



**RystadEnergy**

# Shining Horizons: Global Solar PV Growth and Manufacturing Outlook

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Intersolar 2023

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Solar PV project costs

# Global solar PV additions up by 35% from 2021-22

Global annual solar PV installation volumes are scaling up fast, doubling from 2019-22. Despite high project costs, 35% year-on-year growth is expected from 2022-23.

The acceleration is largely driven by the renewable energy installation targets set by many governments to improve energy security and accelerate the transition to clean fuels.

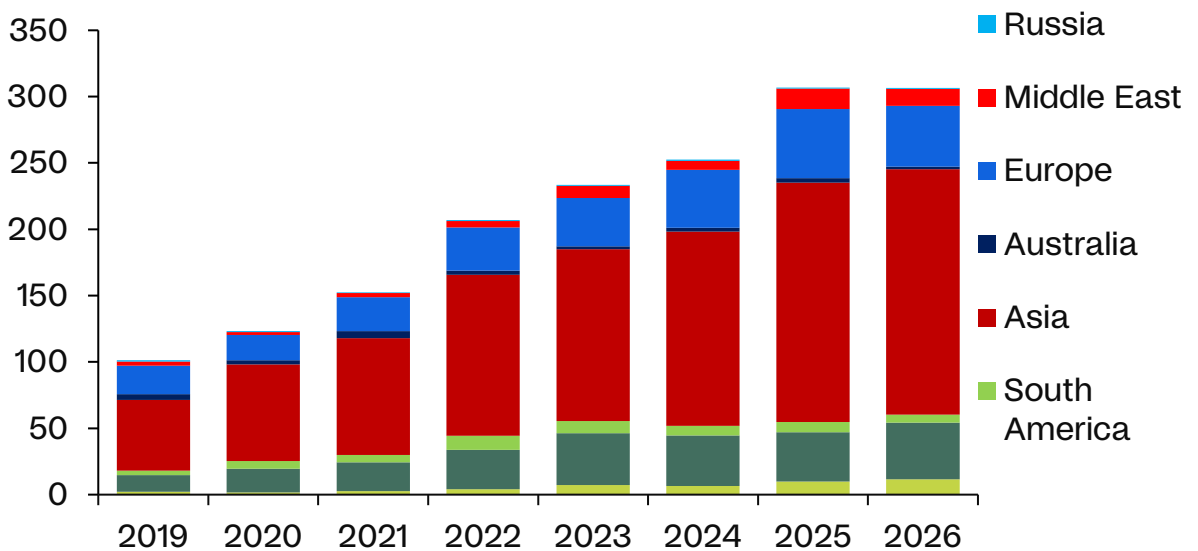
South America installed the bulk of new solar PV in 2022 at 88%, followed by Africa with 58%, the Middle East with 41%, Asia with 38%, North America with 37%, and Europe with 28%.

From 2022-23, we expect solar PV installations globally to grow 13% despite challenges associated with inflation and supply chains.

Asia continues to lead the way and will be responsible for over half of this year's capacity additions, followed by North America and Europe. Through 2026, Africa is set to increase its annual PV installations, with growth in South America and Australia expected to slow down.

## Global solar PV installation by construction year, 2019-2026

Gigawatt AC (GW<sub>AC</sub>)

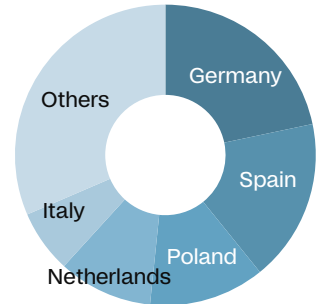
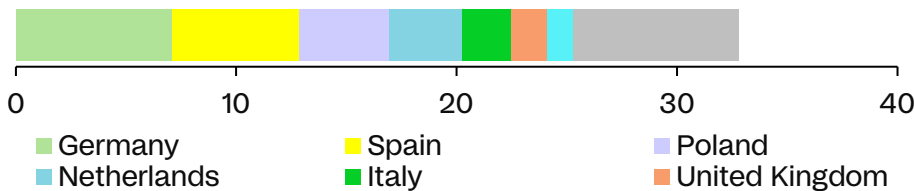


Source: Rystad Energy SolarCube

# Solar PV additions in Europe

## Installed solar PV capacity in Europe by country, 2022

Gigawatt AC (GW<sub>AC</sub>)



For Europe’s solar market, 2022 was a record year in all respects with newly commissioned capacity, investments, awarded capacity and new policies. At the same time, the European energy sector faced many challenges: an energy crisis, record power prices, supply chain bottlenecks, and record inflation.

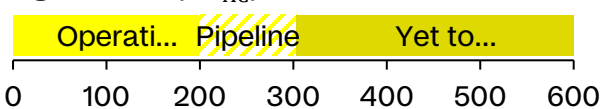
Europe was the second-largest region for newly installed capacity last year, after Asia. A total 32 gigawatts (GW) of new solar PV capacity was installed in Europe last year, lifting cumulative installed capacity over 200 GW. This represents a 28% increase over 2021 (25 GW) and was a record level. This underscores the solar sector’s resilience in the face of

ongoing challenges, and Europe’s growing reliance on renewables to achieve energy security and decarbonization plans.

New capacity was contributed by utility scale solar PV (14 GW) and rooftop PV (17 GW). The new commissioning records were mostly driven by Germany (7 GW), Spain (5.7 GW), Poland (4 GW), and the Netherlands (3.3 GW). In 2023, we expect 36 GW of new solar capacity to come online, though this could be revised upwards with the implementation of policies currently being discussed to fast track permitting.

## Gap to REPowerEU 2030 target, solar PV\*

Gigawatt AC (GW<sub>AC</sub>)



Up to 2030, the EU utility solar PV pipeline totals 104 GW, leaving 300 GW to be filled by new projects or rooftop PV to reach the REPowerEU policy target. About 2 GW of solar PV capacity was awarded in April, led by Germany.

Source: Rystad Energy SolarCube

\*EU Commission targets. EU27 only. Solar PV operating capacities include rooftop PV, solar PV pipeline only includes utility-scale projects.

Source: Rystad Energy RenewableCube, Rystad Energy Solar Solution

# Solar PV installations by type and capacity

The global market for floating solar PV has grown rapidly since 2016, approaching 3.5 GW as of end-2022, mainly led by Asia. We expect capacity additions to double from 2022-23, but to still amount to just 1% of installed solar capacity this year.

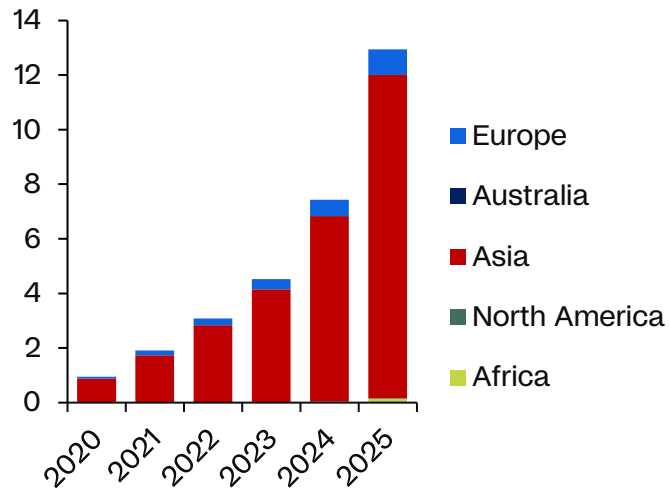
Despite technical challenges, the benefits of using existing grid infrastructure, higher energy efficiency and land occupancy issues provide a huge potential for rapid growth in floating solar PV installations from 2024-25.

