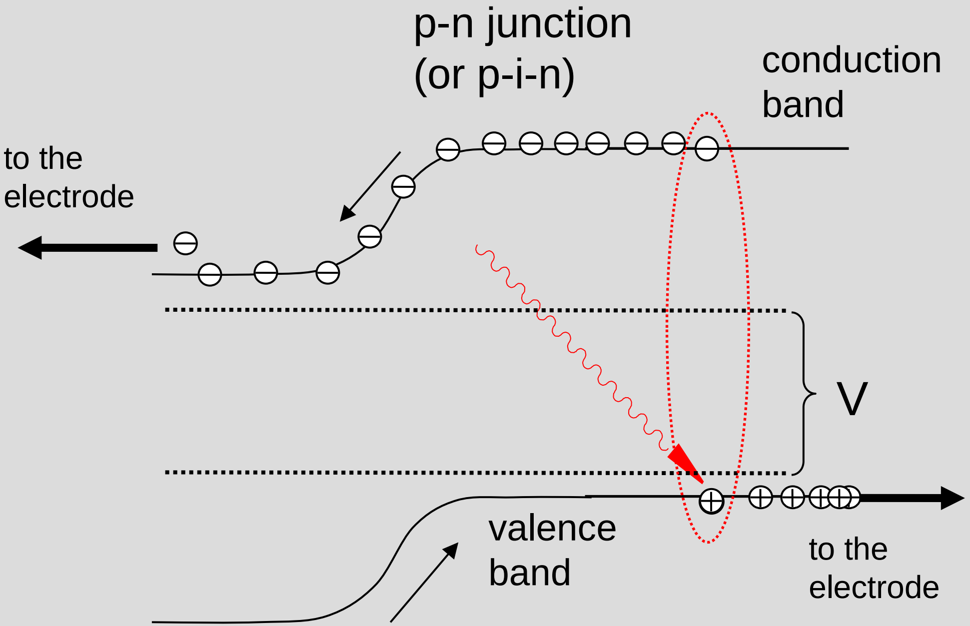


Fraunhofer Institute for Solar Energy Systems ISE, Photovoltaics report, October 2025

First practical p-n junction solar cell: 6% PCE

D. Chapin, C.Fuller, G. Pearson
Bell Labs, 1954

$\eta = 6\%$



n-type semiconductor

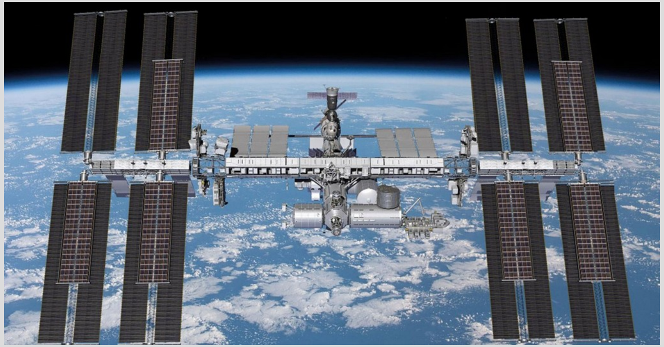
p-type semiconductor

Solar cells for space applications

In **1958**, Vanguard 1 became the first satellite to use silicon solar cells

Programs like the Nimbus program during the **1960s** and **1970s** relied on PV, and improvements in efficiency and durability were driven by space applications. They used single-crystal silicon photovoltaic cells

Early versions of triple-junction cells (often based on GaInP/GaAs/Ge structures) in the **1990s**
By the early **2000s**, triple-junction cells had become the **standard for most commercial and scientific satellites**, replacing earlier silicon and single-junction GaAs cells



The pioneers – grid connected PV at TISO (1982, Cannobbio)

Labor für Photovoltaiksysteme (PV-Labor): BHF has been engaged since the beginning

Berner
Fachhochschule

Heinrich Häberlin
Founder of the PV laboratory (1988)
Development phase and early research on the reliability of PV systems

