PHOTOVOLTAICS REPORT

Prepared by

Fraunhofer Institute for Solar Energy Systems, ISE

with support of PSE Projects GmbH

Freiburg, 21 February 2023

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CONTENT

Introduction
Preliminary Remarks

- The intention of this presentation is to provide up-to-date information. However, facts and figures change rapidly, and the given information may soon be outdated again.
- This work has been carried out under the responsibility of Dr. Simon Philipps (Fraunhofer ISE) and Werner Warmuth (PSE Projects GmbH).
- Price indications are always to be understood as nominal, unless this is stated explicitly. For example, prices in the learning curves are inflation adjusted.
- The slides have been made as accurate as possible and we would be grateful to receive any comments or suggestions for improvement.
  Please send your feedback to simon.philipps@ise.fraunhofer.de and also to warmuth@pse-projects.de
- Please quote the information presented in these slides as follows:
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Quick Facts

Parameter	Value	Status	Reference	Date of data
		Germany / EU27 / Worldwide		
PV installation market	4.9 / 18.2 / 126 GW 5.3 / 25.9 / 174 GW	End of 2020 End of 2021	BNA / SPE / IEA BNA / SPE / IEA	11/2021; 12/2020; 09/2022 02/2022; 12/2021; 09/2022
Cumulative installation	59.8 / 164.9 / 945 GW	End of 2021	ISE / SPE / IEA	07/2022; 12/2021; 09/2022
PV power generation	48.6_{net} / 160.4_{gross} / 1032.5_{gross} TWh	2021	ISE / BP / BP	06/2022; 06/2022; 06/2022
PV electricity share	$9.9\%_{net}$ / $5.5\%_{gross}$ / $3.6\%_{gross}$	2021	ISE / BP / BP	08/2022; 06/2022; 06/2022
		Worldwide		
c-Si share of production	95%	2021	ISE	08/2022
Record solar cell efficiency: III-V MJ (conc.) / mono-Si / CIGS / multi-Si / CdTe	47.1 / 26.7 / 23.4 / 24.4 / 21.0%	06/2021	Green et al.	06/2021
		Germany		
Price PV rooftop system	1,050 to 1,650 €/kWp	2022	BSW	05/2022
LCOE PV power plant	3.1 to 5.7 ct€ / kWh	2021	ISE	
Lowest/Latest PV-Tender Price	4.33/5.00 ct€ / kWh	02/2018; 11/2021	BNA	11/2021

Executive Summary
PV Market: Global

- Photovoltaics is a fast-growing market: The Compound Annual Growth Rate (CAGR) of cumulative PV installations was 30% between year 2011 to 2021.
- In 2021 producers from Asia count for 94% of total c-Si PV module production. China (mainland) holds the lead with a share of 75%. Europe contributed with a share of 1%; USA/CAN with 3%.
- Wafer size increased and by keeping the number of cells larger PV module sizes are realized allowing a power range beyond 600 W per module.
- In 2021, Europe’s contribution to the total cumulative PV installations amounted to almost 22%. In contrast, installations in China accounted for 37% (with 33% in year 2020).
- Si-wafer based PV technology accounted for more than 95% of the total production in 2021. The share of mono-crystalline technology is about 84% of total c-Si production.
- Market shifts from subsidy driven to competitive pricing model (Power Purchase Agreements PPA).

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Executive Summary
PV Market: Focus Germany

- In year 2021, Germany accounted for about 6.9% (59 GWp) of the cumulative PV capacity installed worldwide (848 GWp) with about 2.2 million PV systems installed in Germany. In 2021 the newly installed capacity in Germany was 5.3 GWp according to BNA; in 2020 it was 4.6 GWp.
- PV covered 9.9% of Germany's net electricity generation in 2021 while all Renewable sources delivered about 45.9%.
- In 2021 about 34.4 Mio. t CO_2 equivalent GHG emissions have been avoided due to 48.6 TWh electrical energy generated by PV in Germany.
- PV system performance has strongly improved. Before year 2000 the typical Performance Ratio was about 70%, while today it is in the range of 80% to 90%.

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Executive Summary
Solar Cell / Module Efficiencies

- The record lab cell efficiency* is 26.7% for mono-crystalline and 24.4% for multi-crystalline silicon wafer-based technology. The highest lab efficiency in thin film technology is 23.4% for CIGS and 21.0% for CdTe solar cells. Record lab cell efficiency for Perovskite is 23.7%.
- In the last 10 years, the efficiency of average commercial wafer-based silicon modules increased from about 15% to 20% and more. At the same time, CdTe module efficiency increased from 9% to 19%.
- In the laboratory, best performing modules are based on mono-crystalline silicon with 24.4% efficiency. Record efficiencies demonstrate the potential for further efficiency increases at the production level.
- In the laboratory, high concentration multi-junction solar cells achieve an efficiency of up to 47.1% today. With concentrator technology, module efficiencies of up to 38.9% have been reached.

* Only official lab record efficiencies with minimum cell area of 1 cm^2 are listed. Latest reference: Solar Cell Efficiency Tables (Version 60), Progress in Photovoltaics: Research and Applications, May 2022

Executive Summary
Energy Payback Time

- Material usage for silicon cells has been reduced significantly during the last 16 years from around 16 g/Wp to less than 2.5 g/Wp due to increased efficiencies, thinner wafers and diamond wire sawing as well as larger ingots.
- The Energy Payback Time of PV systems is dependent on the geographical location: PV systems produced in Europe and installed in Northern Europe need around 1.1 years to balance the input energy, while PV systems in the South equal their energy input after 0.9 years, depending on the technology installed and the grid efficiency.
- A PV system located in Sicily with wafer-based Silicon modules has an Energy Payback Time of around one year. Assuming 20 years lifespan, this kind of system can produce twenty times the energy needed to produce it.

Executive Summary
Inverters

- Inverter efficiency for state-of-the art brand products is 98% and higher.
- The market share of string inverters is estimated to be 64%. These inverters are mostly used in residential, small and medium commercial applications in PV systems up to 150 kWp. The market share of central inverters, with applications mostly in large commercial and utility-scale systems, is about 34%.
  A small proportion of the market (about 1%) belongs to micro-inverters (used on the module level). The market share for DC / DC converters, also called “power optimizers”, is estimated to be 5% of the total inverter market.
- Trends: Digitalisation, Repowering, new features for grid stabilization and optimization of self-consumption; storage; utilization of innovative semiconductors (SiC or GaN) which allow very high efficiencies and compact designs; 1500 V maximum DC string voltage.

Executive Summary
Price Development

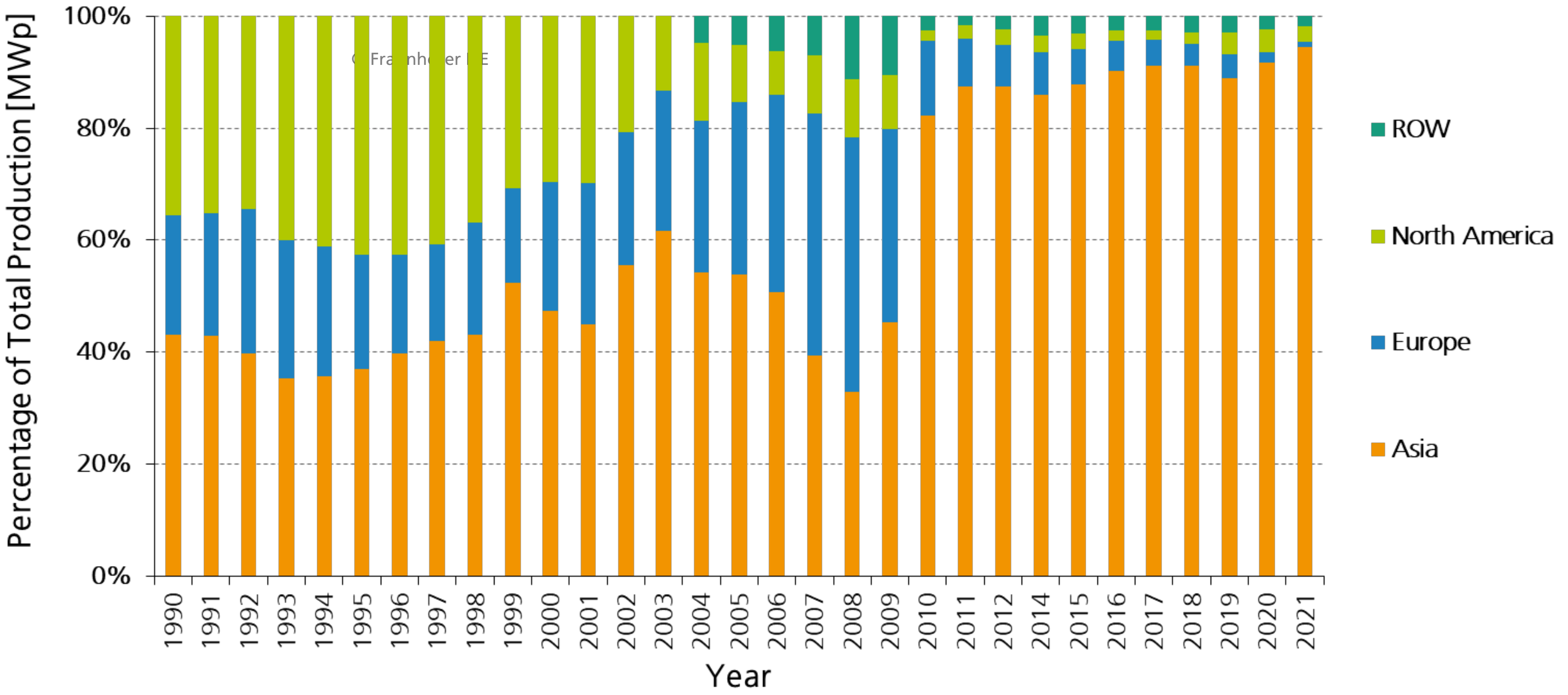
- In Germany prices for a typical 10 to 100 kWp PV rooftop-system were around 14,000 €/kWp in 1990. At the end of 2020, such systems cost only 7.4% of the price in 1990. This is a net-price regression of about 92% over a period of 30 years.
- The Experience Curve – also called Learning Curve - shows that in the last 40 years the module price decreased by 25% with each doubling of the cumulated global module production. Cost reduction results from economies of scale and technological improvements.

1. PV Market

- By region
- By technology

PV Module Production by Region 1990-2021

Percentage of Total MWp Produced



Data: Up to 2004 Strategies Unlimited; 2005 to 2009: Navigant Consulting; 2010 to 2019: IHS Markit; since 2020 IEA PVPS. Graph: PSE 2022; Date of data: 26-April 2022

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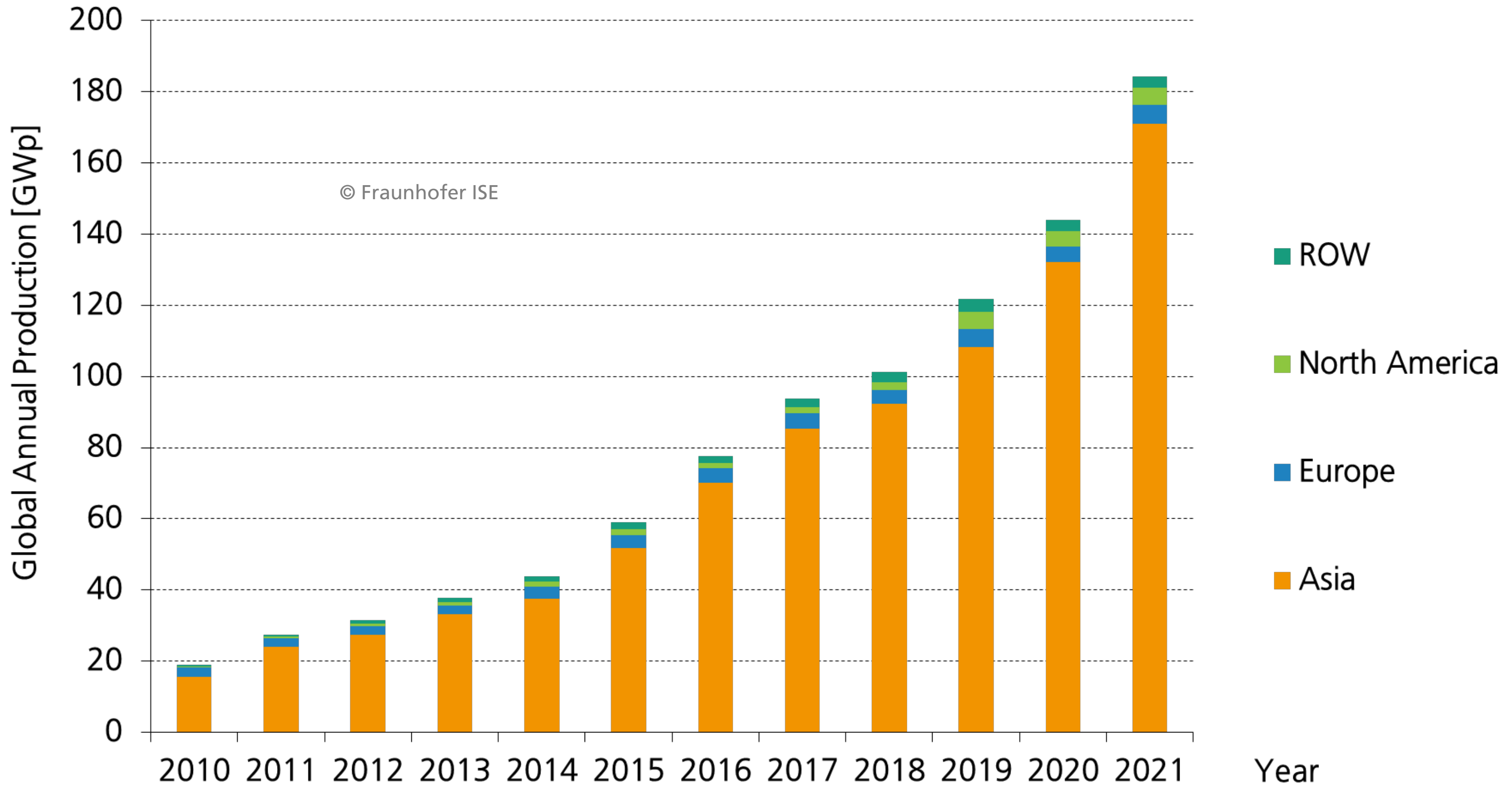
PV Module Production by Region
Global Annual Production



Data: Until 2020 IHS Markit; IEA 2021. Graph: PSE 2021; Date of data: 31-July 2022

About 82% of the global PV module has been produced in Asia in year 2010. It increased to about 93% of total global production in year 2021. China (mainland) accounted with 138 GWp for 75% of the global module production in year 2021 according to IEA.
The annual production has increased by a factor of 9.7 in these eleven years.

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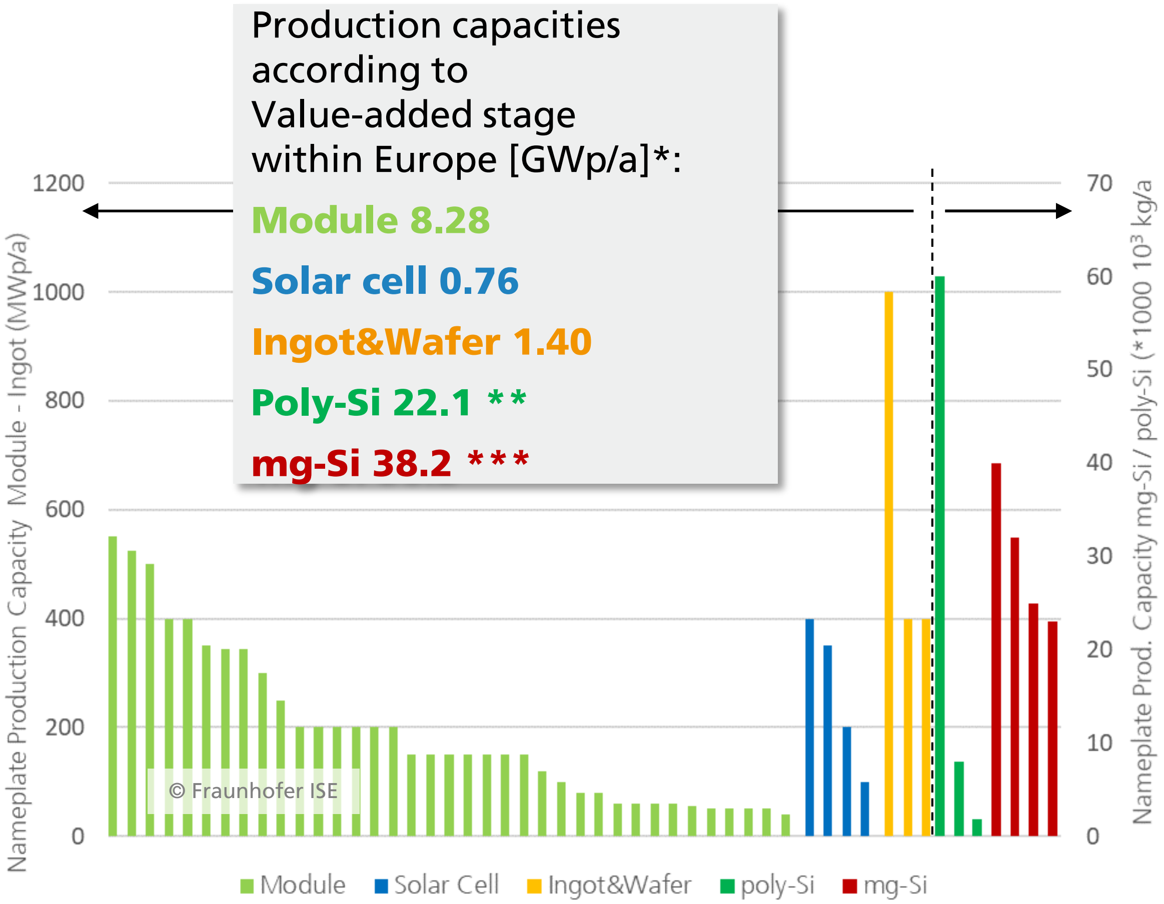
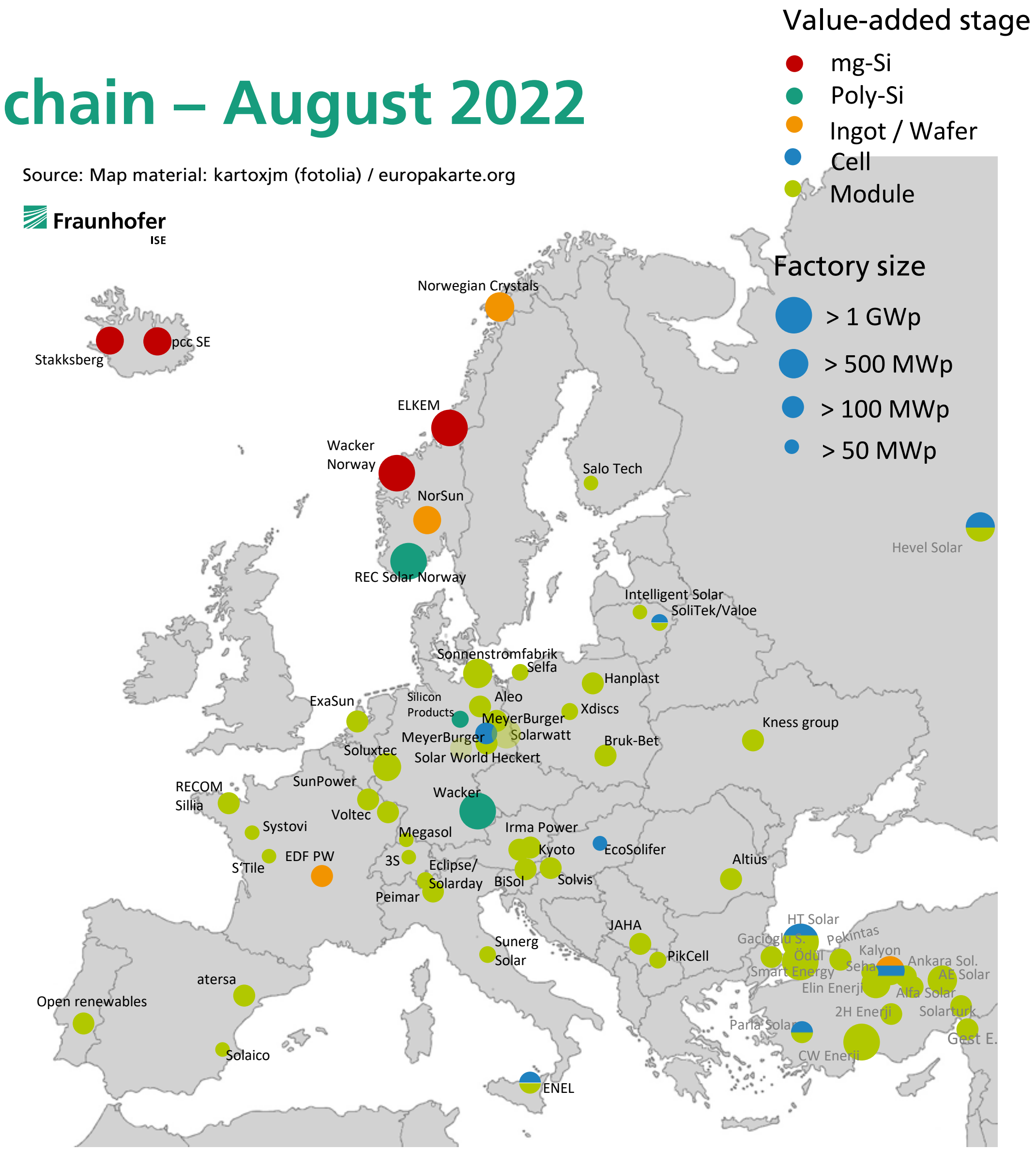
Status Quo – PV Production in Europe