Utility scale solar PV installations are rising in popularity. By 2023, almost half of projects will be over 1 GW in capacity. Large-scale solar PV projects clearly benefit from economies of scale and offer

a lower levelized cost of energy, despite the major investment required.

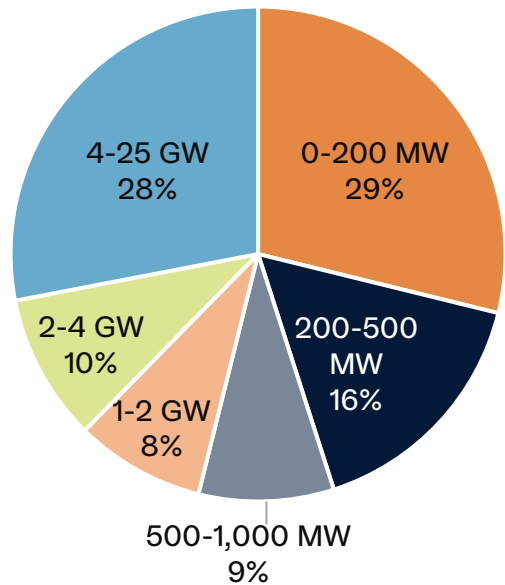
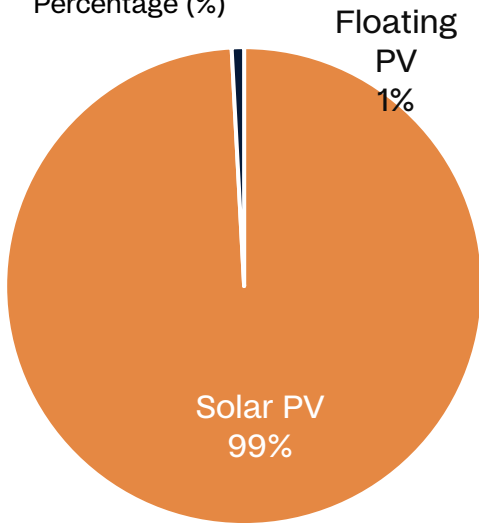
## Floating PV capacity outlook by region

Gigawatts AC (GW<sub>AC</sub>)



## Forecast for global solar PV installations by technology type and capacity, 2023

Percentage (%)



Source: Rystad Energy SolarCube

# Global solar PPAs becoming price-competitive

Power purchase agreement (PPA) auctions have been receiving ever-lower price bids from developers globally as solar PV projects become cheaper and more price competitive with non-renewable counterparts.

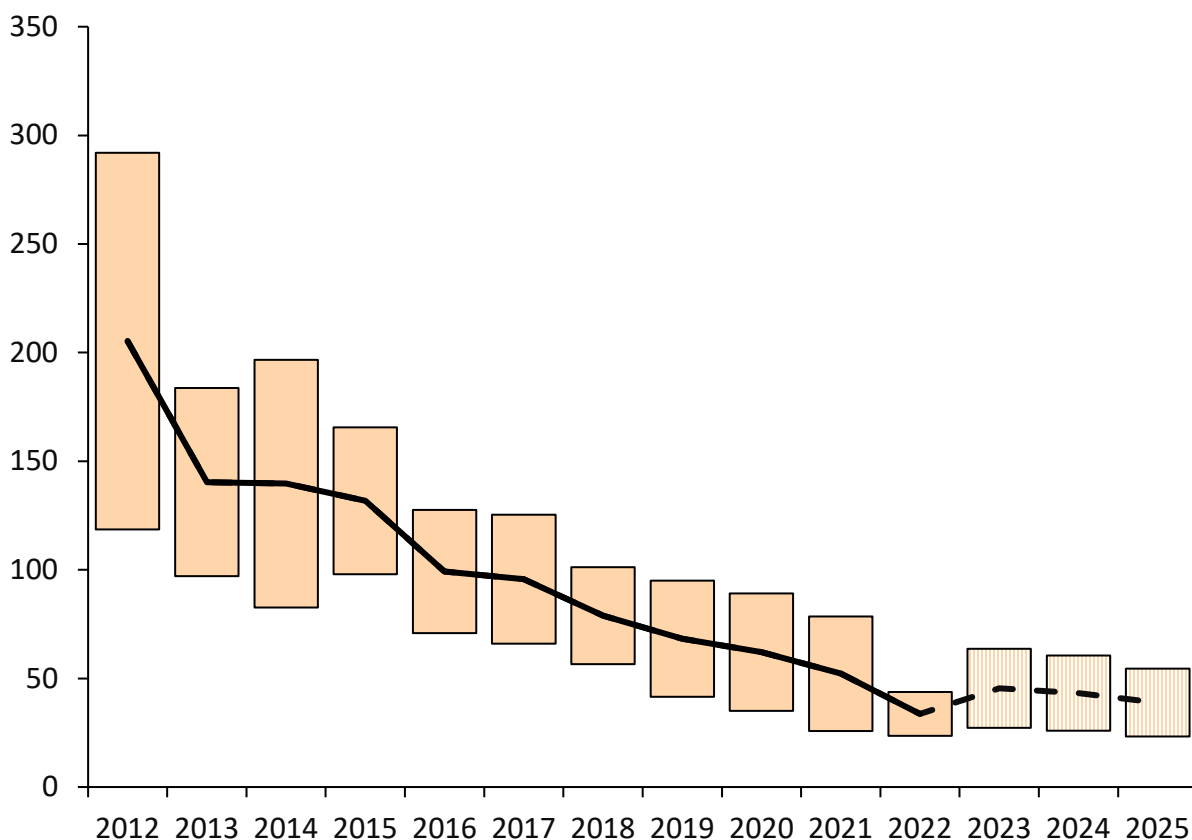
Utility solar PV PPA prices are set to average \$46 per megawatt-hour (MWh) in 2023, up 35% from 2022. With price inflation and supply bottlenecks following the pandemic, many developers are under pressure to carry out

projects according to the contract signed before inflation fed through.

On the other hand, Russia's war in Ukraine has pushed up solar PPA prices in Europe, especially lately, due to the need to secure energy supply and decarbonize power. Global solar PPA prices are set to decline again in 2024.