Urs Muntwyler
Head for around a decade (approx. 2010–2021)
Expansion including toward electric mobility and applied systems engineering

Christof Bucher
Head since 2022
Stronger focus on grid integration and system behavior of PV systems

Major incentives in pushing PV deployment

- **Rooftop Solar Push in Japan. Residential PV Subsidy** Program **(1990s–2000s).** Starting in the 1990s, Capital **subsidies for residential PV systems**
- **1000-Dächer-Programm** (**1990). **Subsidies **covering a large share of installation costs** (often 60–70%). Supported relatively small systems (by today's standards)
- **Renewable Energy Sources Act (EEG)**, introduced in 2000. Most influential PV policies ever. Long-term, above-market payments for solar electricity fed into the grid (Feed-in-tarif). Massive early market driving global cost reductions.
- **100.000-Dächer-Programm (1999).** Install photovoltaic systems on **about 100,000 rooftops** across the country.
- **China: Early phase – Manufacturing focus (early 2000s).** Domestic deployment push **(around 2009 onward)**. Rapid scale-up **(2013–2017)**

5 reasons for the successful rise of PV technology

1. Rapid cost decline due to **mass manufacturing and learning effects**.

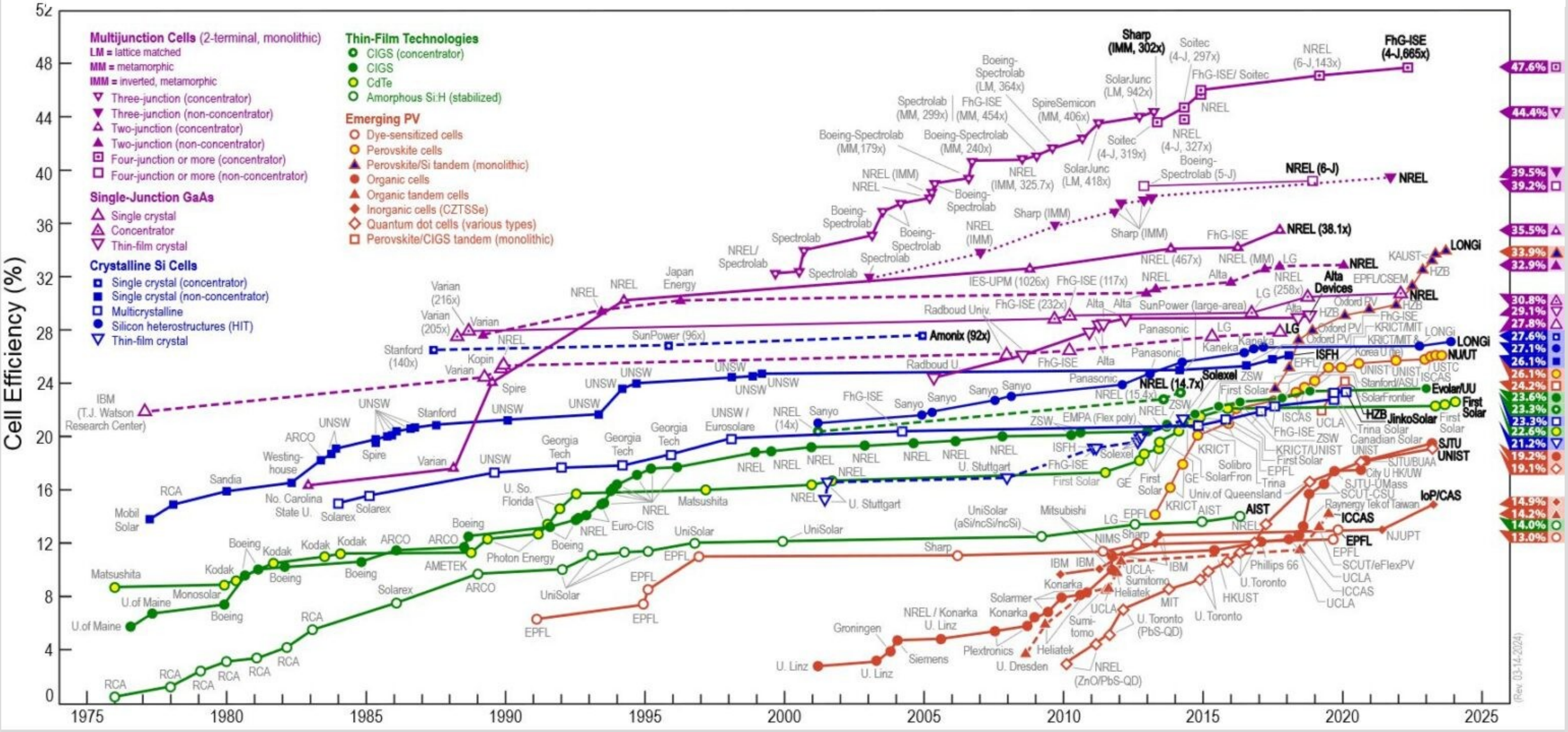
2. Simplicity and scalability, no complex parts. Good for rooftops, deserts, built environment, utility-scale farms etc.