Overview of PV production along the value chain – August 2022



Data and Graph: Jochen Rentsch, Fraunhofer ISE 2022; last update: 23.08.2022



* without Turkey and Russia
** 2,800 kg/MWp poly-Si are currently required for ingot production
*** currently 3.150 kg/MWp mg-Si required for ingot production

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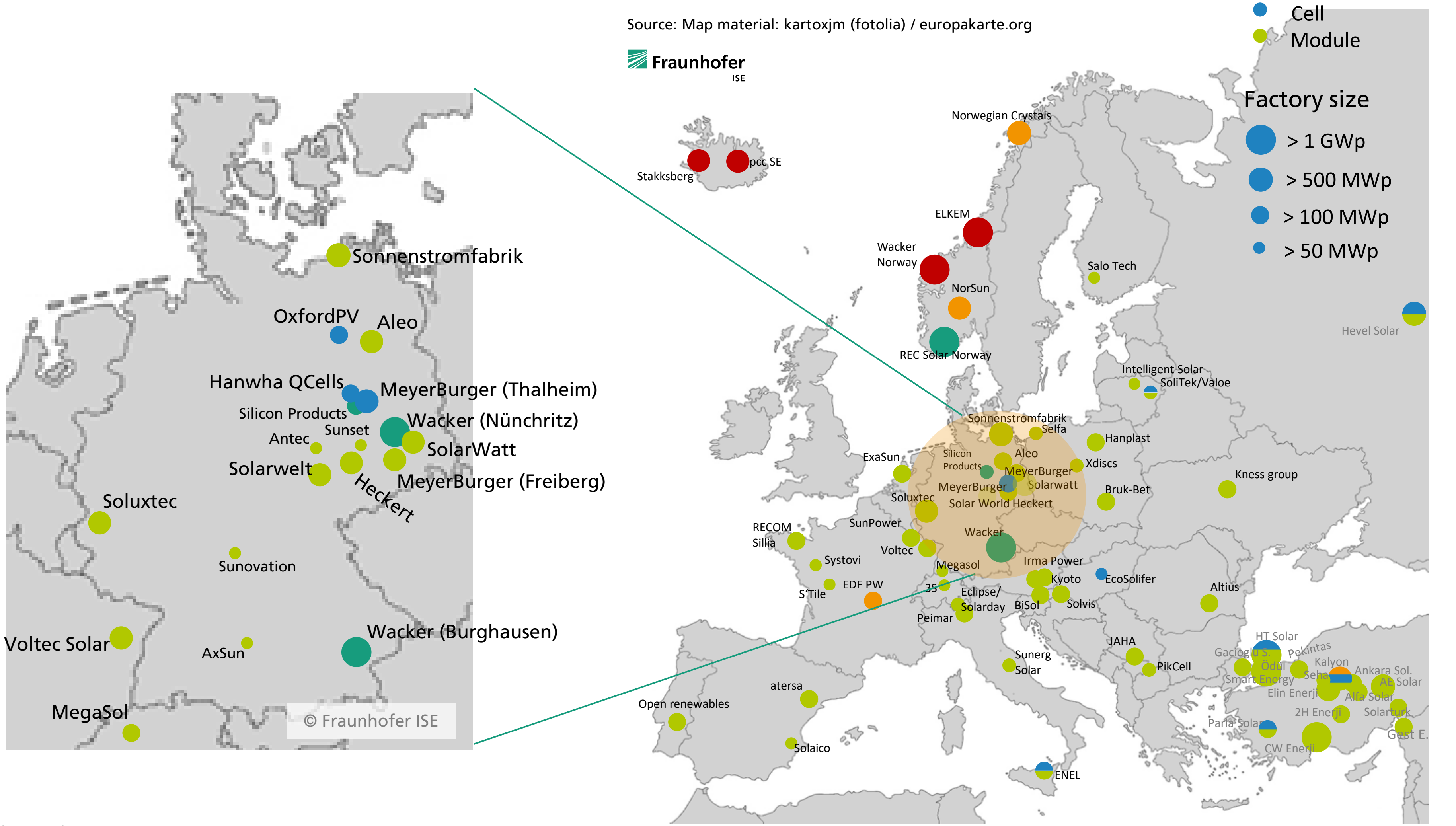
Status Quo – PV Production in Germany

Overview of PV production along the value chain – August 2022



Data and Graph: Jochen Rentsch, Fraunhofer ISE 2022; last update: 23.08.2022

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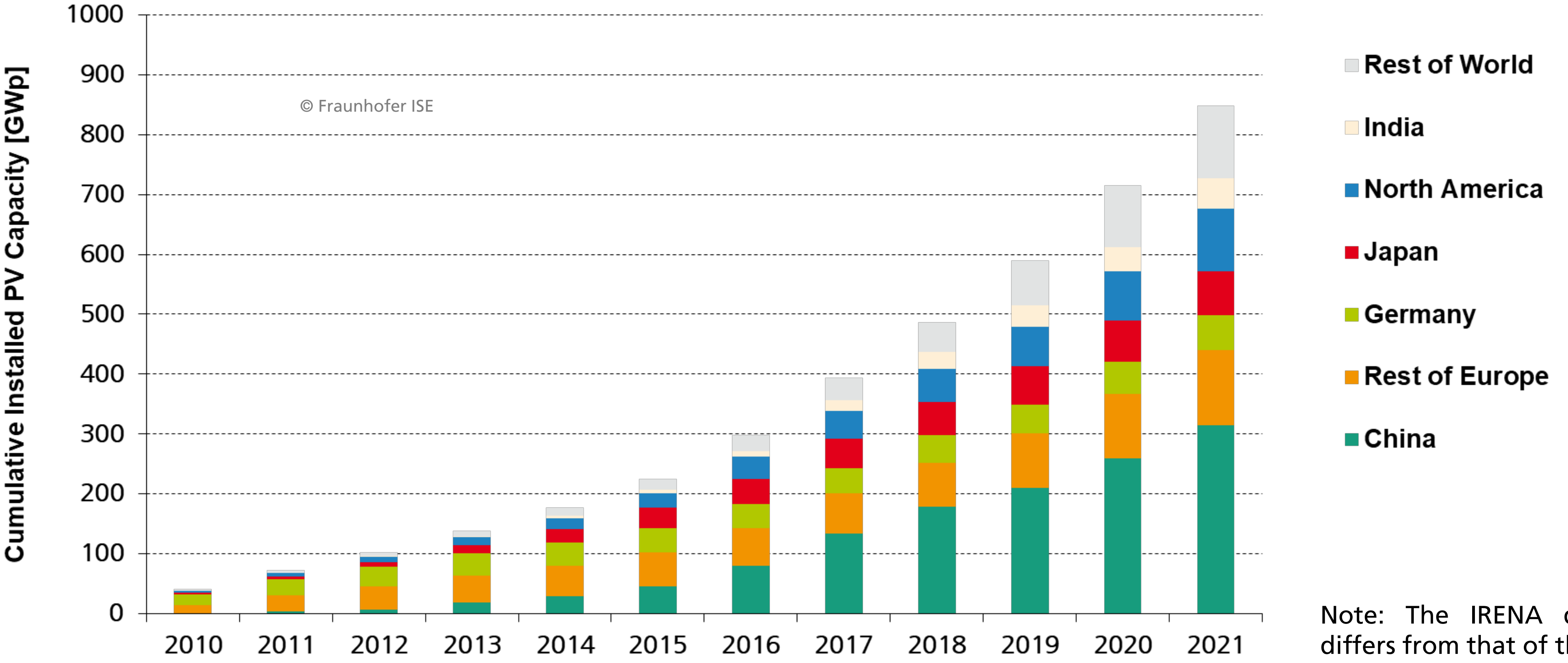
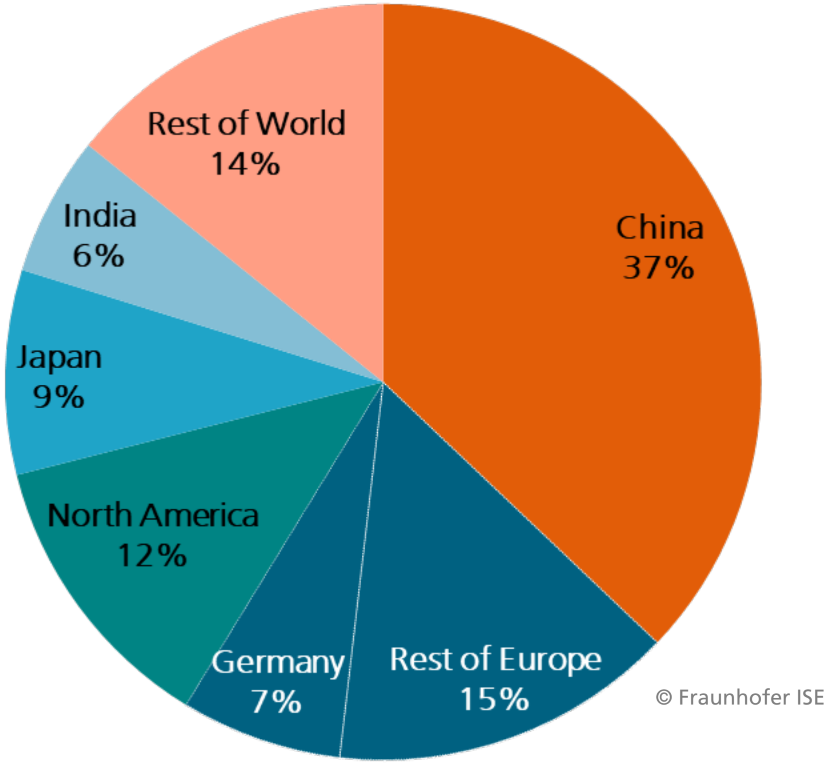
Global Cumulative PV Installation
From 2010 to 2021



Data: IRENA 2022. Graph: PSE 2022. Date of data: Apr-2022

Note: The IRENA data shown here differs from that of the IEA PVPS:
IRENA: 848 GWp
IEA-PVPS: 945 GWp

Global Cumulative PV Installation by Region
Status 2021

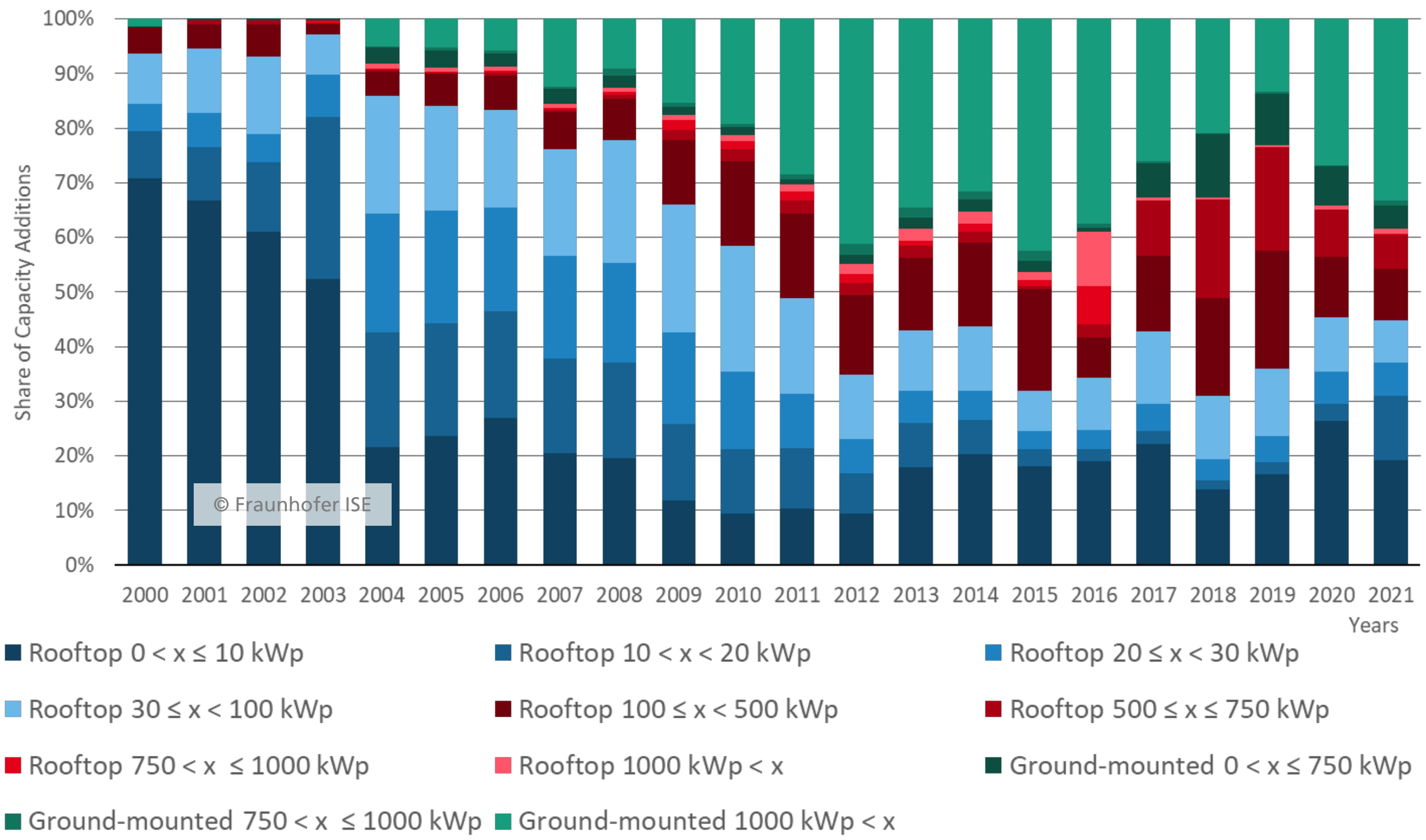


The total cumulative installations amounted to about 850 GWp at the end of year 2021.

All percentages are related to global installed PV capacity, including off-grid systems.