## Global solar PPA trend by construction year

USD per megawatt-hour (MWh)

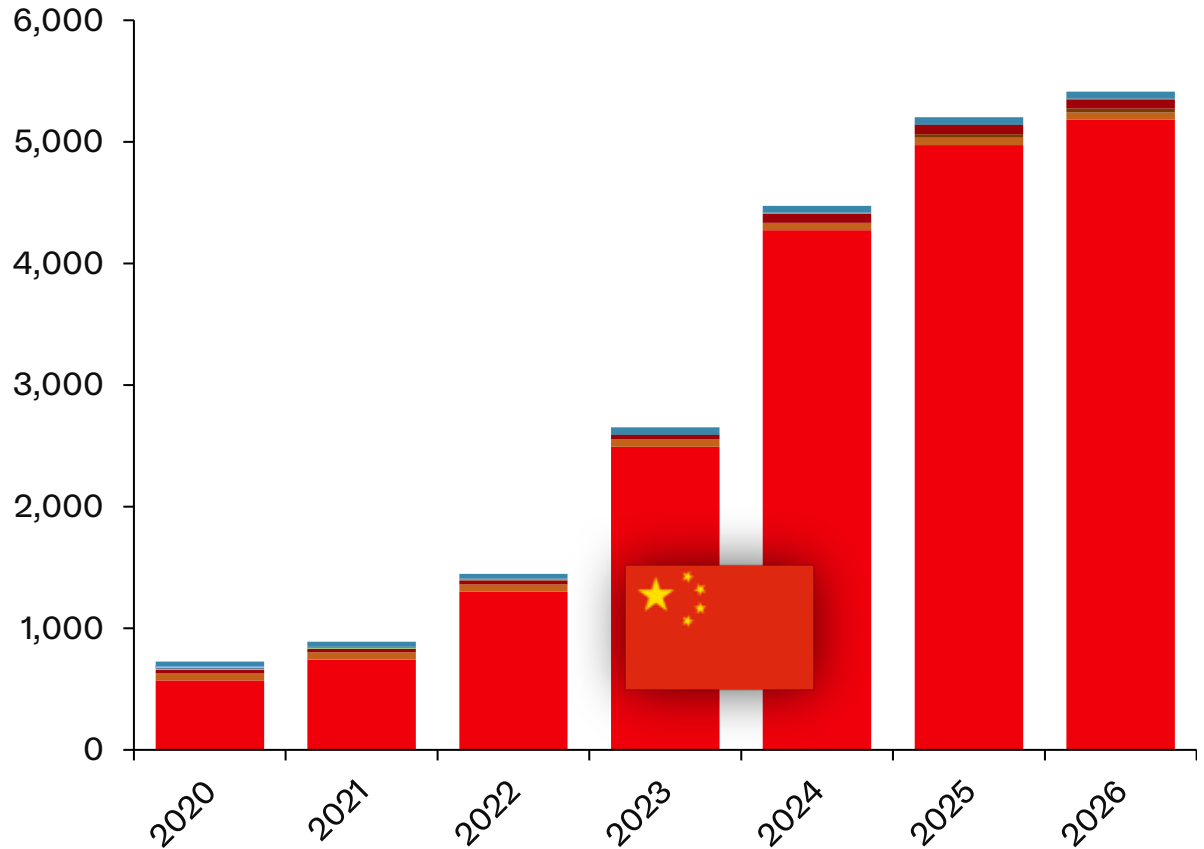


Source: Rystad Energy SolarCube

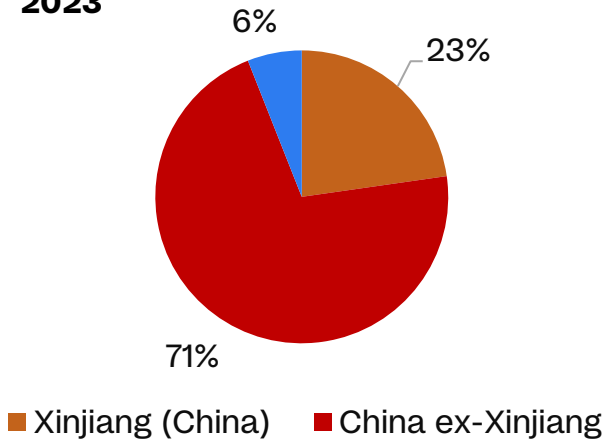
# Polysilicon manufacturing capacity

## Global polysilicon manufacturing capacity, 2020-2026

Thousand tonnes



## Global manufacturing capacity share, 2023



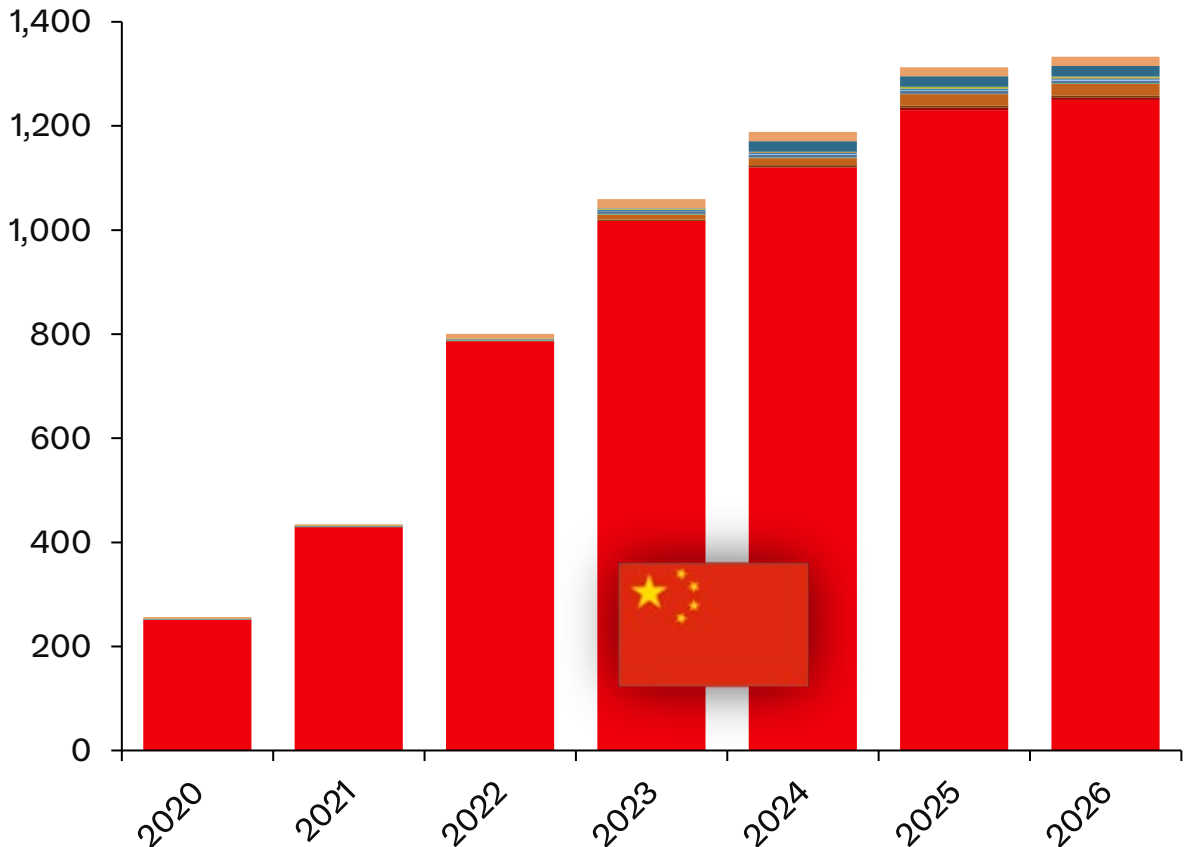
China has further cemented its position as the world's dominant producer of solar-grade polysilicon. Major capacity ramp-ups have been undertaken following supply shortages in 2021 and 2022. As a result, China is expected to hold a 94% share of global production capacity by the end of 2023. By contrast, Europe, Malaysia and the US combined account for about 5% of global production.