3. Strong policy support early on. Countries like Germany used feed-in tariffs (FIT). Guaranteed demand -> industry growth. China supported manufacturing and large-scale deployment as well as FIT. The US used tax credits and incentives (e.g., later strengthened under the Inflation Reduction Act).

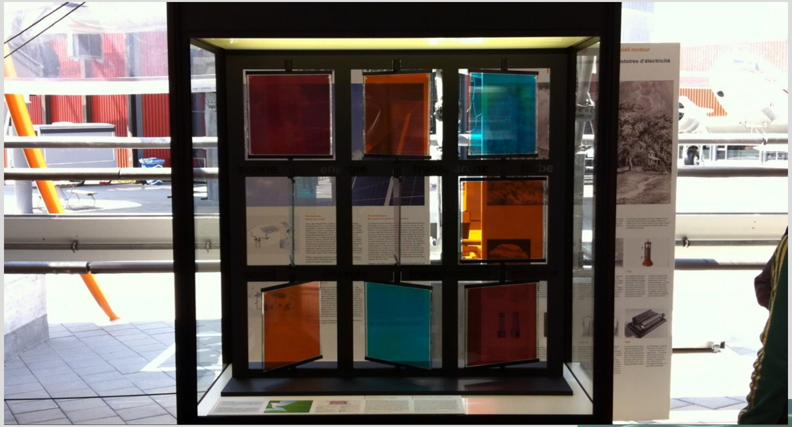
4. Manufacturing scale-up (especially China)

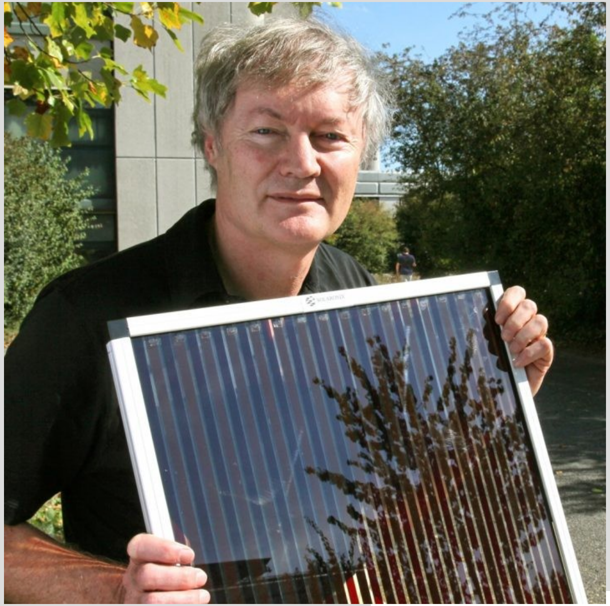
5. Energy security and climate goals. Countries want **domestic, low-carbon energy sources**. PV reduces dependence on imported fossil fuels. It aligns with decarbonization targets worldwide.