Data: IRENA 2022. Graph: PSE 2022; Date of data: Apr-2022

Annually Installed PV System Capacity in Germany
Percentage of Annual Capacity by System Size



The annual distribution of PV System size classes strongly depend on:

- Regulations
- Market incentives (like EEG)
- Tender procedures
- Bankability (trust of investors)

Source until year 2020: Fraunhofer ISE, own calculations based on EEG-master and -flow data (netztransparenz.de, Sept. 2021)

Source for year 2021: MaStR (05.07.2022) + Data validation algorithm

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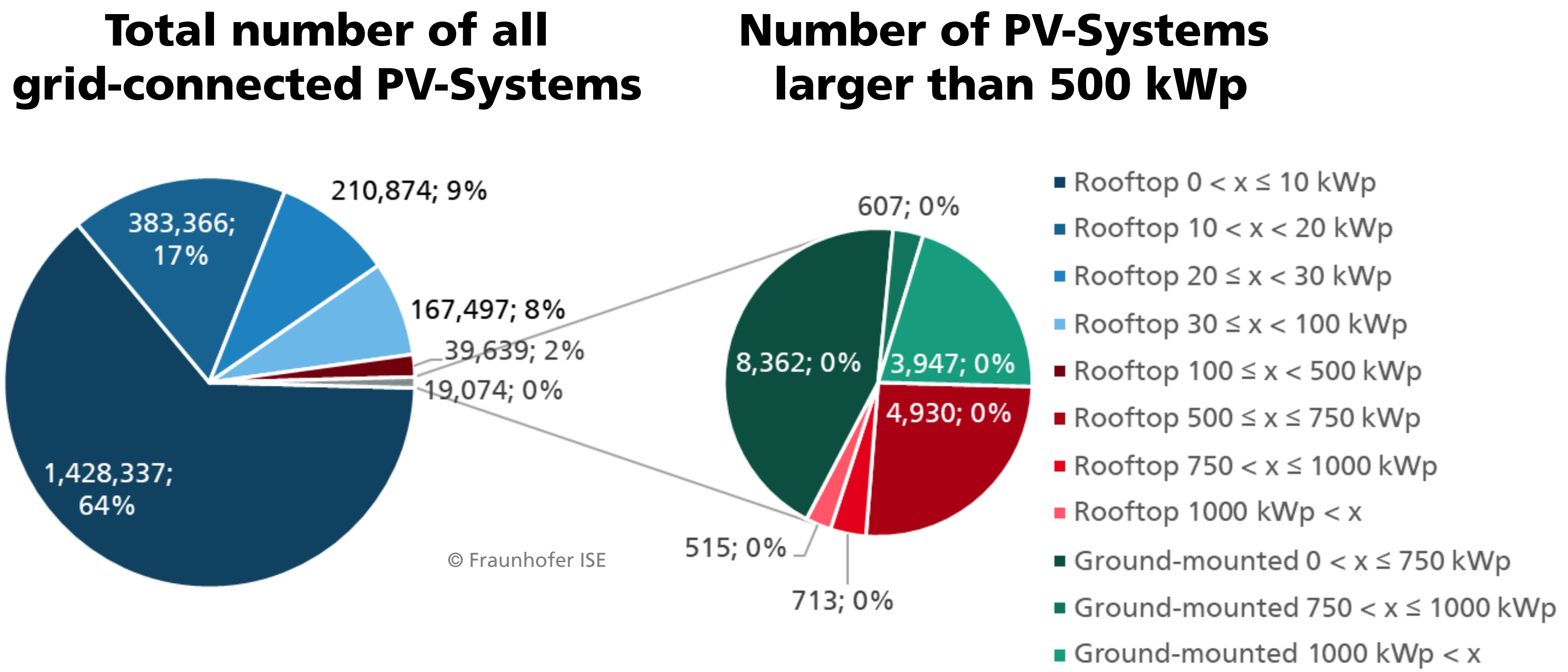
Share of Number of PV-Systems Installed

Percentage of Cumulative Installations by System Size in Germany in 2021



End of 2021 about 2.25 million grid-connected PV-Systems were installed in Germany.

Source: Fraunhofer ISE, own calculations based on MaStR (05.07.2022) and Data validation algorithm

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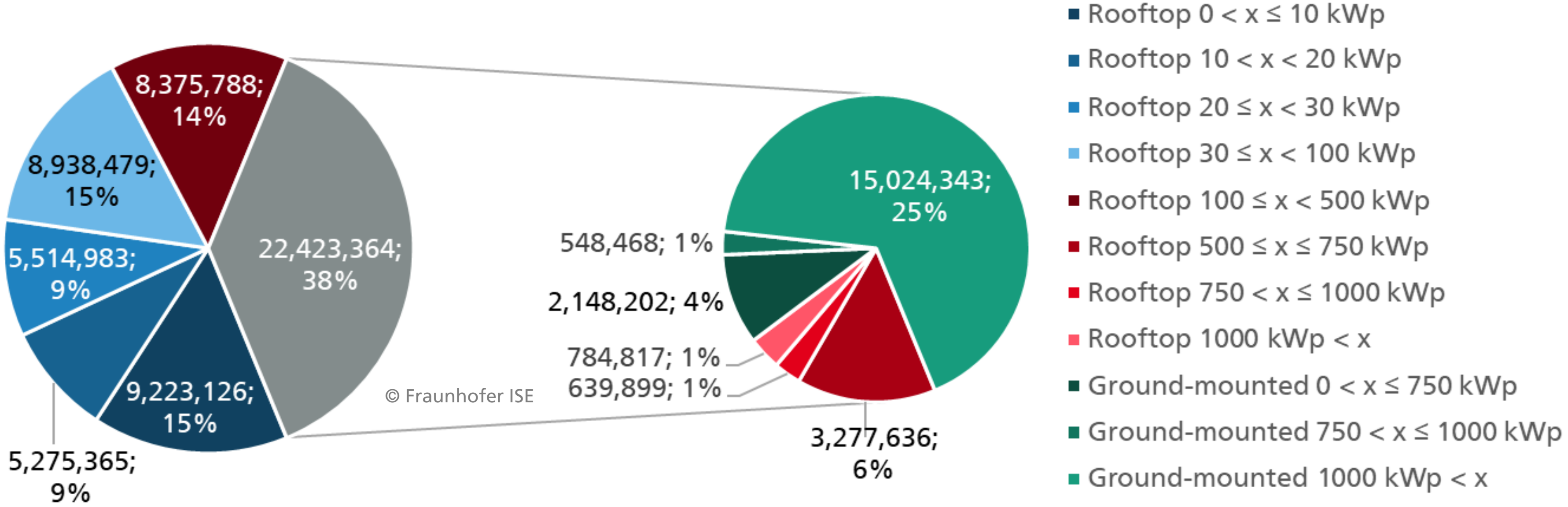
Share of Capacity of PV-Systems Installed

Percentage of Cumulative Installations by System Size in Germany in 2021

PV Capacity in kWp and percentage of all grid-connected PV-Systems **PV Capacity in kWp and percentage of Systems larger than 500 kWp**



At the end of 2021 a total cumulated PV capacity of about 59.8 GW was installed in Germany.

Source: Fraunhofer ISE, own calculation based on MaStR (05.07.2022) + Data validation algorithm

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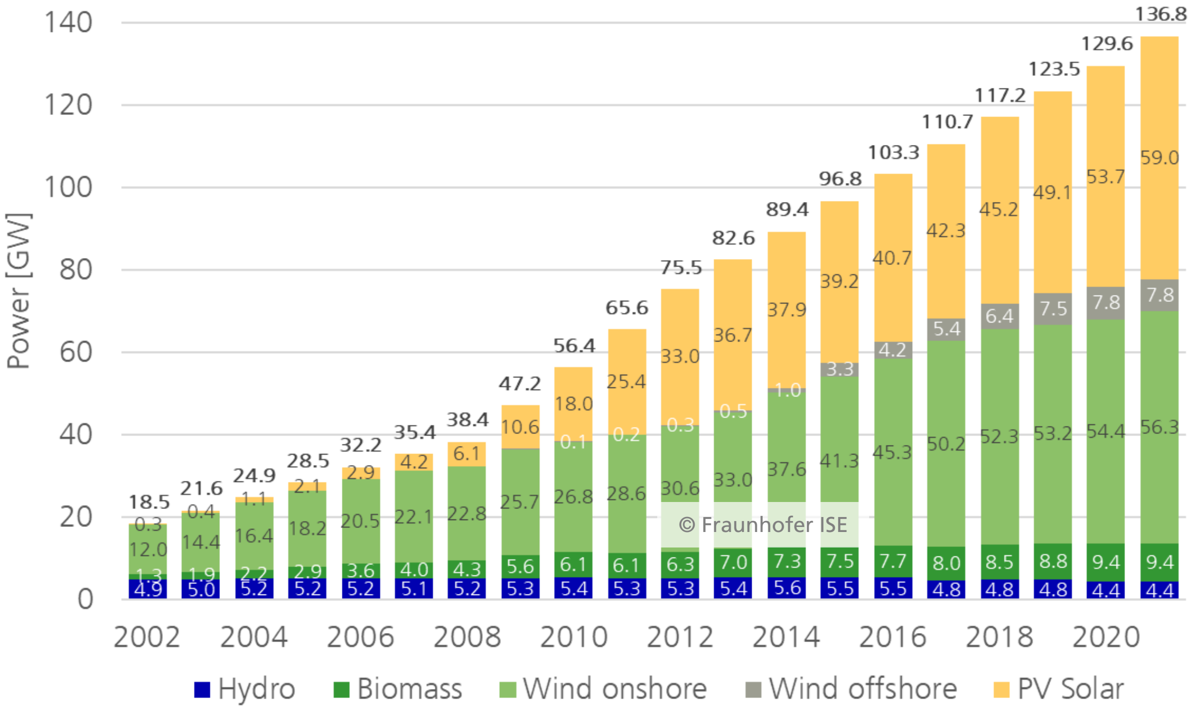
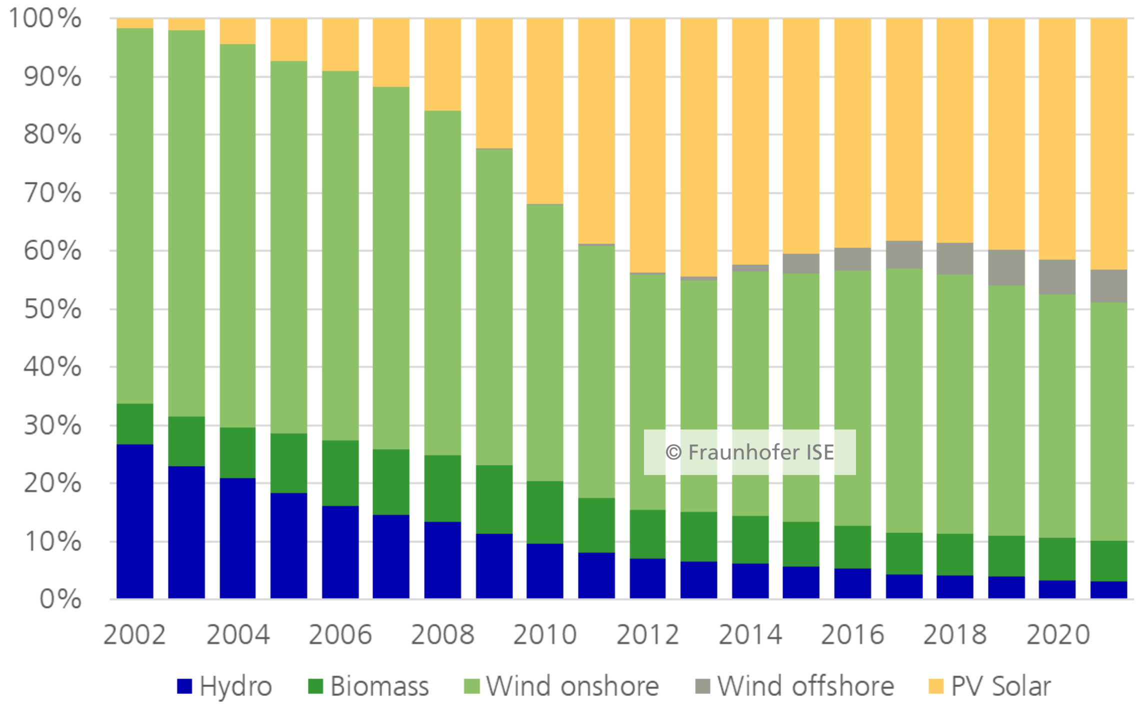
Electrical Capacity of Renewable Energy Sources
Germany





136.8 GW of total 234.2 GW net installed electricity generation capacity in Germany were from renewable energy (RE) sources in Germany in year 2021. This results in a RE share of 58.4% of total capacity.

Data: Energy Charts by Prof. Dr. Bruno Burger. Date of data: Jan-2022

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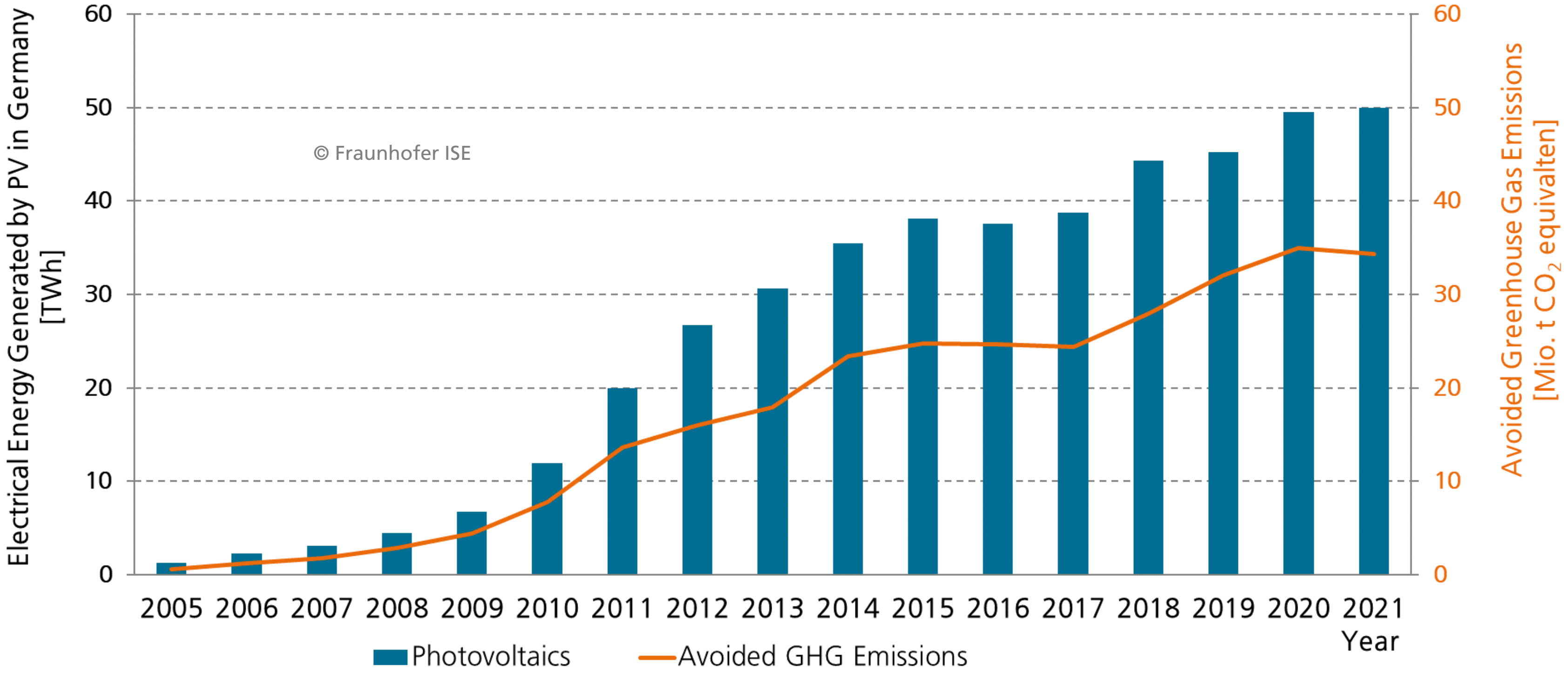
PV Energy Generated and Resulting GHG Avoided Emissions

Germany



- In 2021 Greenhouse Gas emissions of about 34 Mio. t CO_2-equivalent were avoided due to 50 TWh PV electricity consumed in Germany.

Data: BMU, BDEW, BMWi, Federal Environmental Agency (UBA) 2022. Graph: PSE 2022

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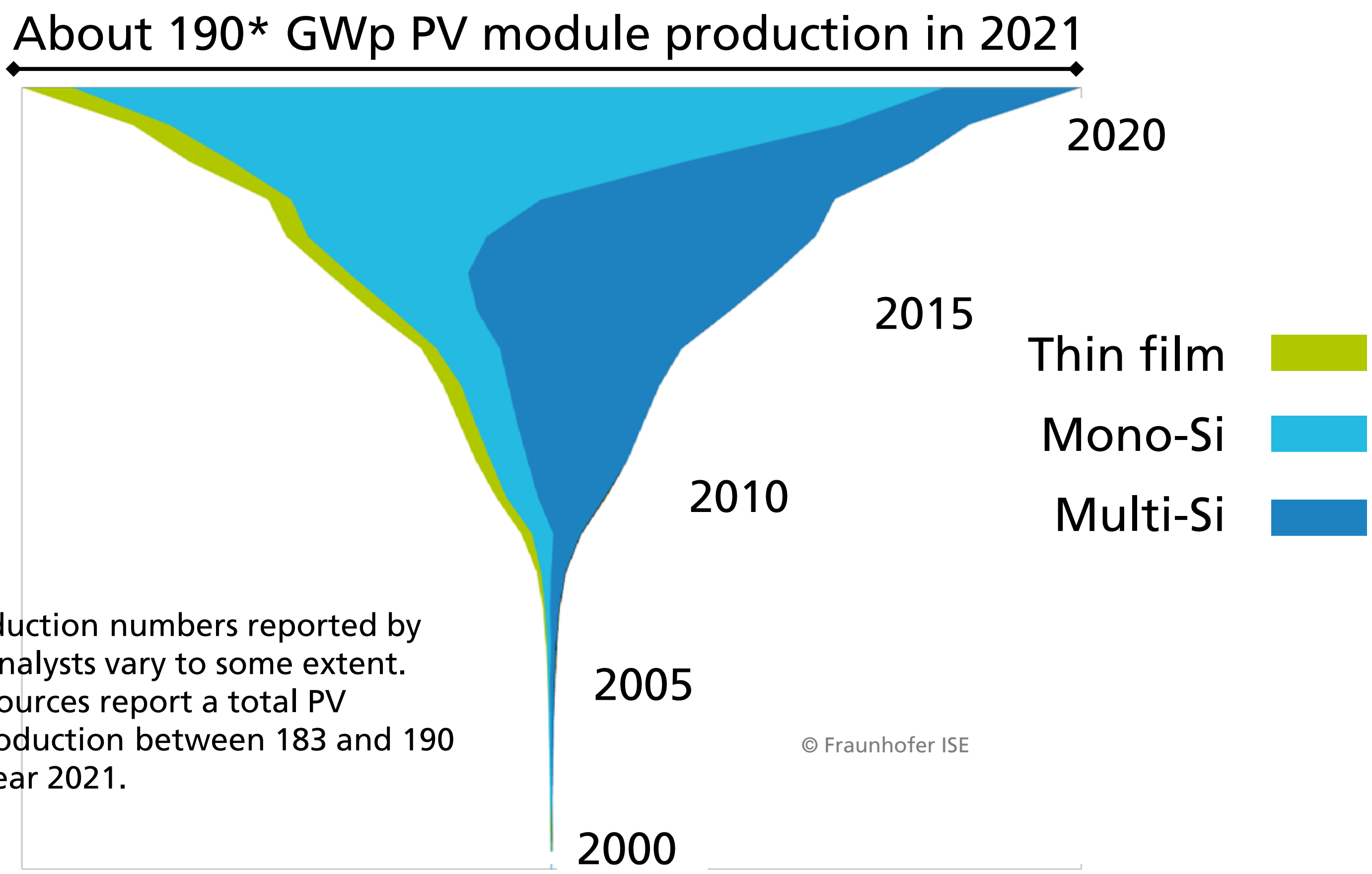
Annual PV Production by Technology
Worldwide (in GWp)



*2021 production numbers reported by different analysts vary to some extent. Different sources report a total PV module production between 183 and 190 GWp for year 2021.