Source: Rystad Energy SolarCube

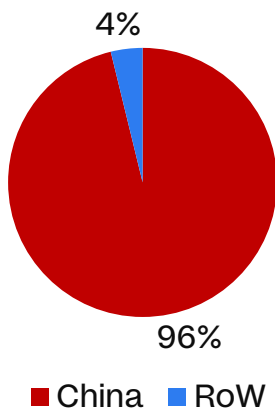
# Wafer manufacturing capacity

## Global wafer manufacturing capacity, 2020-2026

Gigawatts DC (GW<sub>DC</sub>)



## Global manufacturing capacity share, 2023



Despite a growing number of countries around the world now manufacturing their own modules and cells, nearly all ingot and wafer production is still undertaken in China as of May 2023.

By end-2023, China is expected to hold a 96% share of global wafer production.

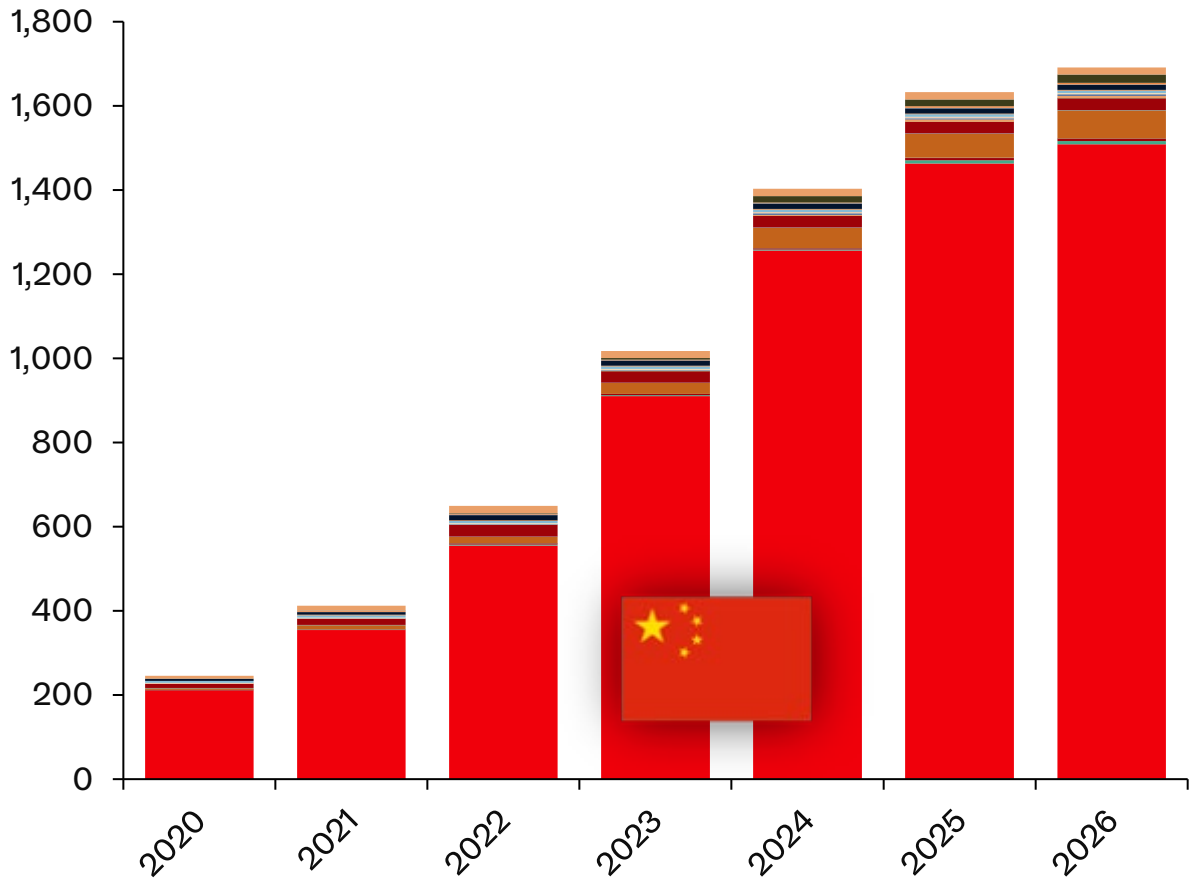
Source: Rystad Energy SolarCube



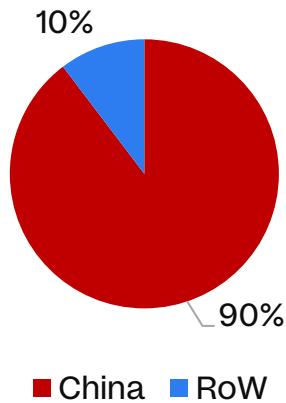
# Solar cell manufacturing capacity

## Global solar cell manufacturing capacity, 2020-2026

Gigawatts DC (GW<sub>DC</sub>)



## Global manufacturing capacity share, 2023



Global solar cell supply has undergone rapid expansion and seen low utilization rates in recent years.