NREL chart of fame – record research-cells



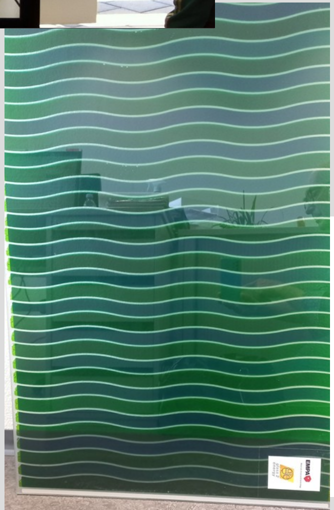
Dye sensitized solar cells – a Swiss success story





SOLARONIX (1993)

Glass to energy G2E (2013)



EPFL

G24i R2R factory in Cardiff (2009)

greatcellsolar MATERIALS

The silicon route – important build up of industry in Switzerland

Indeotech (2008)

œrlikon solar (2007)

unine UNIVERSITÉ DE NEUCHÂTEL

PRAMAC

SOLAXESS WHITE & COLOR SOLAR TECHNOLOGY (2015)

csem

EPFL

Other thin film technologies (in Switzerland)

Empa

Materials Science and Technology

Perovskia

Flisom

Flexible Solar Modules

If you can dream it, you can do it (Walt Disney)

PhD at Empa/EPFL
On organic solar cells

Founder of Weihua Solar

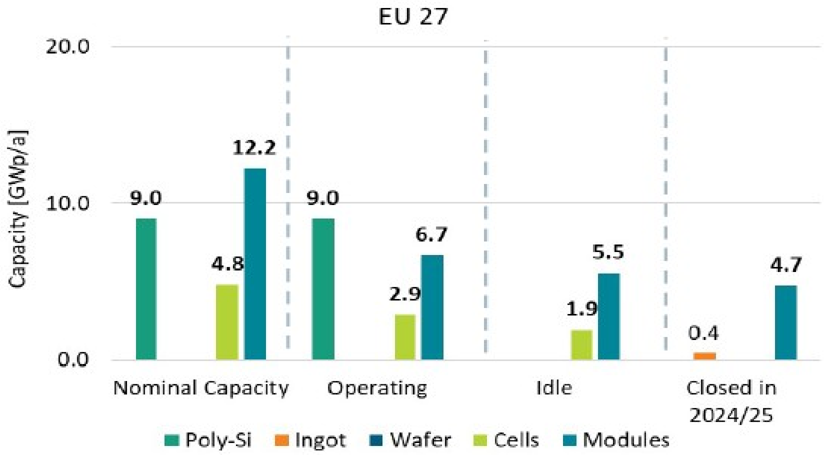
CEO of GCL – Optoelectr.

GCL Optoelectronics, a unit of GCL Group, has officially commissioned the world’s first gigawatt-scale manufacturing facility for **perovskite solar modules.**