Data: from 2000 to 2009: Navigant; from 2010: IHS Markit. Graph: PSE 2022. Date of data: Jan-2022

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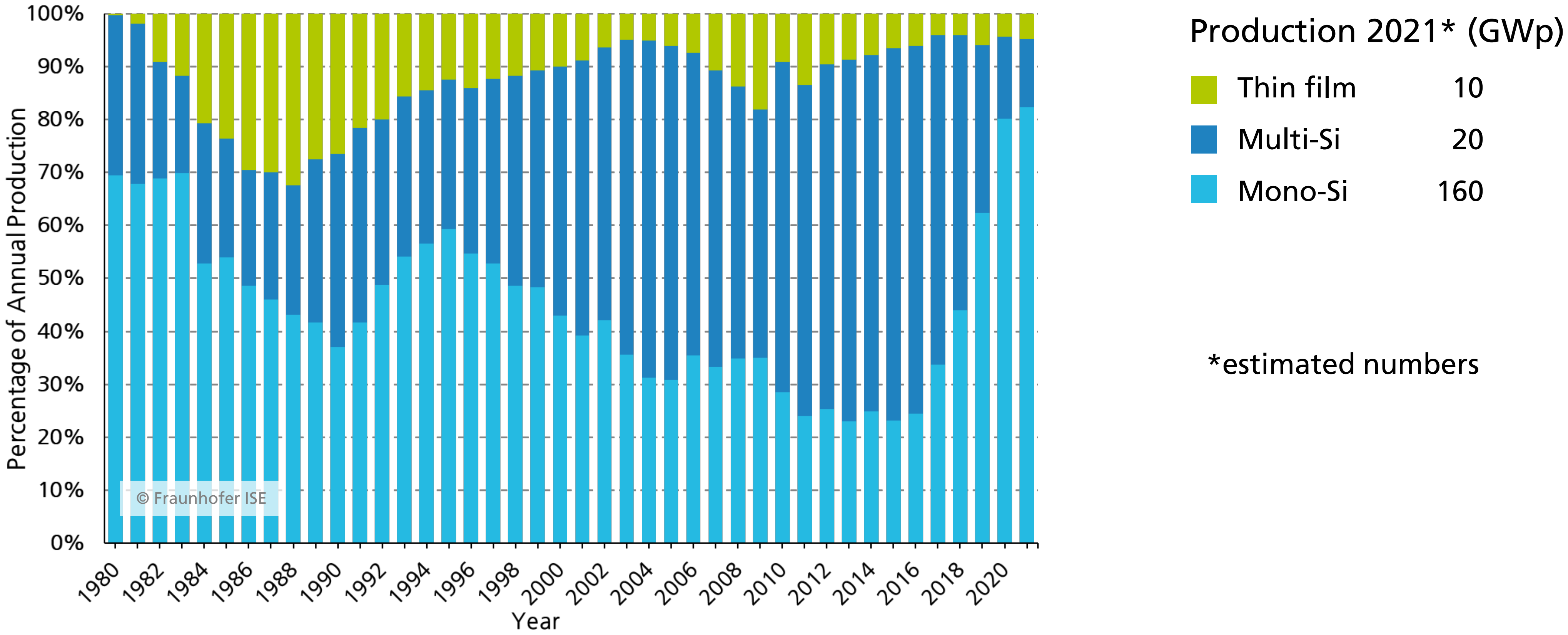
PV Production by Technology
Percentage of Global Annual Production



Data: from 2000 to 2009: Navigant; from 2010 to 2021 IHS Markit; from 2022 IEA. Graph: PSE 2022 . Date of data: July 2022

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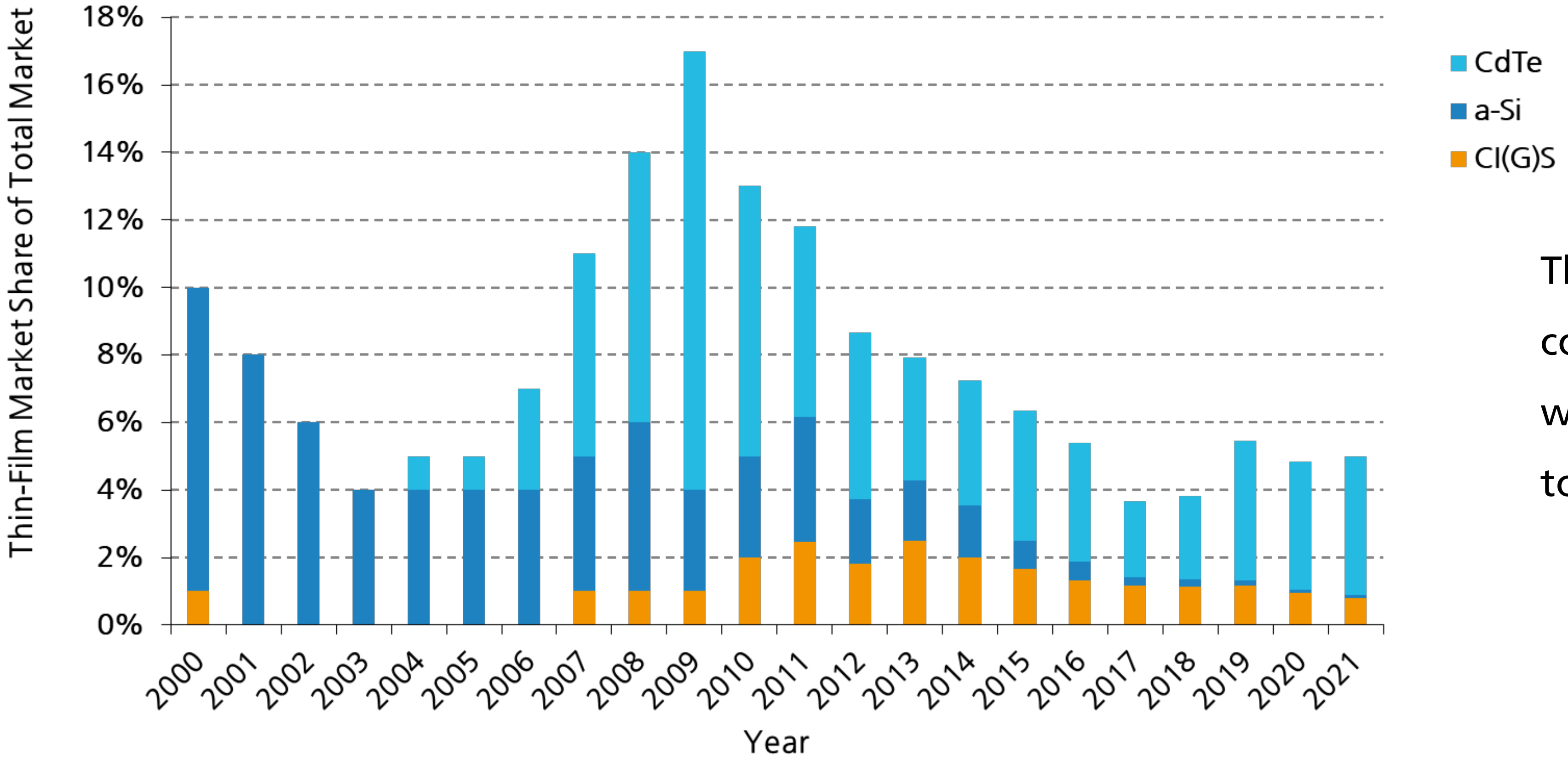
Market Share of Thin-Film Technologies

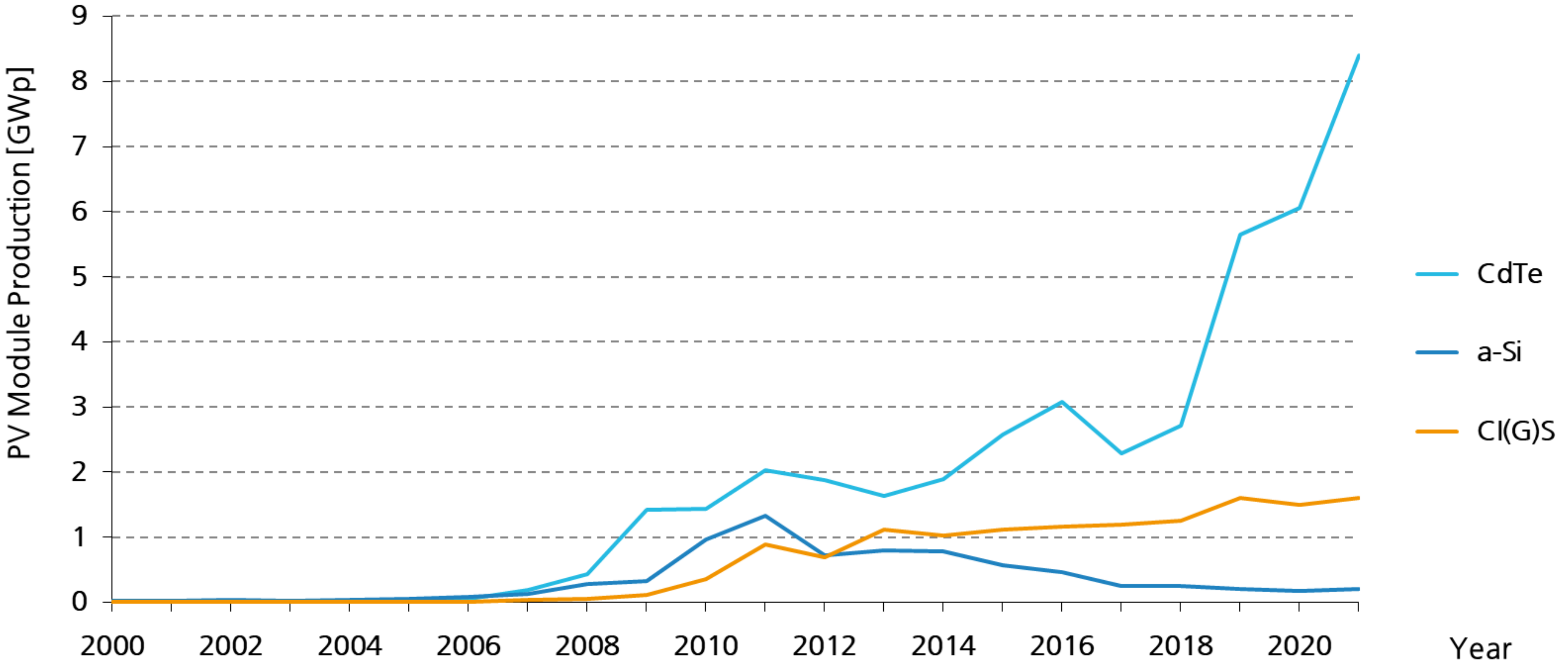
Percentage of Total Global PV Production



Thin-Film technology contributed in year 2021 with about 5% to the total PV-market.

Data: from 2000 to 2009: Navigant; from 2010 to 2021 IHS Markit; from 2022 IEA. Graph: PSE 2022 . Date of data: July 2022

Thin-Film Technologies
Annual Global PV Module Production

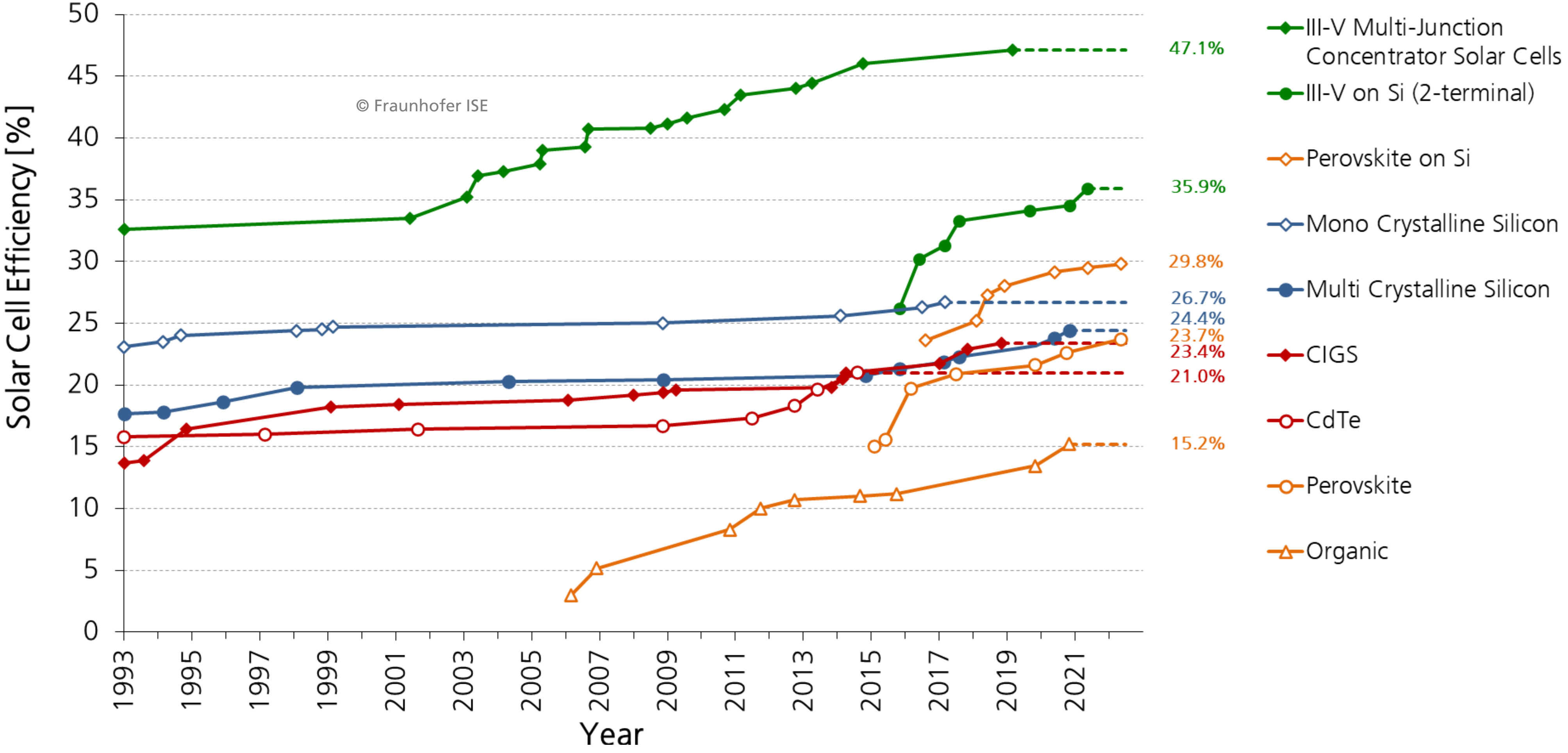


Data: from 2000 to 2009: Navigant; from 2010 to 2021 IHS Markit; from 2022 IEA. Graph: PSE 2022 . Date of data: July 2022

2. Solar Cells / Modules / System Efficiency

- Development in the Laboratories
- Development in the PV Industry
- Performance Ratio (PR)

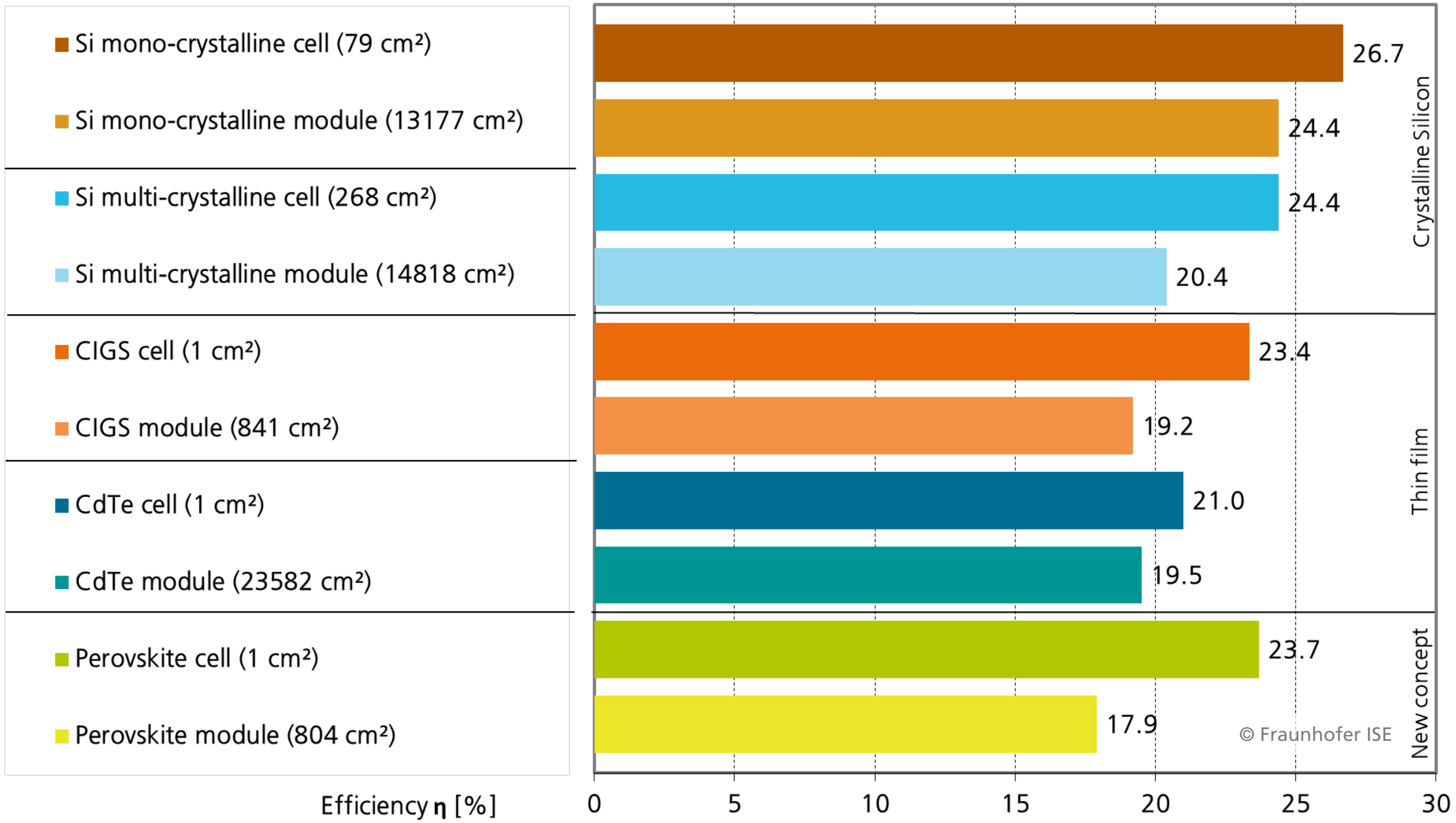
Development of Laboratory Solar Cell Efficiencies