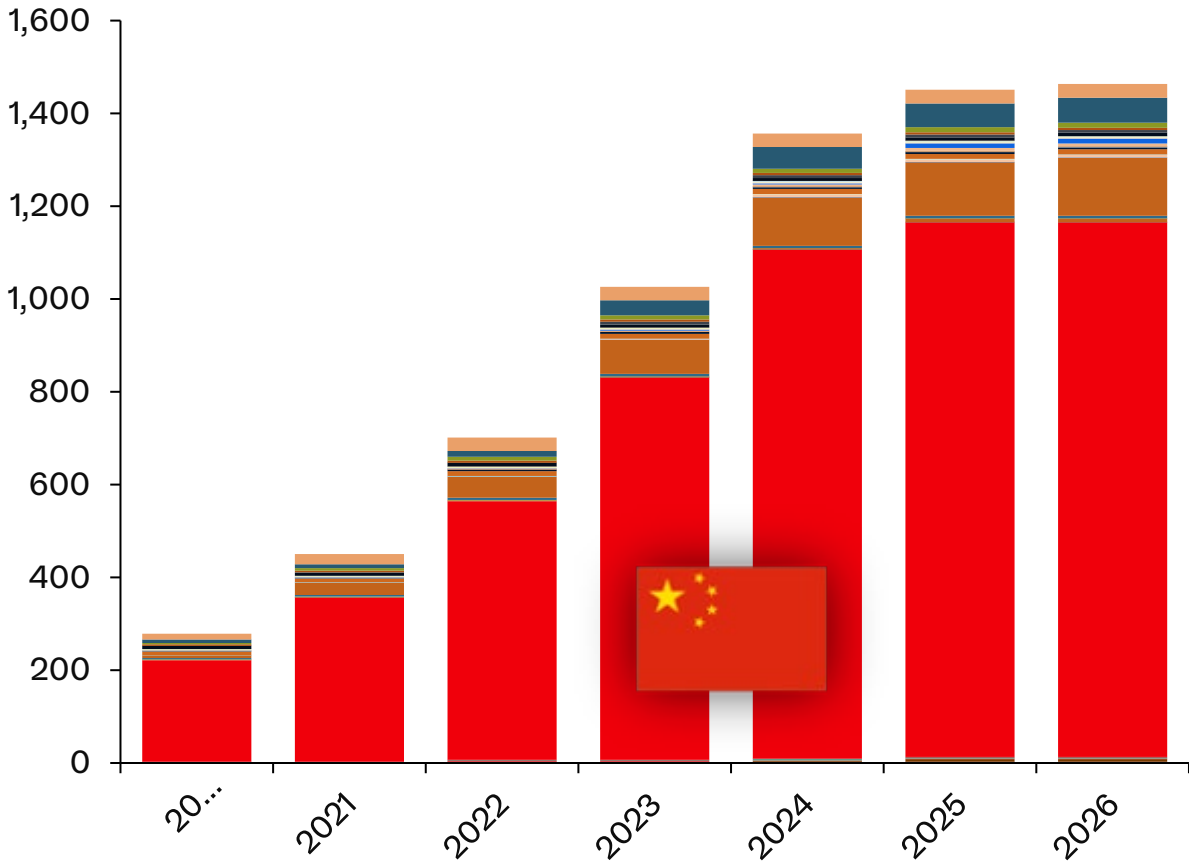
In terms of geographical location, China dominates the industry and is forecast to hold a 90% share of cell manufacturing capacity by end-2023.

Source: Rystad Energy SolarCube

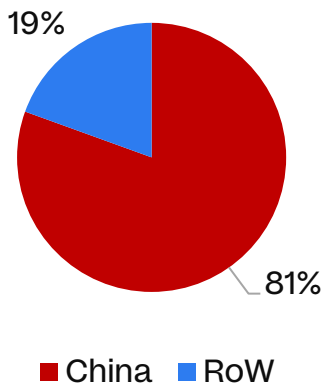
# Solar module manufacturing capacity

## Global solar module manufacturing capacity, 2020-2026

Gigawatts DC (GW<sub>DC</sub>)



## Global manufacturing capacity share, 2023



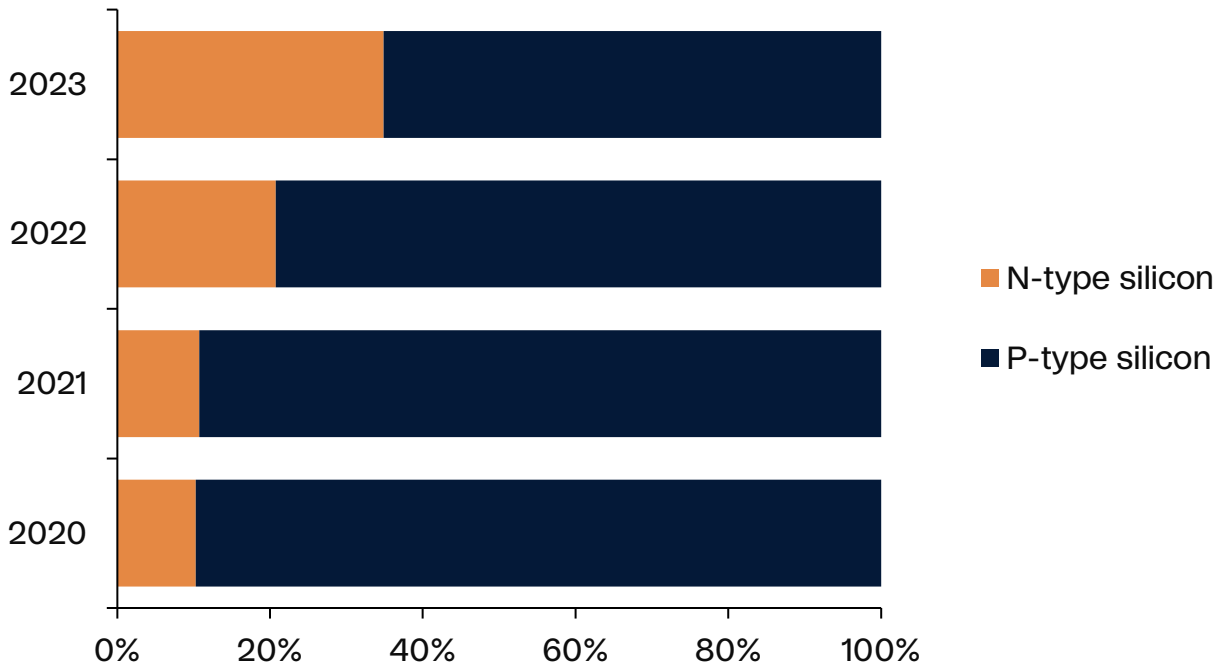
With India, Europe and the US trying to onshore the solar supply chain with generous production incentives, module manufacturing capacities outside of mainland China are rapidly increasing.

China is still set to be the largest player by the end of 2023, with a forecasted market share of 81% of global production capacity.

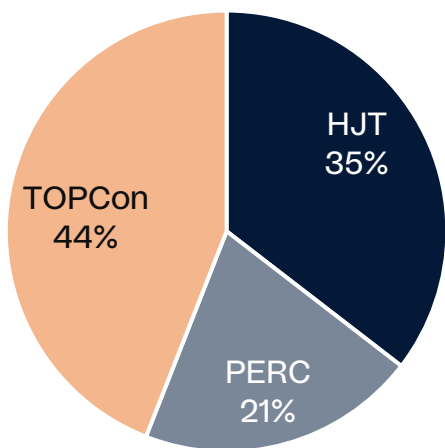
Source: Rystad Energy SolarCube

# Solar PV cell technologies

**Solar PV cell technologies by silicon type, 2020-2023**  
Percentage share (%)



**Cell technology share, 2023**



With the transition into newer cell technologies such as heterojunction (HJT) and TOPCon, the market share of n-type silicon used in the production of solar cells is expected to increase in the next few years.

Manufacturers are also seeing efficiency gains from utilizing n-type silicon which is not affected by light-induced degradation.

Almost 80% of cell manufacturing projects starting up in 2023 will use either TOPCon or HJT cell technology.