1 GWp/year plant

EU PV Manufacturing Landscape – Status Quo

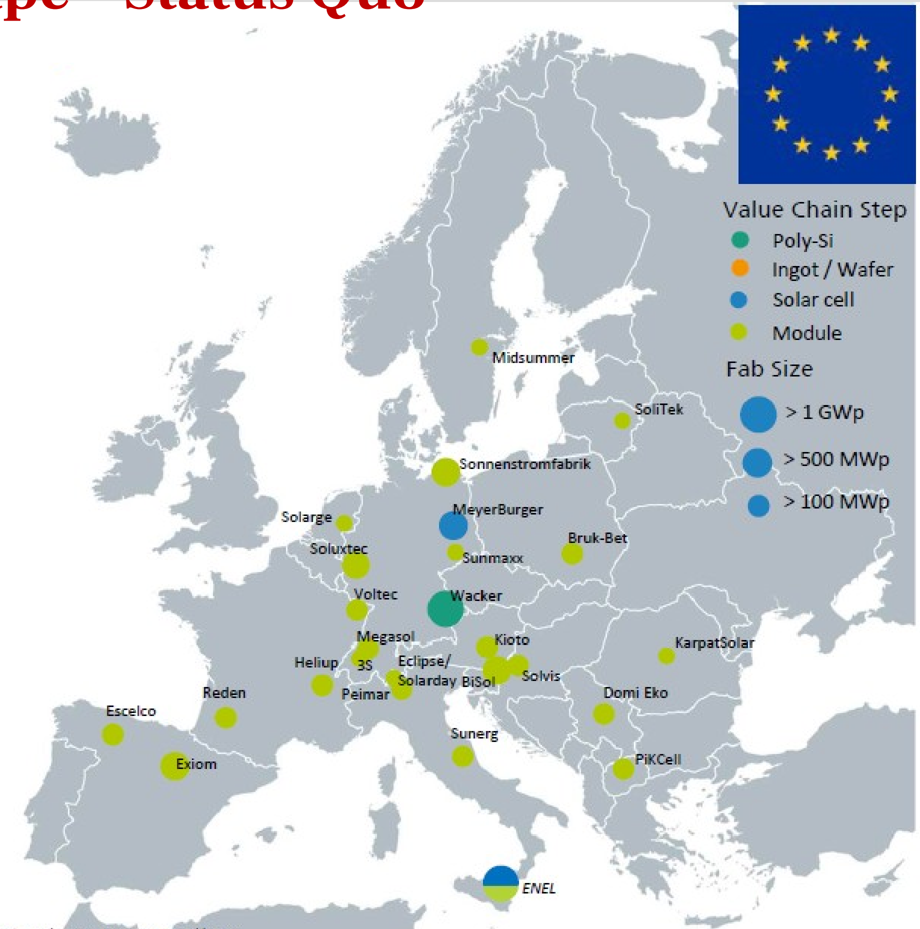
EU 27



Status Quo in the EU

- Many PV Module manufacturers still exist. But almost all of them with a small production capacity (< 1 GWp/a).
- Cell production capacity of <5 GWp/a.
- No active Ingot & Wafer production.
- One Polysilicon manufacturer.

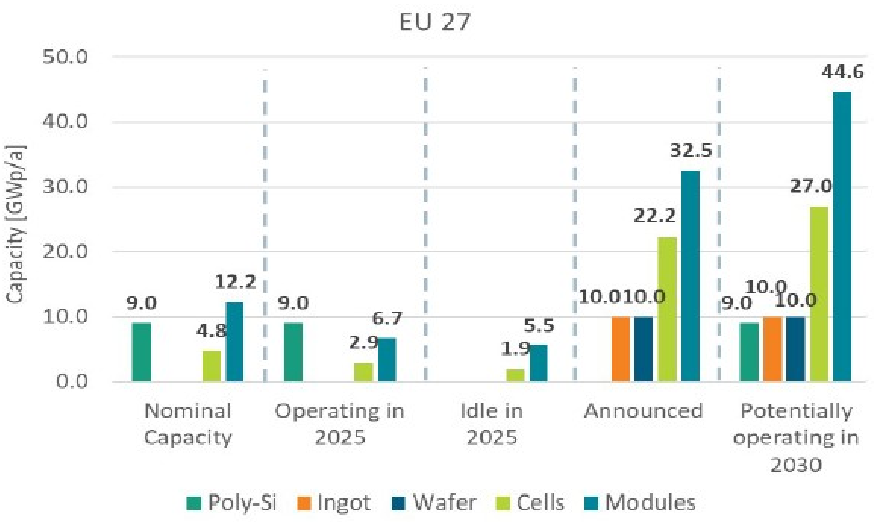
Data and Graph: Dr. Jochen Rentsch, Fraunhofer ISE 2025; last update: 08/2025