Data: Solar Cell Efficiency Tables (Versions 1 to 60), Progress in Photovoltaics: Research and Applications, 1993-2022. Graph: Fraunhofer ISE 2022. Date of data: May 2022

Only official lab record efficiencies published in the Solar Cell Efficiency Tables, Progress in Photovoltaics: Research and Applications are included in the graph. The following novel results will be included as soon as they are published in the tables:
III-V multi-junction solar cell, 47.6% by Fraunhofer ISE; Perovskite on Si, 31.25% by CSEM / EPFL

Efficiency Comparison of Technologies:
Best Lab Cells vs. Best Lab Modules



Data: Green et al.: Solar Cell Efficiency Tables (Version 60), Progress in PV: Research and Applications 2022. Graph: PSE 2022. Date of data: May 2022

Note: In mass production Cell-to-Module ratio (CTM) improved in past years by reducing losses and using possible gains when integrating solar cells in modules. Fraunhofer ISE provides SmartCalc.CTM software suite for the precise CTM power loss analysis. It considers geometrical losses, optical losses & gains as well as electrical losses.

www.cell-to-module.com

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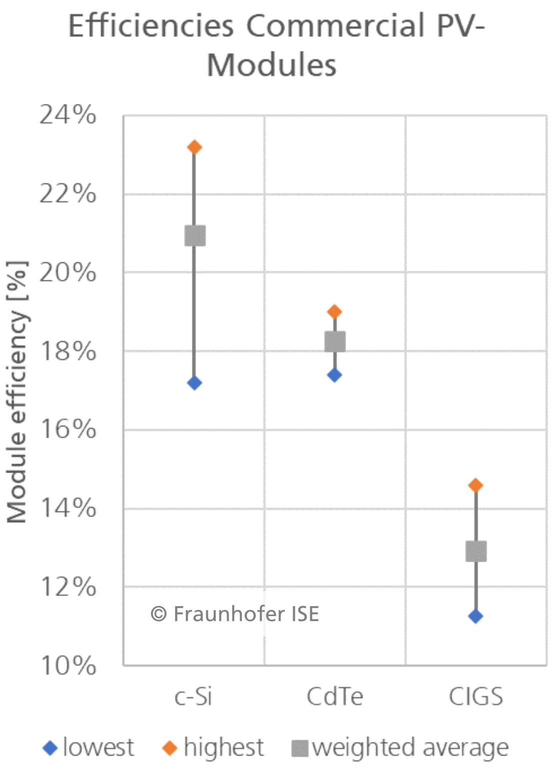
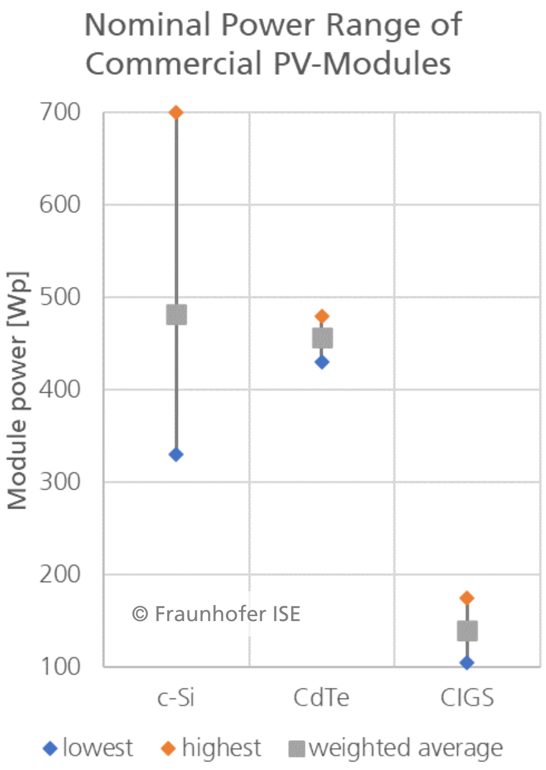
Current Efficiencies and Power of Commercial PV Modules
Sorted by technology





Total weighted average efficiency of crystalline Silicon(c-Si) wafer-based modules is 20.9% in Q4-2022 (was 20.4% in Q4-2021); weighting factor is total shipments in year 2022. Lowest module efficiency in this group is 17.2 (was 16.3% one year before) and highest value is 23.2% (was 22.4% in 2021).

Top 10 manufacturers represent about 75% of total shipment volume and origin mainly in Asia.

Predominant c-Si technology is mono-PERC with half-cut cells and Multi-Busbar.

Note: The selection is based on modules from the top10 manufacturers in 2022 (except CIGS) with module data sheets available worldwide mid of February 2023. For CIGS technology, only a very limited amount of supplier data was available, and the products indicated are manufactured for niche markets such as building integrated PV (BIPV) or flexible module applications, so comparability with the other two technologies is limited.

Data Source: Top 10 module supplier ranking: pv-tech.org; company product data sheets; Date of data: 16-Feb. 2023 Fraunhofer ISE

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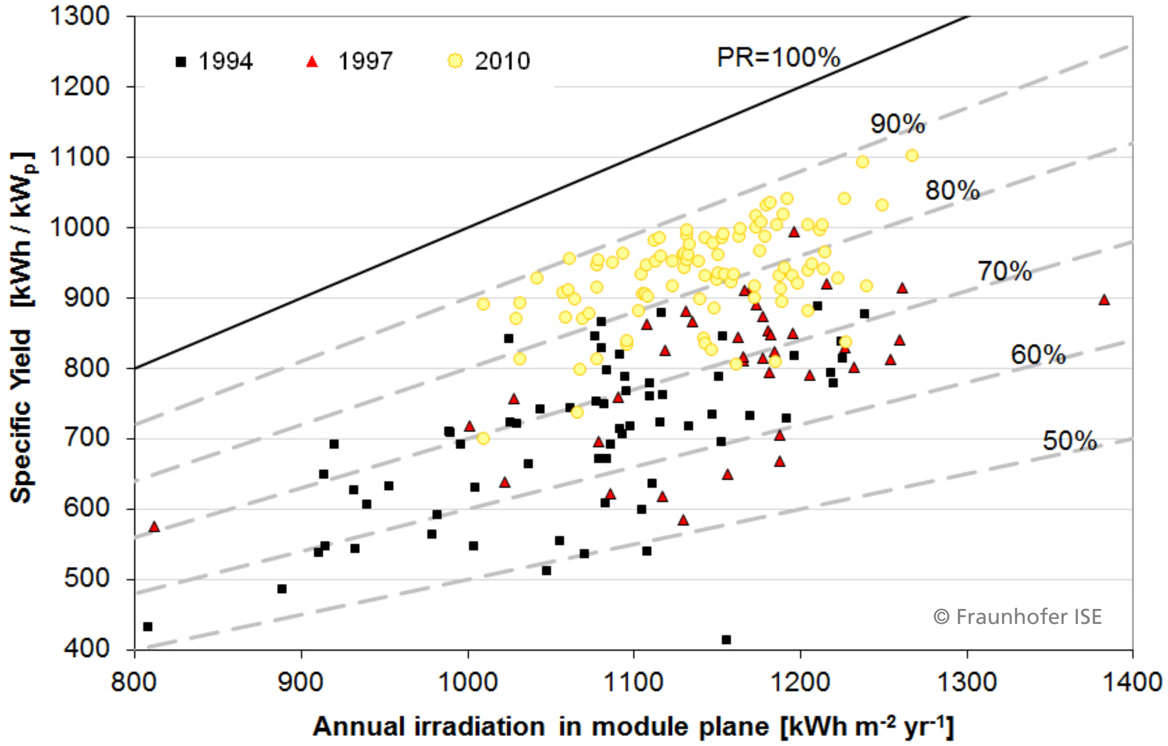
Performance Ratio Development for PV Systems
Germany



In the 1990's

- Typical PR ~70 %
- Widely ranging PR values

Today

- Typical PR ~83 %
- Less variance in PR as compared to 1990's

Source: Fraunhofer ISE "1000 Dächer Jahresbericht" 1994 and 1997; 2011 system evaluation, CPIA 2021

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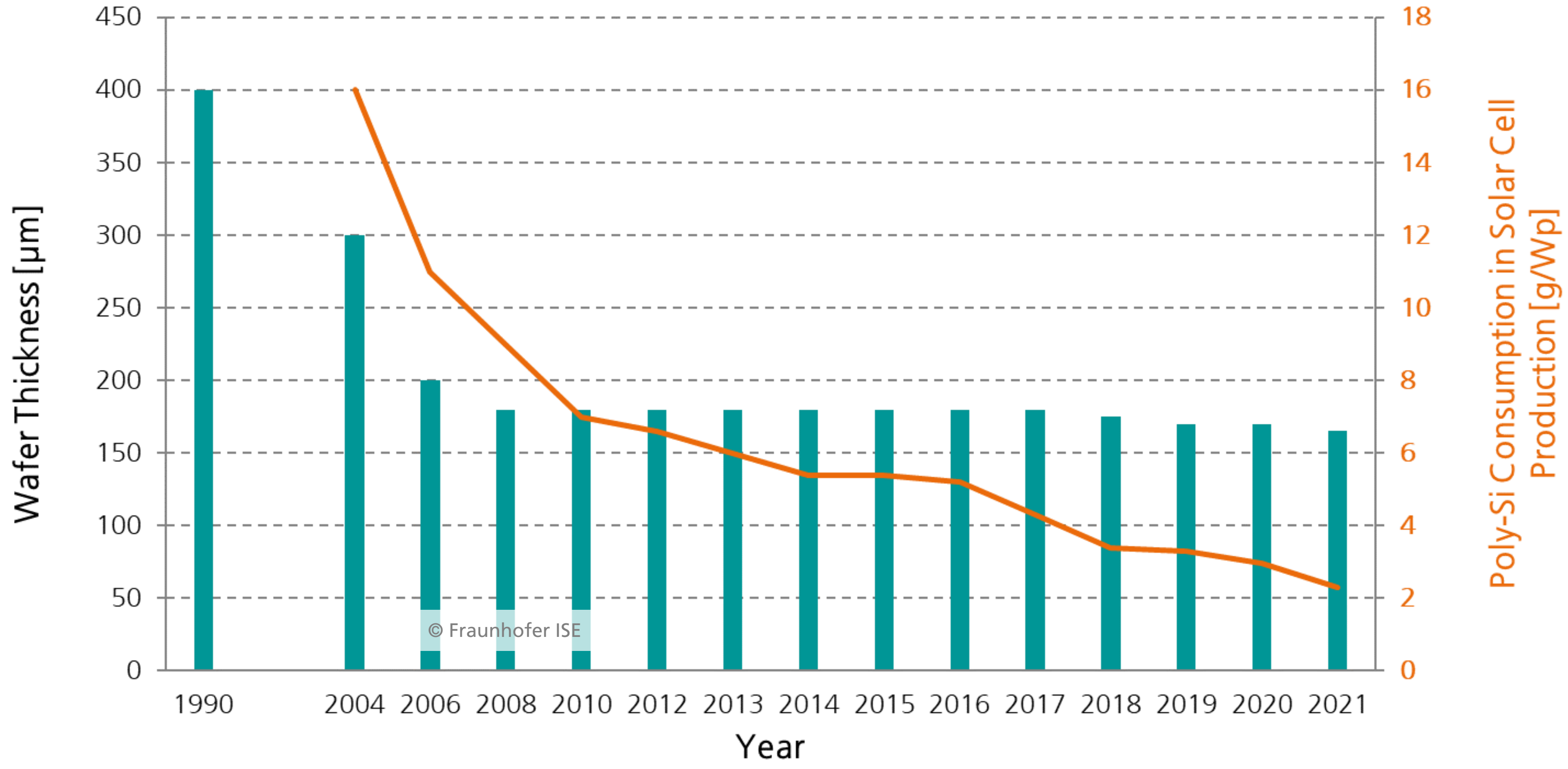
3. Energy Return of Invest (EROI) & Energy Payback Time (EPBT)

- Silicon usage, wafer thickness and kerf loss for c-Si
- EPBT: Development and comparison

c-Si Solar Cell Development
Wafer Thickness [µm] & Silicon Usage [g/Wp]



Data: until 2012: EU PV Technology Platform Strategic Research Agenda, from 2012: ITRPV 2015; ISE 2016 without; 2017 to 2020 with recycling of Si. Graph: PSE Projects GmbH 2021

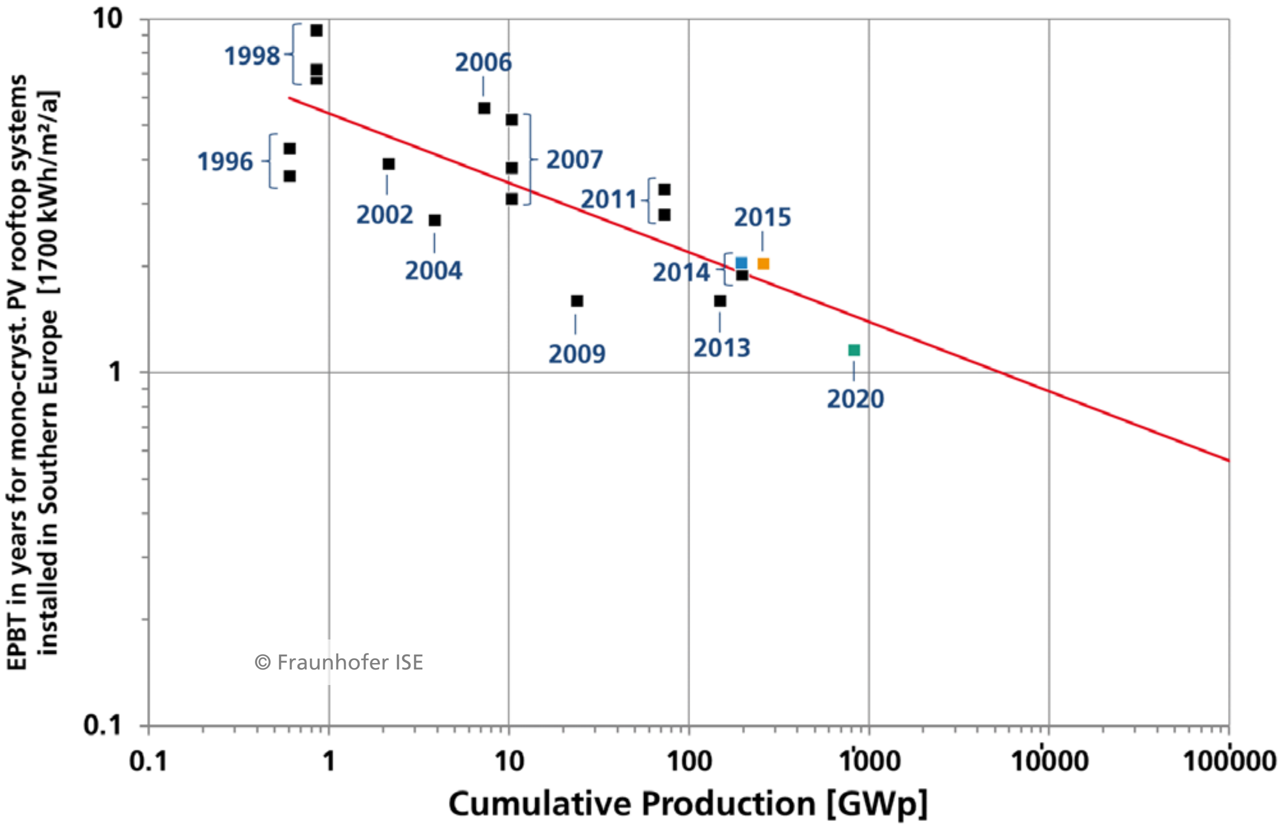
Historic Trend in Energy Payback Time
Harmonized Study data for mono-crystalline Silicon Rooftop PV-Systems

- **Learning Rate:**
  Each time the cumulative production doubled, the EPBT went down by 12.8 % for the last 24 years.