Source: Rystad Energy SolarCube

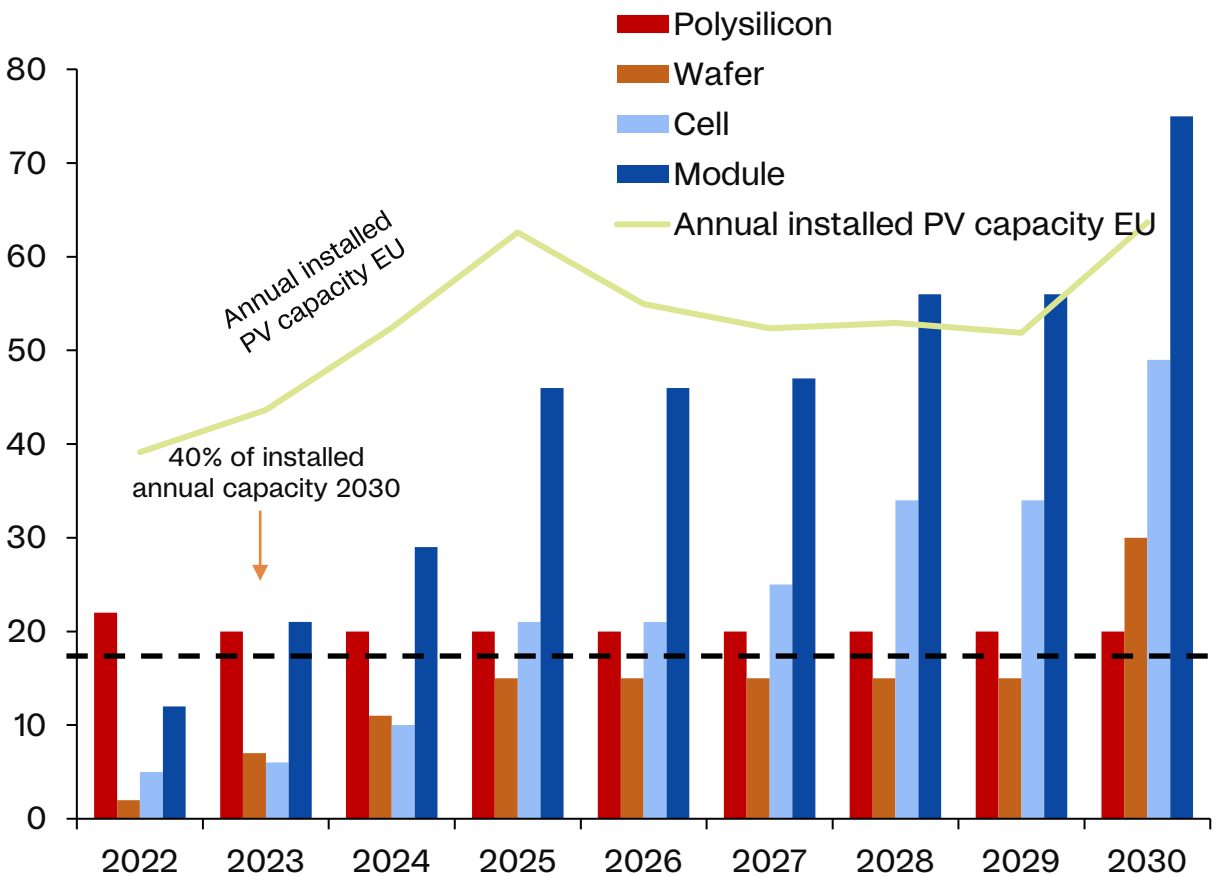
# Impacts of the EU Green Deal

The EU’s Green Deal Industrial Plan aims to boost the competitiveness of Europe’s net-zero industry, providing a supportive environment for scaling up solar PV manufacturing. Current goals include ensuring that 40% of solar panels are made within the EU by 2030. While Europe currently has manufacturing capacity across all aspects of the solar panel value chain, these will need to be scaled up. While manufacturing capacity for wafers, cells and modules is set to expand

significantly in the coming few years, Europe is the only region without polysilicon manufacturing capacity following the closure of the REC production plant in Norway last year.

The EU has also fallen behind in providing well-defined incentives for domestic manufacturing, leading to cancelled projects in the region and companies moving investments to the US in response to incentives under the Inflation Reduction Act (IRA).

**Europe manufacturing capacity: commodity vs demand, 2022-2030**  
Gigawatts DC (GW<sub>DC</sub>)



Source: Rystad Energy SolarCube

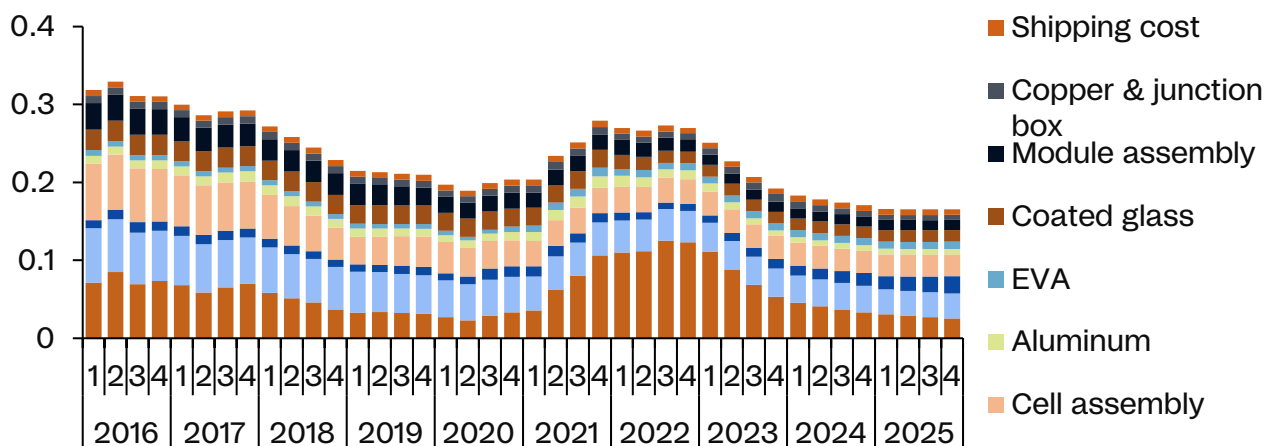
# Regional panel prices, manufacturing costs

Polysilicon prices hit a turning point in 4Q22 with supply catching up to demand. Other commodities along the value chain followed suit in the beginning of 2023 with module prices in the Chinese market stabilizing around \$0.22/watt after the Lunar New Year. Module prices are expected to continue falling as polysilicon prices approach pre-pandemic levels.

Markets that rely heavily on imports from China, such as Europe and Australia, saw elevated module prices fall in late-2022. Module prices in other countries such as the US and India remain high as supply backlog issues and commodity tariffs persist. European and Chinese module spot prices remain tightly connected, but relatively decoupled from US prices.