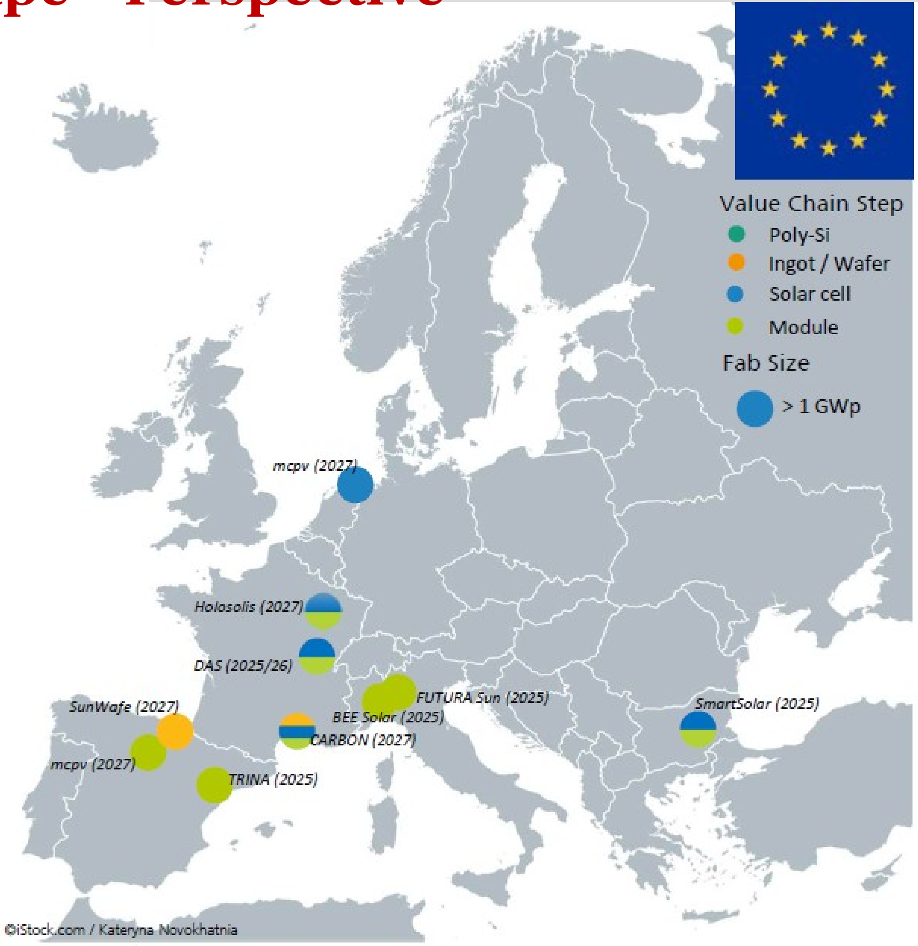


Source: ©iStock.com / Kateryna Novokhatnia

EU PV Manufacturing Landscape – Perspective

Announced / Planned GW Fabs





Diversification of European PV supply:

- GWp PV Manufacturing projects in Europe announced.
- What is planned in other global regions?

Source: ©iStock.com / Kateryna Novokhatnia

Data and Graph: Dr. Jochen Rentsch, Fraunhofer ISE 2025; last update: 08/2025

Vision for future Photovoltaics in Switzerland

- Swiss PV Manufacturing Excellence
- Building-Integrated Photovoltaics (BIPV)
- Standardized characterization of new PV technologies
- Alpine Solar Leadership
- Integrated Battery Ecosystems
- Smart and Resilient Grid Solutions
- Solar Mobility and Energy Storage
- Energy Conversion and Sustainable Carriers
- Turning Excess Solar Energy into Opportunity
- Education and Workforce Development