Harmonization methodology
based on Koppelaar (2016) harmonized results and harmonization parameters

1) Performance Ratio	
based on average annual PV yield during lifetime	
PV system lifetime	25
Degradation	0.70%
PR (initial)	80%
PR (incl. average degradation during lifetime)	**73.6%**
2) Grid efficiency	
for converting PV yield in primary energy equivalents	
grid efficiency	**35%**

EPBT of Leccisi (2016), Louwen (2014) and Friedrich (2020) were harmonized with 1) PR (incl. average degradation) and 2) grid efficiency to results of Koppelaar (2016)*



Irradiation: 1700 kWh/m²/a at an optimized tilt angle; **Years:** Estimated average year of original data

Data: Lorenz Friedrich, Fraunhofer ISE. Graph: PSE 2021

*■ Koppelaar (2016) - Solar-PV energy payback and net energy: Meta-assessment of study quality, reproducibility, and results harmonization, Renewable and Sustainable Energy Reviews
■ Leccidi et al. (2016) - The Energy and Environmental Performance of Ground-Mounted Photovoltaic Systems—A Timely Update, Energies
■ Louwen et al. (2014) - Life-cycle greenhouse gas emissions and energy payback time of current and prospective silicon heterojunction solar cell designs, Progress in Photovoltaics
■ Friedrich et al. (2020) - Global Warming Potential and Energy Payback Time Analysis of Photovoltaic Electricity by Passivated Emitter and Rear Cell (PERC) Solar Modules, submitted JPV

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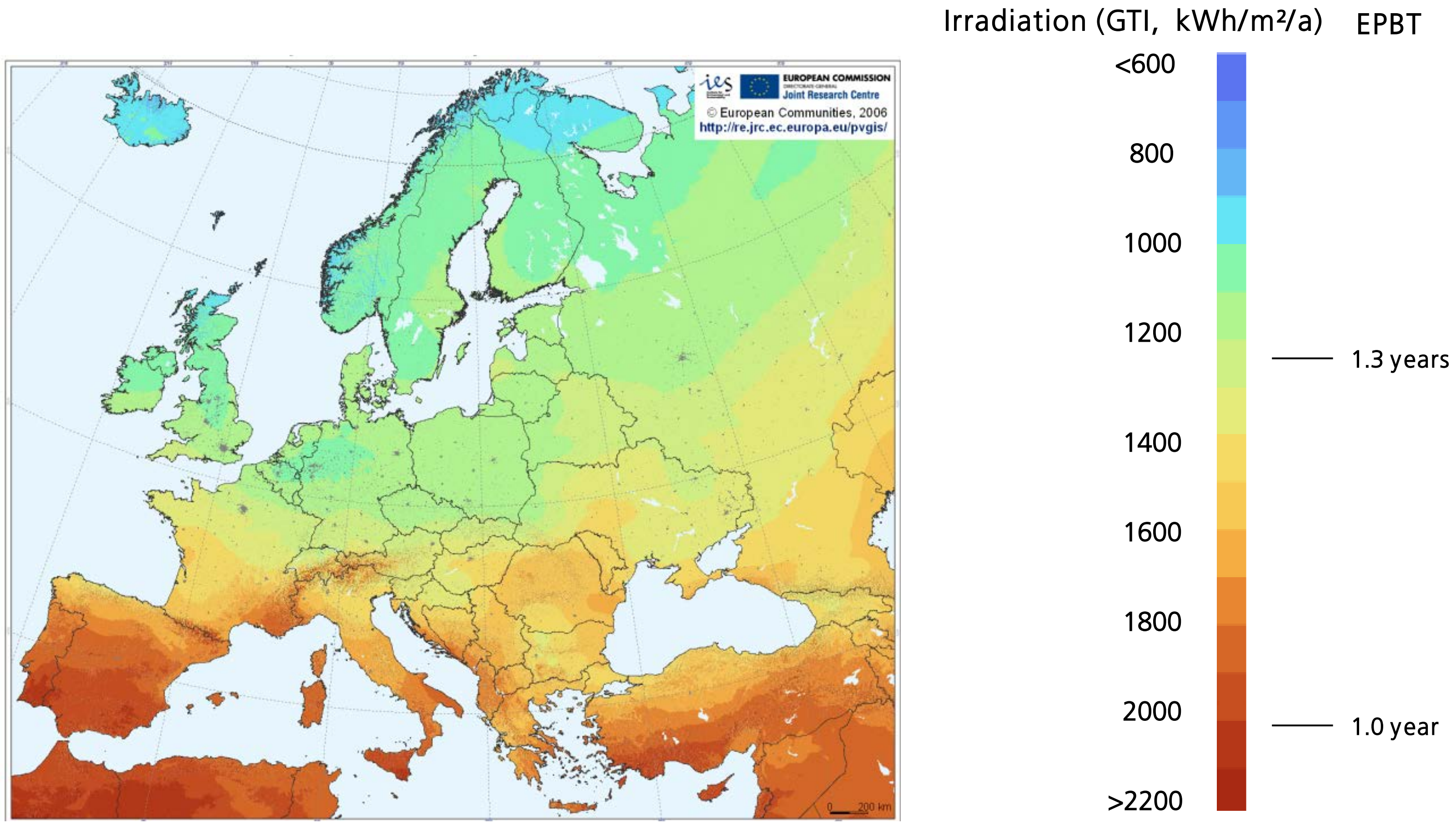
Energy Pay-Back Time of Silicon PV Rooftop Systems
Geographical Comparison

- Rooftop PV-system using mono-crystalline Silicon cells* produced in China
- EPBT is dependent on irradiation, but also on other factors like grid efficiency**.
- Better grid efficiency in Europe may decrease the EPBT by typically 9.5 % compared to PV modules produced in China.



Data: Lorenz Friedrich, Fraunhofer ISE. Image: JRC European Commission. Graph: PSE 2020 (Modified scale with updated data from Fraunhofer ISE)

*Cz PERC cells module with 19.9% efficiency

**relation between primary energy to produced electricity in the grid used for manufacturing of the PV system

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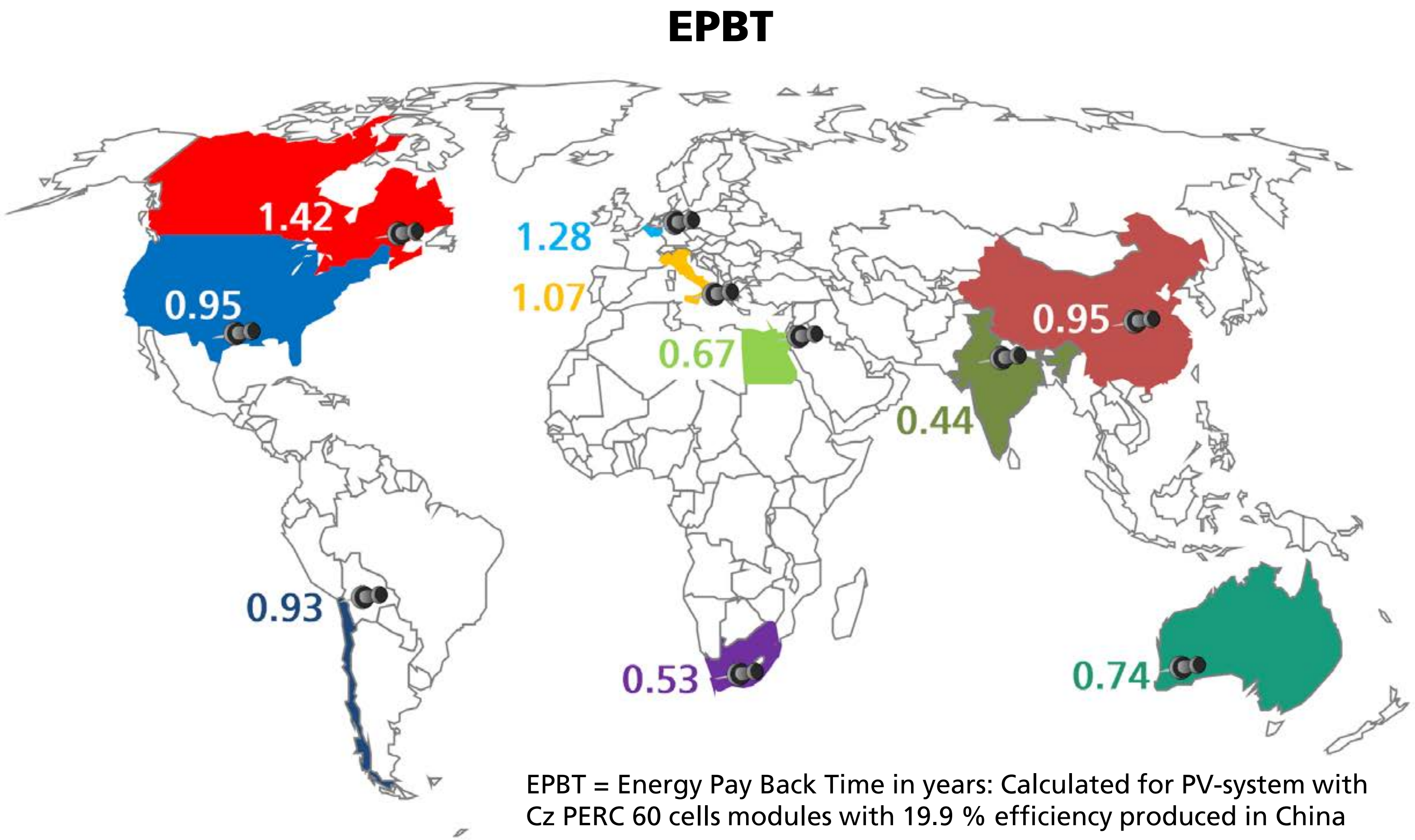
World Map EPBT of Silicon PV Rooftop Systems –
Comparison of EPBT China

Influencing factors and interpretation:

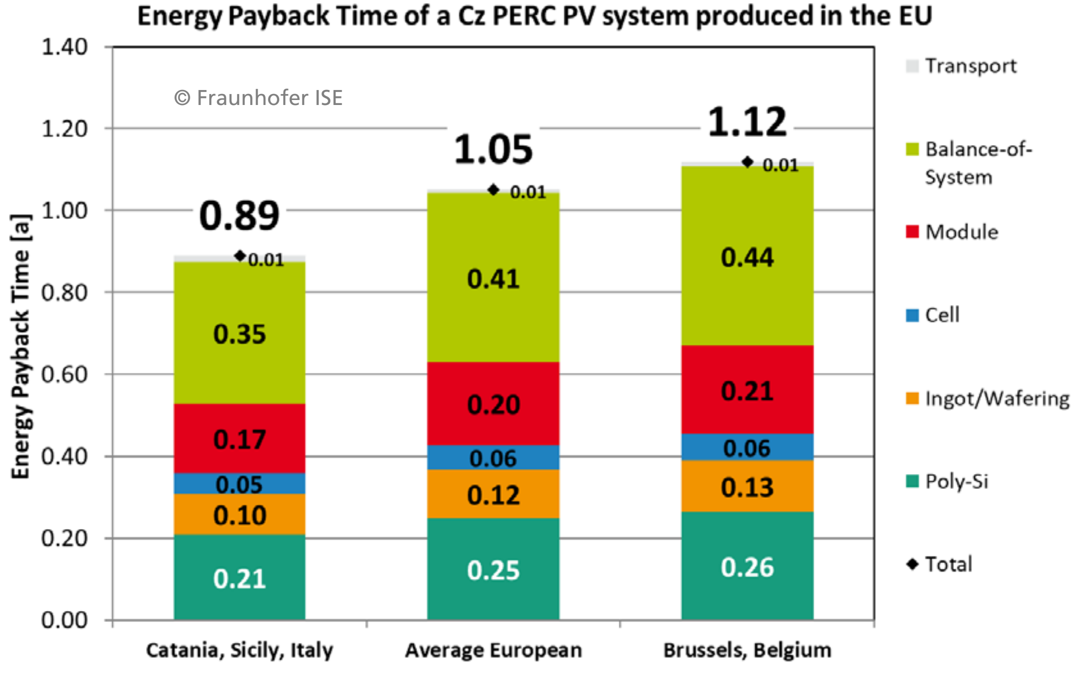
- EPBT: The lower, the better
- Irradiation: The higher, the better
- Grid efficiency: The higher, the better in countries where upstream production is located; (better energy mix to generate electrical power; less losses in the electrical transmission network). At downstream (where PV is installed) a low grid efficiency reduces the EPBT.

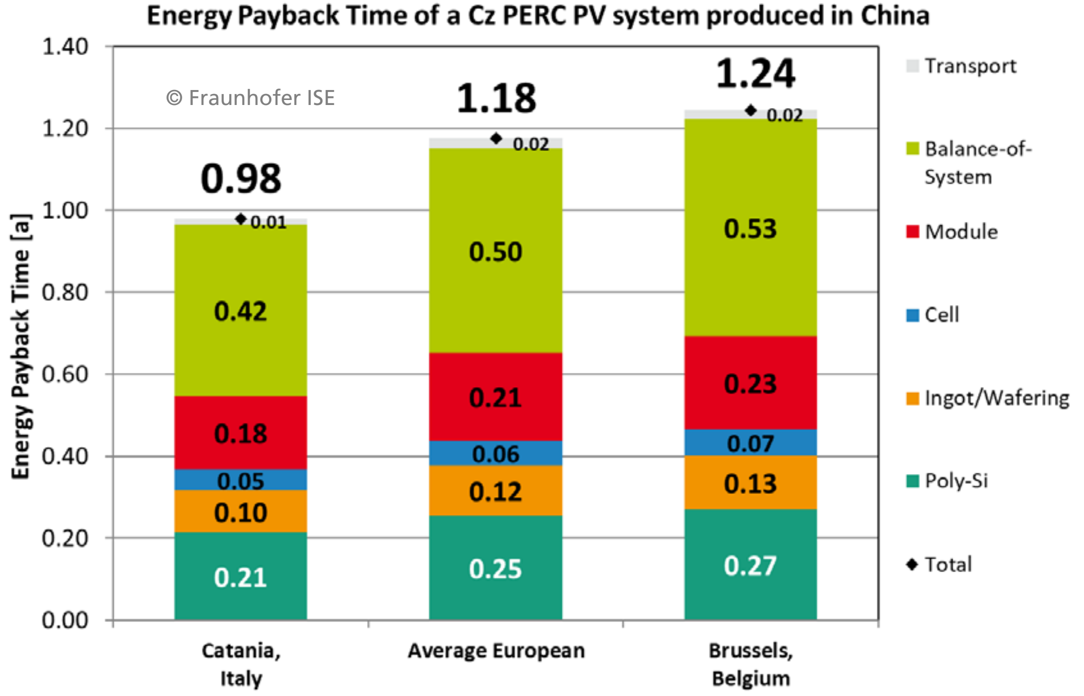


EPBT = Energy Pay Back Time in years: Calculated for PV-system with Cz PERC 60 cells modules with 19.9 % efficiency produced in China

Data: Lorenz Friedrich, Fraunhofer ISE. Graph: PSE 2020

Energy Pay-Back Time of Silicon PV Rooftop Systems –
Comparison of EPBT China / EU, local Irradiation and Grid Efficiency 2021





EPBT for PV systems produced in Europe is shorter than for those produced in China because of better grid efficiency in Europe.

Data: Lorenz Friedrich, Fraunhofer ISE. Calculations for year 2021 made at 22-July 2022

4. Inverters

- Inverter/Converter Market

Inverter/Converter Market 2020

Inverter / Converter	Power	Efficiency	Market Share (Estimated)*	Remarks
String Inverters	up to 150 kWp	up to 98% (DC/AC)	64.4%	• 3 - 17 €-cents /Wp • Easy to replace
Central Inverters	More than 80 kWp	up to 98.5% (DC/AC)	33.7%	• 3 - 5 €-cents /Wp • High reliability • Often sold only together with service contract
Micro-Inverters	Module Power Range	90%-97% (DC/AC)	1.4%	• ~ 25 €-cents /Wp • Ease-of-replacement concerns
Power Optimizer	Module Power Range	up to 99.5% (DC/DC)	5.1%	• ~ 8 €-cents /Wp • Ease-of-replacement concerns • Output is DC with optimized current • Still a DC / AC inverter is needed

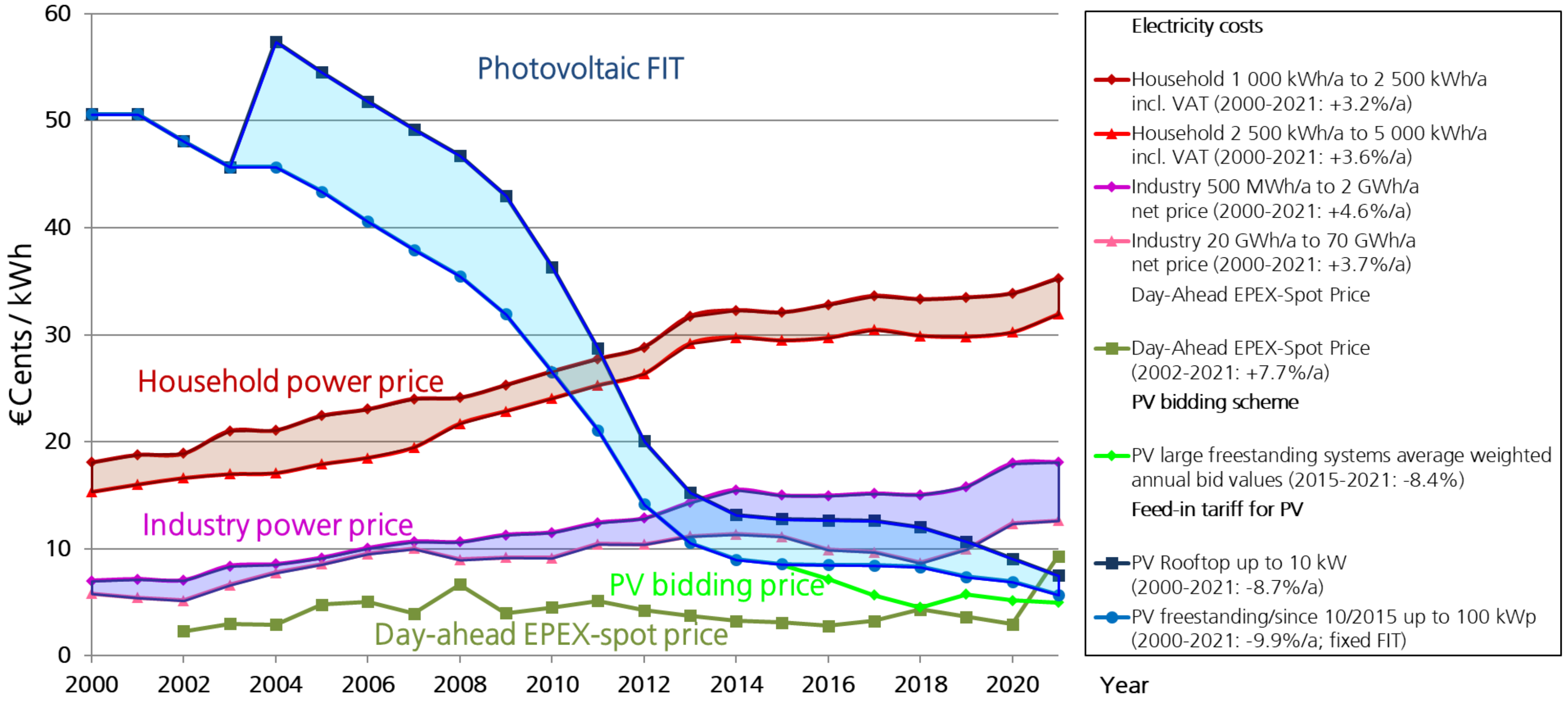
Data: IHS Markit 2021; IRENA 2021. Remarks: Fraunhofer ISE 2021. Date of data: Jun-2021

*Total Market Share related to shipment in MWac is greater than 100% because DC/DC converters are required to be paired with string inverters