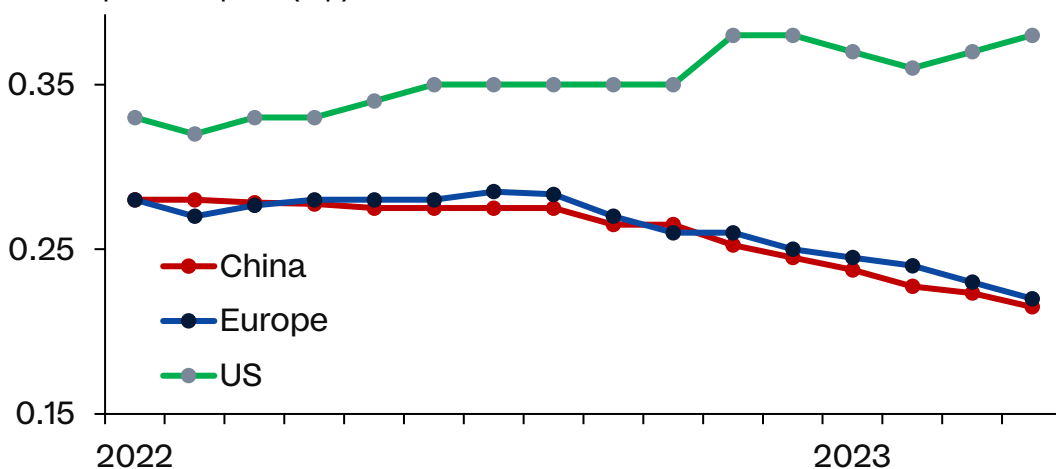
## M10 PERC module manufacturing costs in China

USD per watt-peak (Wp)



## M10 PERC module spot prices in the US, Europe and China, 2022-2023

USD per watt-peak (Wp)



Source: Rystad Energy SolarCube

# Solar PV system costs by system size

To date, 2023 has been dominated by the rising cost of solar PV projects significantly increasing the costs of project installations. Although module prices have stabilized near 2019 levels, other costs related to balance of system and engineering procurement and construction (EPC) have increased.

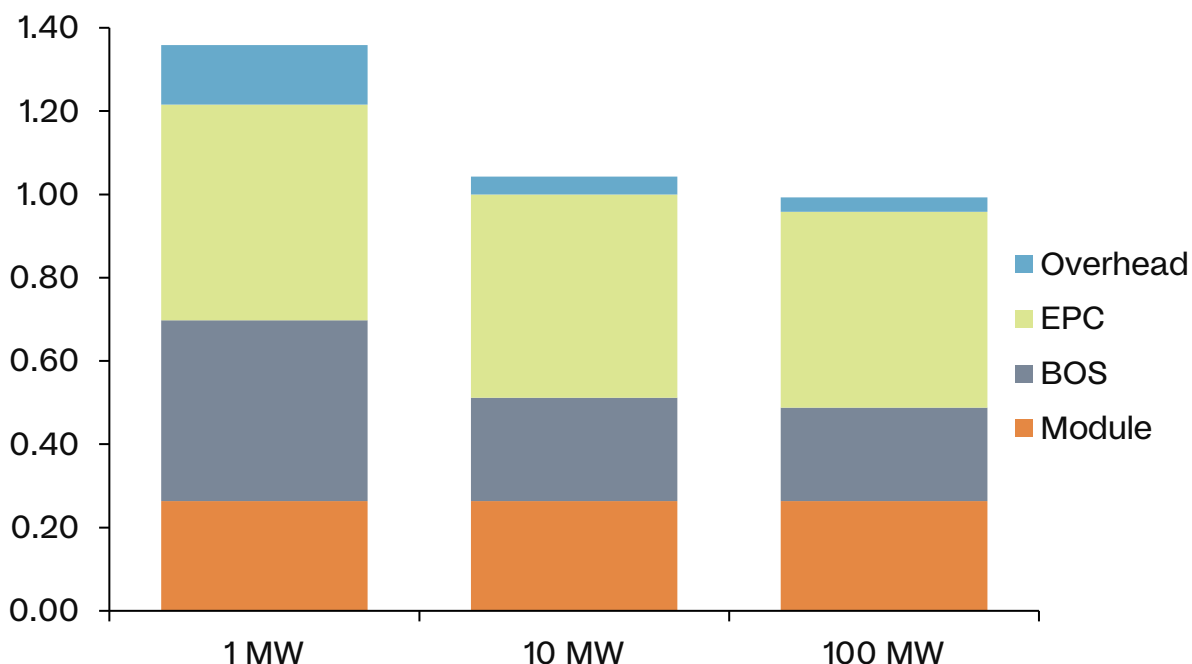
Larger project sizes can, however, benefit from certain economies of scale associated with system installation. On a per watt-peak (Wp) basis, cost reductions can be expected from standardised set-ups of racking and mounting systems, as well as fixed

costs such as installation equipment and permitting distributed over larger system sizes. Other balance-of-system costs can expect reductions as different types of equipment are chosen. For example, the cost of balance-of-system components such as inverters will reduce as central inverters are chosen over string inverters.

Lastly, as system set-ups become increasingly simplified with larger project sizes, installation costs are expected to decrease as the difficulty of installation reduces.

## European project costs by system size

2023: USD per watt-peak (Wp)



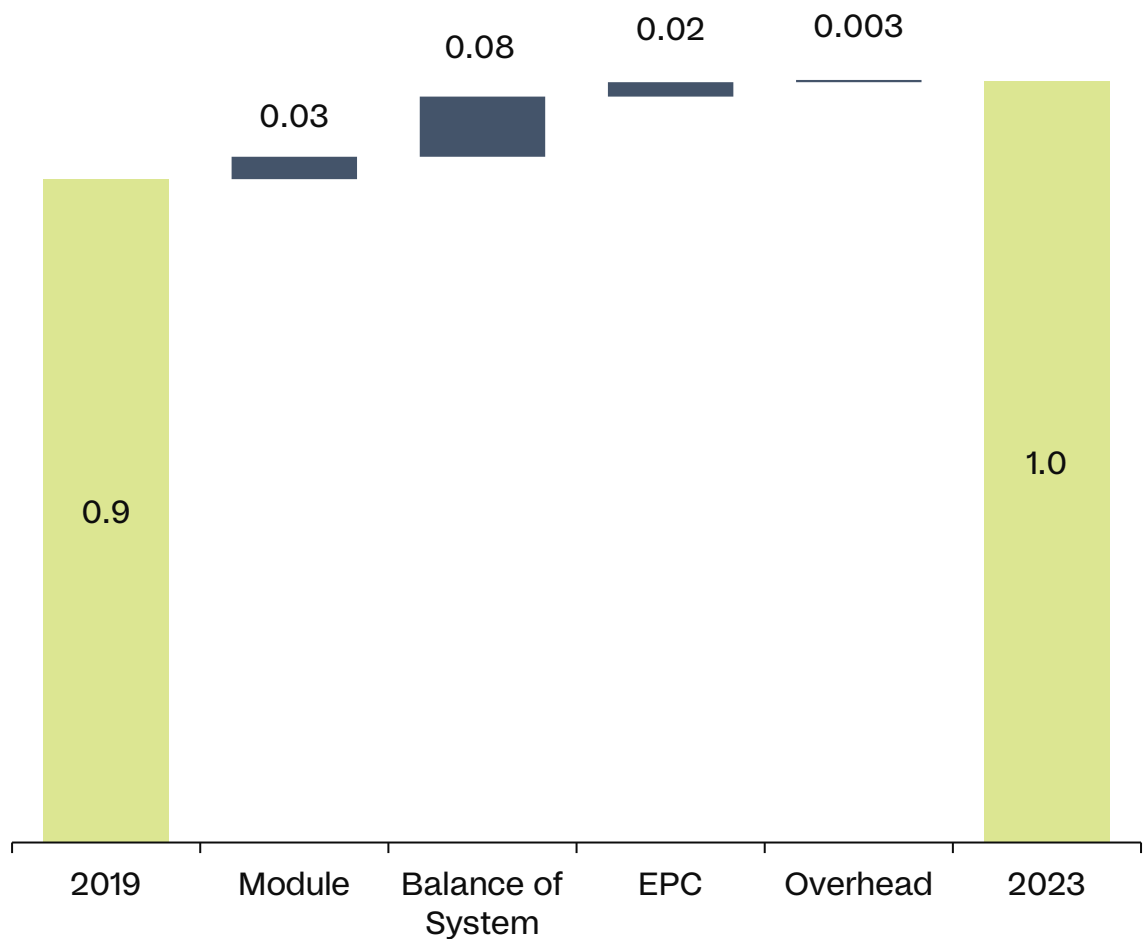
Source: Rystad Energy Cost Estimating Solution – Low Carbon, May 2023