5. Price Development

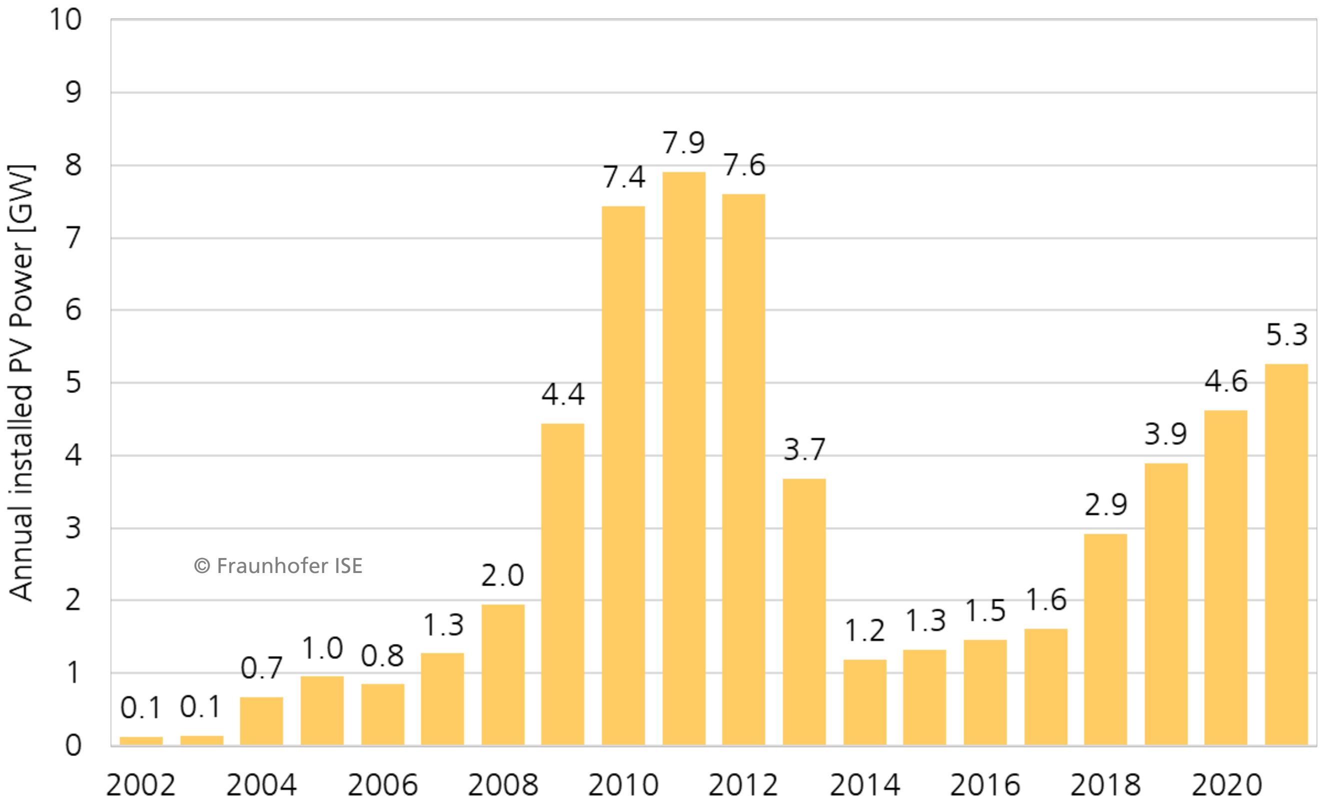
- Electricity costs
- Market incentives in Germany
- Costs for PV systems
- Price Learning Curve

Electricity Prices, PV Feed-In Tariffs (FIT) and bidding scheme in Germany



Data: BMU and BMWi Energiedaten 2021. Design: B. Burger - Fraunhofer ISE. Date of data: Jan. 2022

PV Market Development and Incentive Schemes in Germany



Data: BNA. Graph: B. Burger, Fraunhofer ISE Energy-Charts. Date of Data: 31-Jan-2022

Market Incentive	Start	End
1'000 Roofs Program	1990	1995
Cost-covering remuneration	1993	1999
100'000 Roofs-Program	1999	2003
EEG	2000	ongoing
PV Tendering scheme	2015	ongoing

The EEG 2023 law relies on a massive expansion of renewable energies with total installed PV capacity of 215 GW in year 2030.
In this year (2022), 7 GW of new PV system capacity are to be connected to the grid, next year 9 GW. From 2026, the expansion target is 22 GW of new installations on annual basis.

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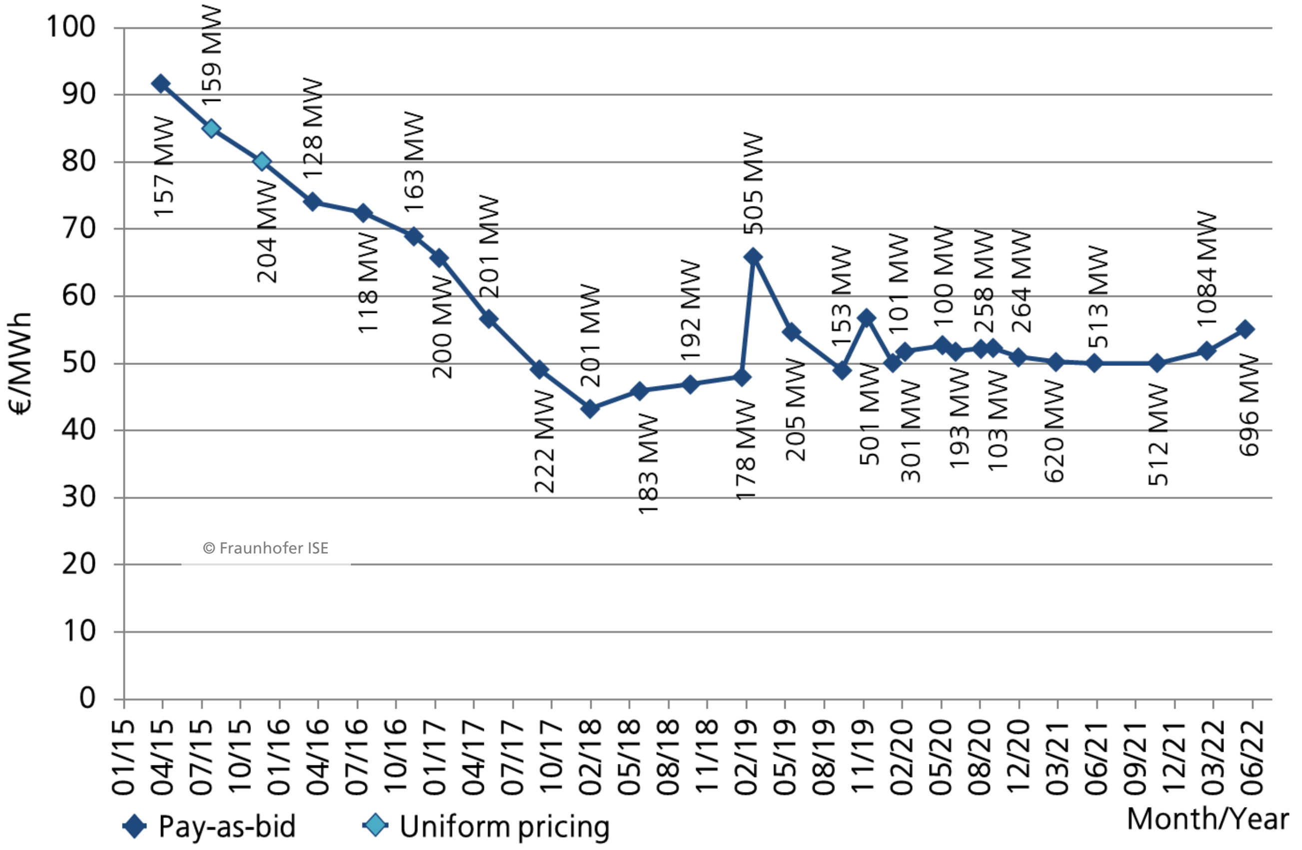
PV-Tender in Germany
Average, quantity weighted Award Value



Data: BNA. Graph: PSE 2022 – Date of data: Jun-2022

Lowest PV-Tender Round was in Feb. 2018 with 4.33 ct€ / kWh as average quantity weighted award price.

PV-Tender scheme started in April 2015 and total capacity of this scheme accumulates to 8.3 GW by Jun-2022 with 5.51 ct€ / kWh as latest average quantity weighted award price.

Special tenders are not displayed in the graph.

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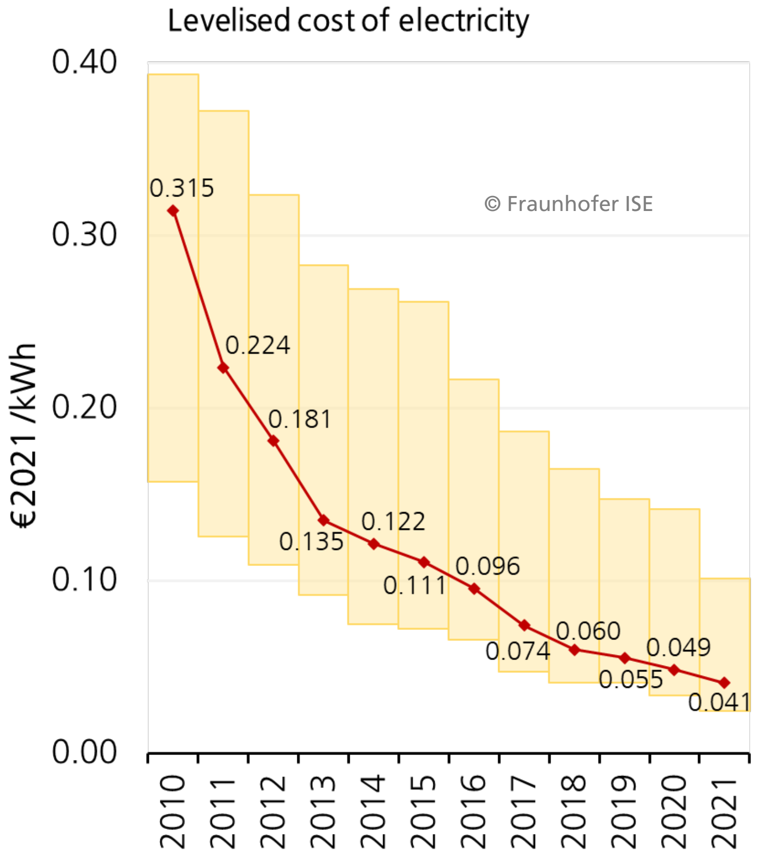
Global Weighted Average Levelised Costs of Electricity for Large PV Systems
(with 5th percentile and 95th percentile)



The global weighted average LCoE was in year 2021 for large PV systems 0.041 €/kWh (= 41 €/MWh).

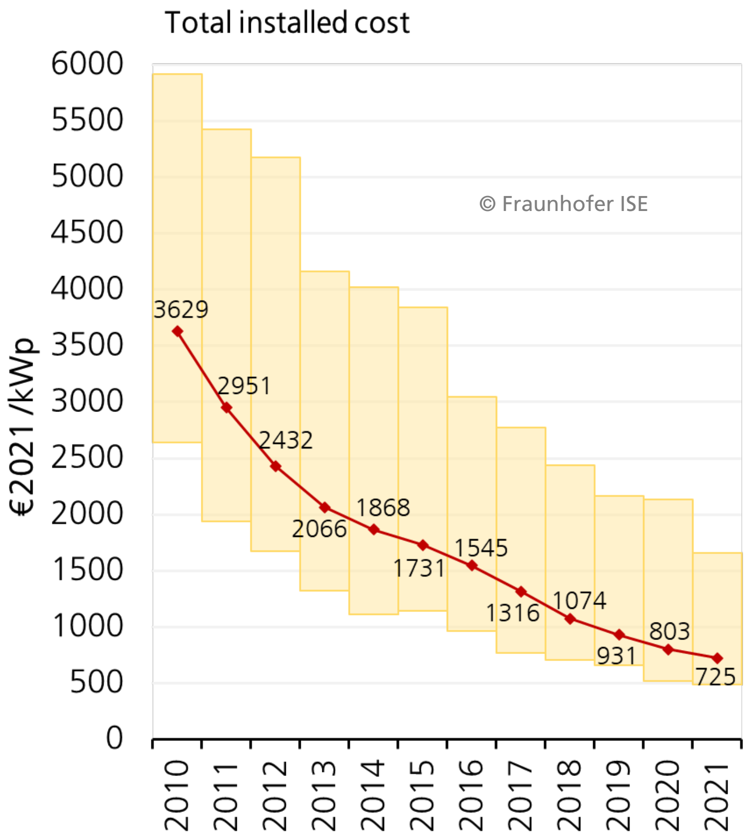
The 5th percentile is a value associated with the location within the data where 5% of data is below that value. In year 2021 the 5th percentile was 0.025 €/kWh (= 25 €/MWh).

The 95th percentile is the value where 5% of the data has a larger value. In year 2021 the 95th percentile was 0.101 €/kWh (= 101 €/MWh).

The LCoE decreased by about 17% on year-to-year basis in the last 11 years.

Data: IRENA (2022), Renewable Power Generation Costs in 2021, International Renewable Energy Agency, Abu Dhabi. Currency converted from USD to EUR. Date of data: July 2022

Global Weighted Average Total Installed Costs For Large PV Systems
(with 5th percentile and 95th percentile)



The global weighted average total cost for large PV systems was 725 €/kWp in year 2021.

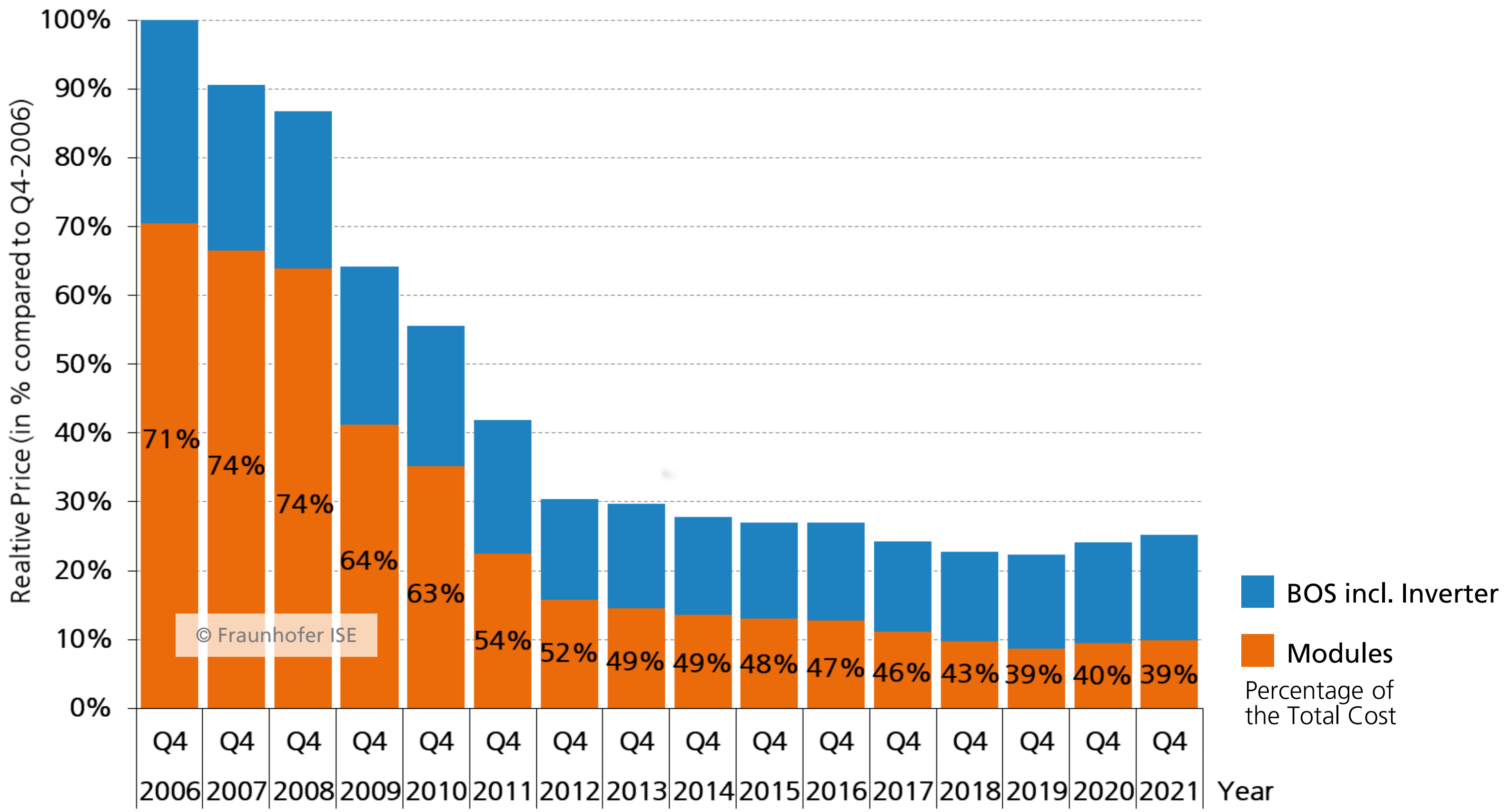
The 5th percentile is a value associated with the location within the data where 5% of data is below that value. In year 2021 the 5th percentile was
488 €/kWp.

The 95th percentile is the value where 5% of the data has a larger value. In year 2021 the 95th percentile was 1658 €/kWp.

Total installed cost for large PV systems decreased by about 14% on year-to-year basis in the last 11 years.

Data: IRENA (2022), Renewable Power Generation Costs in 2021, International Renewable Energy Agency, Abu Dhabi. Currency converted from USD to EUR. Date of data: July 2022

Price Development for PV Rooftop Systems in Germany
(10kWp - 100kWp)



Data: BSW-Solar. Graph: PSE 2021. Date of data: Nov-2021

Balance of System (BOS) encompasses all components of a PV system other than the PV modules; like inverter, mounting system, switches, wiring and installation work. Annual average BOS cost increased by 10.8% on y-to-y basis in 2021 and annual average PV module cost increased by 20.0% due to COVID-19 market disturbances.

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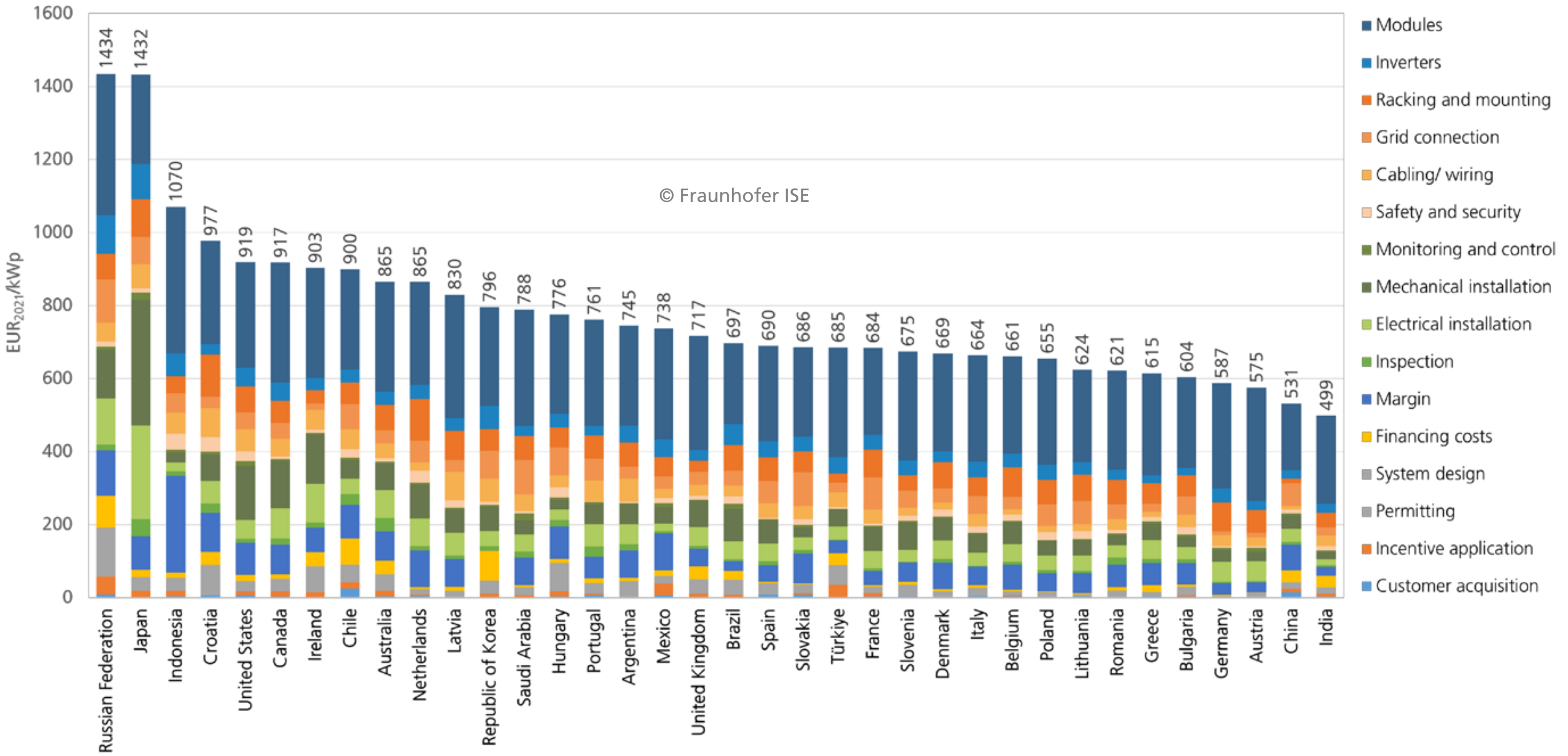
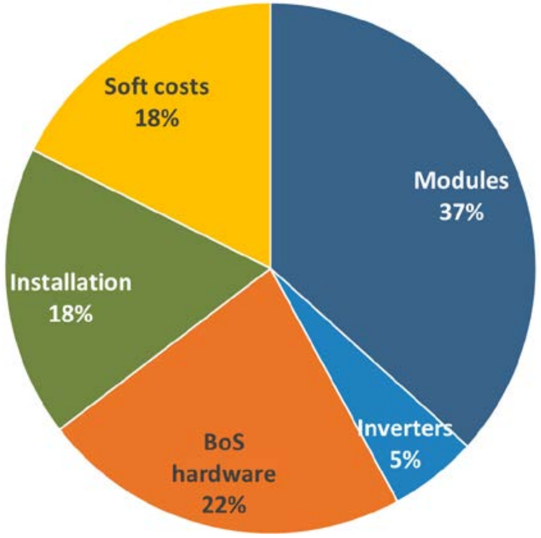
Breakdown of Utility-scale PV Total Installed Costs
By Country in 2021



Breakdown of cost components
(average of available country data):



Data: IRENA (2022), Renewable Power Generation Costs in 2021, International Renewable Energy Agency, Abu Dhabi. Currency converted from USD to EUR. Date of data: Jul-2022

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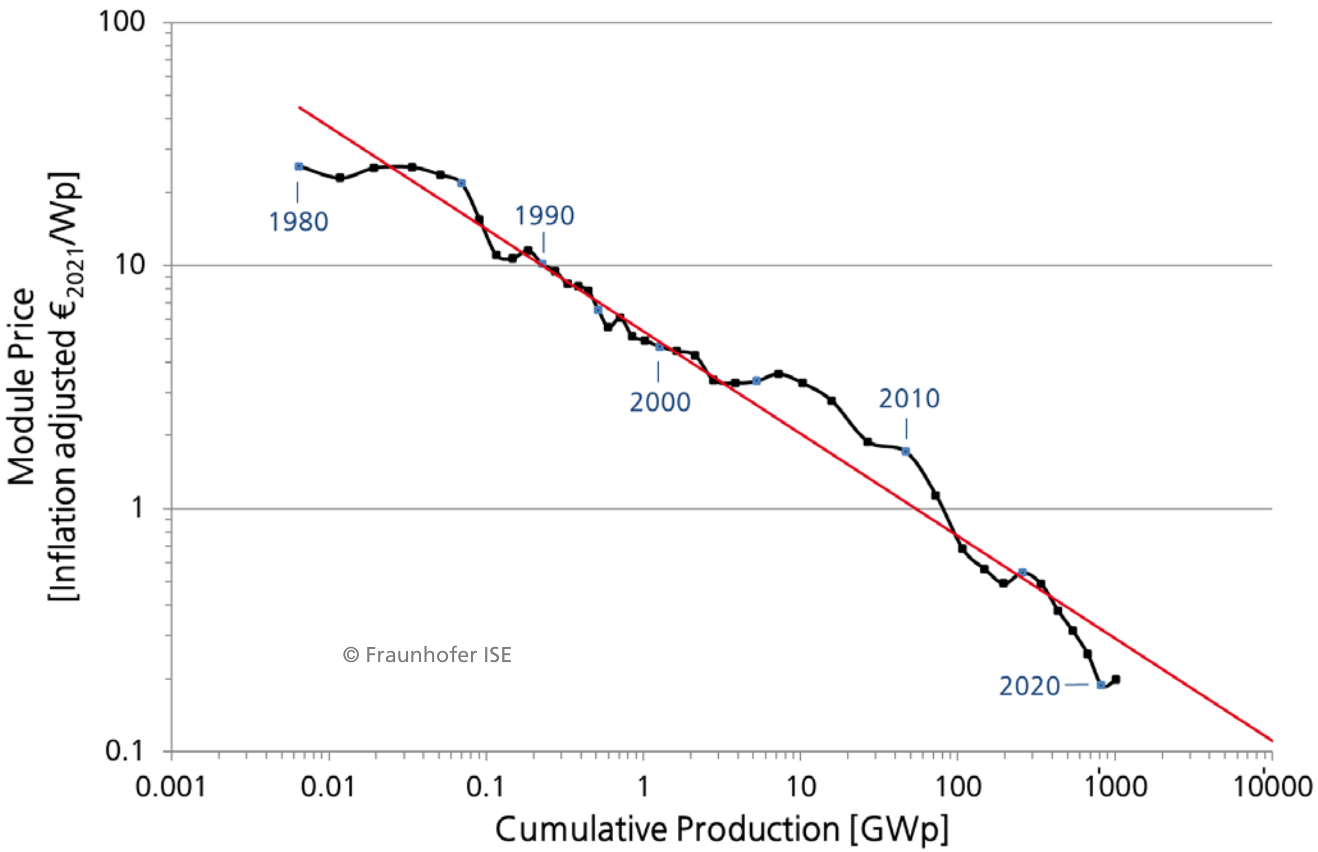
Price Learning Curve
Includes all Commercially Available PV Technologies



Learning Rate:
Each time the cumulative PV module production doubled the price went down by about 25% for the last 41 years.

Data: from 1980 to 2010 estimation from different sources: Strategies Unlimited, Navigant Consulting, EUPD, pvXchange; from 2011: IHS Markit; Graph: PSE 2022

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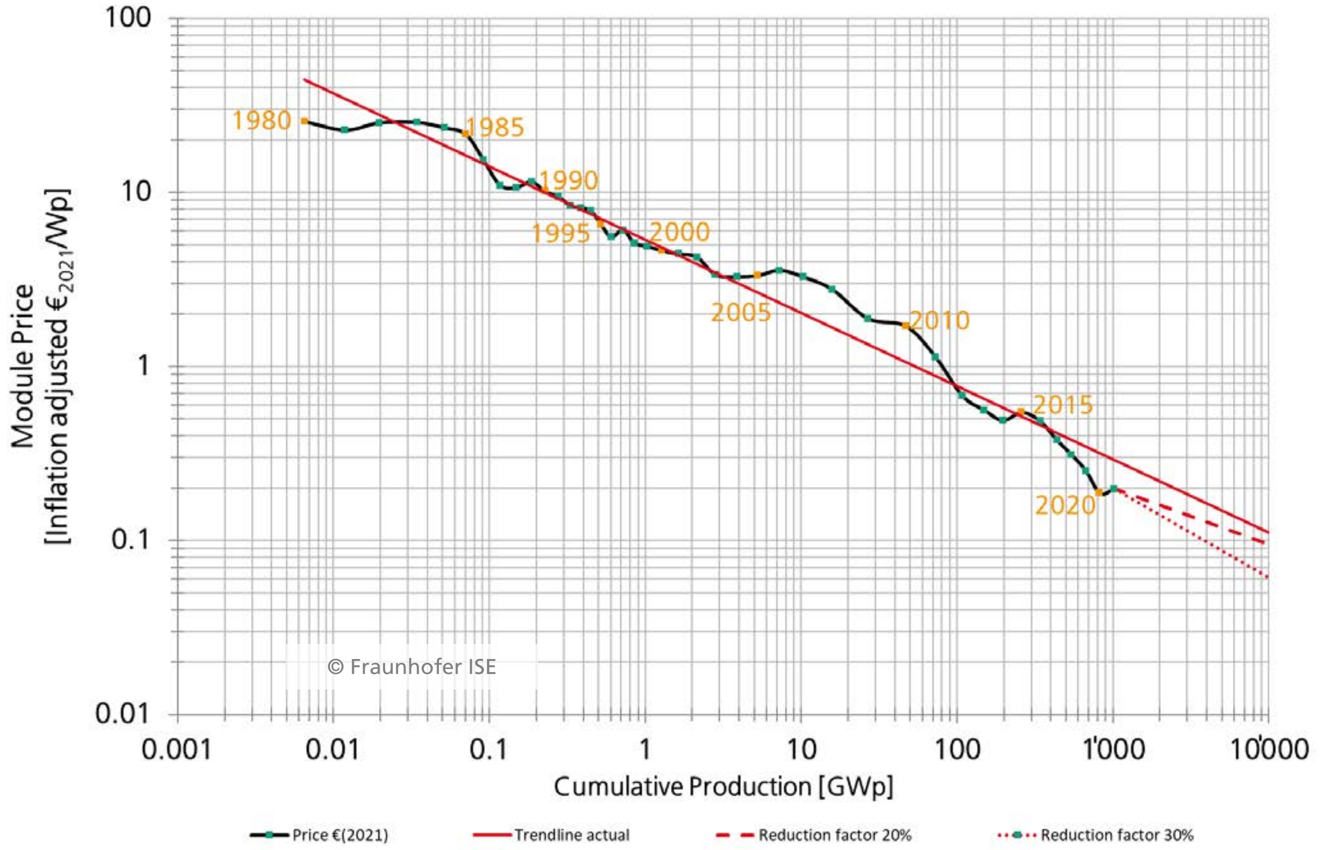
Price Learning Curve

Includes all Commercially Available PV Technologies



Learning Rate:
Each time the cumulative PV module production doubled the price went down by about 25% for the last 41 years.

Data: from 1980 to 2010 estimation from different sources: Strategies Unlimited, Navigant Consulting, EUPD, pvXchange; from 2011: IHS Markit; Graph: PSE 2022

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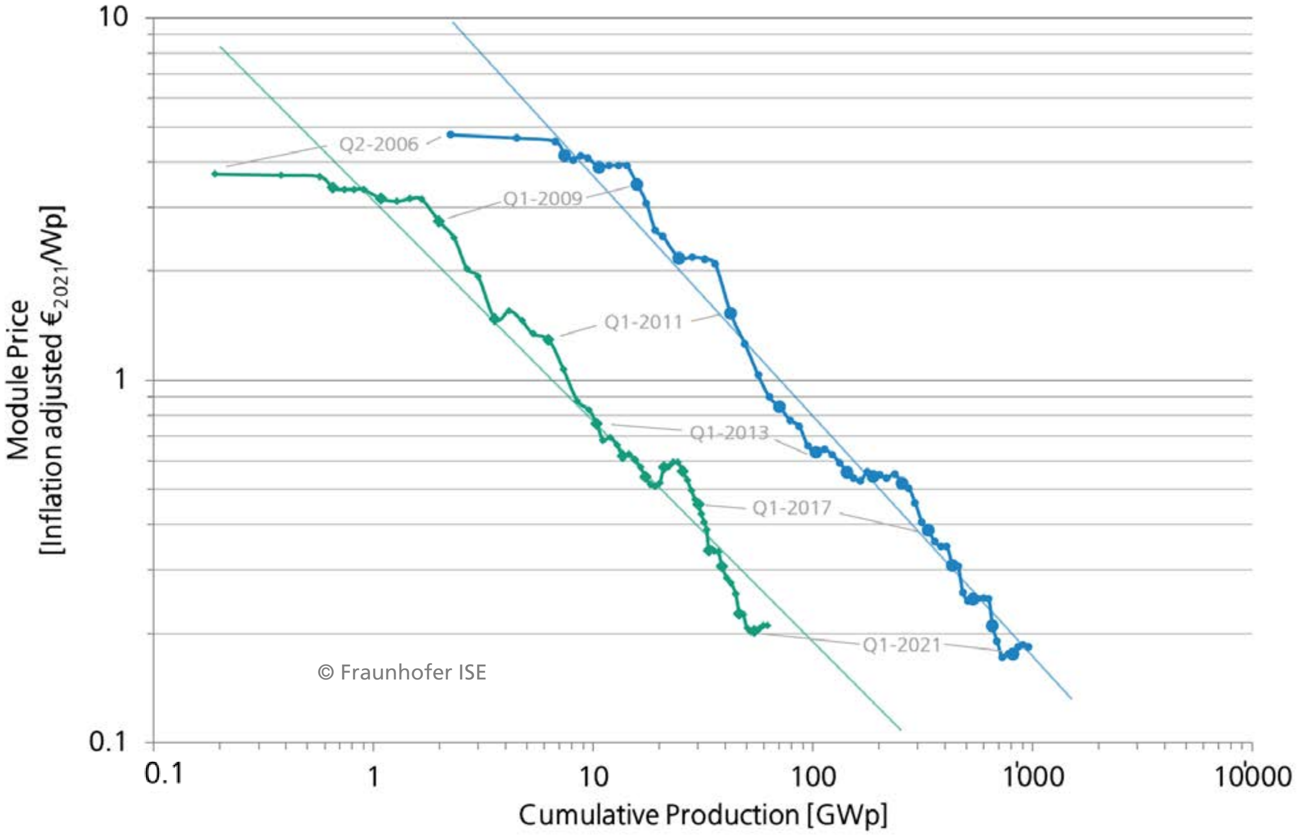
Price Learning Curve by Technology
Cumulative Production up to Q4-2021



Estimated cumulative PV module production up to Q4-2021:

●	c-Si	958 GWp
◆	Thin Film	62 GWp

Crystalline Technology
(from Q2-2006 to Q4-2021) **LR 31**
Thin Film Technology
(from Q2-2006 to Q4-2021) **LR 29**

Data: from 2006 to 2010 estimation from different sources : Navigant Consulting, EUPD, pvXchange; from 2011: IHS Markit. Graph: PSE 2022

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Further Reading
Selected studies and analyses

- ISE Energy Charts
- Study: Levelized Cost of Electricity - Renewable Energy Technologies
- Recent facts about photovoltaics in Germany
- Power Generation from Renewable Energy in Germany
- What will the Energy Transformation Cost? Pathways for Transforming the German Energy System by 2050
- Sustainable PV Manufacturing in Europe – An Initiative for a 10 GW Green Fab
- Meta Study: Future Crosssectoral Decarbonization Target Systems in Comparison to Current Status of Technologies

Please click on the link to find the respective information.

Abbreviations

Abbr.	Explanation	Abbr.	Explanation
AC	Alternating Current	HJT (also HIT)	Heterojunction with Intrinsic Thin-Layer
Al-BSF	Aluminum Back Surface Field	IBC	Interdigitated Back Contact (solar cells)
BIPV	Building Integrated PV	LCOE	Levelized Cost of Energy
BOS	Balance of System	LCPV	Low Concentrator Photovoltaic
CdTe	Cadmium-Telluride	MJ	Multi Junction
CI(G)S	Copper Indium (Gallium)Diselenide	MPP	Maximum Power Point
CPV	Concentrating Photovoltaic	n-type	Negatively doped wafer (with phosphorous)
c-SI	Crystalline Silicon	PERX	Passivated emitter and rear cell
Cz	Czochralski Method	PR	Performance Ratio
DC	Direct current	p-type	Positively doped wafer (with boron)
EEG	Renewable Energy Source Act (Erneuerbare-Energien-Gesetz)	PV	Photovoltaic
EPBT	Energy PayBack Time	RE	Renewable Energies
EROI	Energy Return of Invest	ROI	Return on Investment
FZ	Floating Zone	SI	Silicon
GaAs	Gallium Arsenide	SIC	Silicon carbide
GaN	Gallium nitride	VAT	Value Added Tax
HCPV	High Concentrator Photovoltaic		

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Harry Wirth	ISE
Werner Warmuth	PSE

The information provided in this ‚Photovoltaics Report' is very concise by its nature and the purpose is to provide a rough overview about the Solar PV market, the technology and environmental impact.

There are many more aspects and further details can be provided by Fraunhofer ISE. Upon request, you are welcome to receive a tailor-made offer.

Please contact us if you are interested in ordering this service.

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