# Solar PV project costs increased by 15% between 2019 and 2023

The cost of European solar PV projects significantly increased between 2019 and 2023. This was largely due to the cost of modules, balance-of-system components and labor which contributed to a 15% increase as service price inflation rose in most segments.

## Impact of service price inflation on project costs

USD per watt-peak (Wp)



\*Based on a 100 MW project in Germany

Source: Rystad Energy Cost Estimating Solution - Low Carbon, May 2023

# Dependence on Chinese module exports

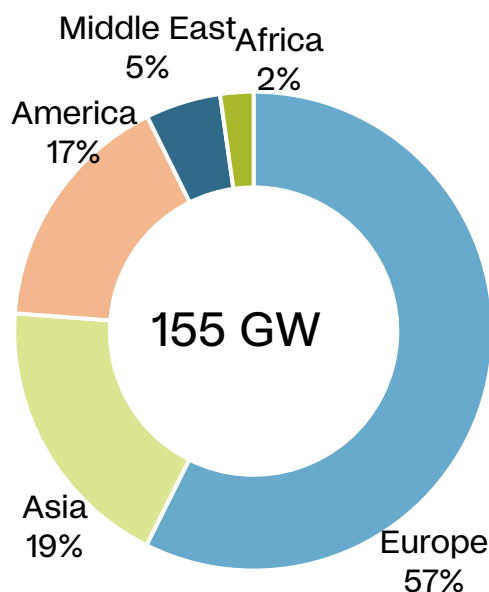
From 2019-23, module prices rose by 14% on average, with some as high as 30% last year, before beginning to stabilize in early 2023.

As polysilicon prices surged due to Covid-19-related shutdowns in China which limited manufacturing output, module prices followed suit.

Although Europe has some domestic manufacturing capacity, its capacity for manufacturing cell and wafers has historically been limited, resulting in dependence on imported modules from China and Southeast Asia.

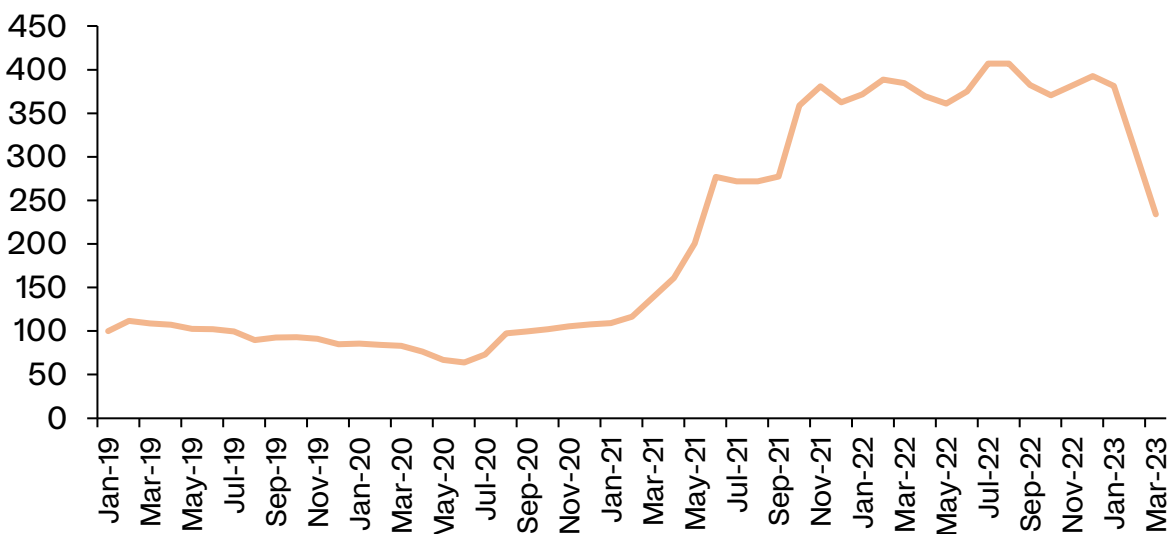
From 2021-22, module exports from China to Europe increased by 110% from 41 GW to 87 GW, making Europe the largest importer of Chinese modules, and ultimately exposing European players to the risks associated with spikes in Chinese polysilicon prices.

**Chinese module exports by region, 2022**



## Chinese polysilicon price movements

indexed to 2019 = 100



Source: Rystad Energy Solar Supplier Analysis, Rystad Energy research and analysis; May 2023



# Rising raw material prices, higher wages putting pressure on project costs

Balance-of-system costs, such as mounting structures, cabling and inverters, also increased significantly during the 2019-23 period.

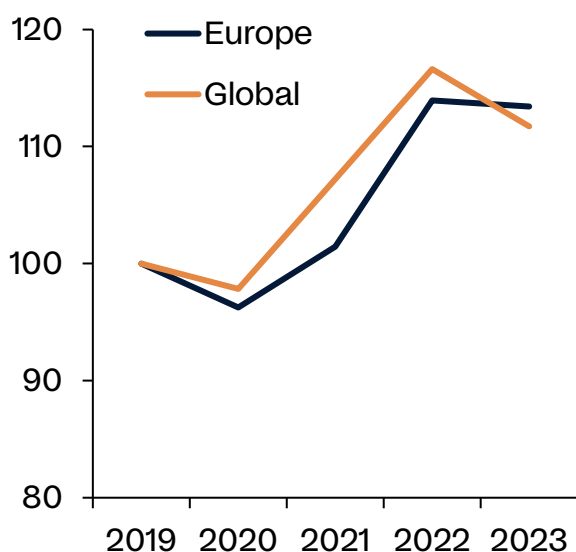
This can largely be attributed to spikes in key raw material prices for steel and copper, which inflated by 27% and 34% respectively between 2019 and now. Prices have since begun to stabilize, albeit at higher levels.

The construction of solar PV projects is a labor-intensive process that requires an array of different skilled personnel. Construction workers, engineers, electricians, machine operators, as well as white-collar workers are required to set up an asset.

Many such workers have seen wages rise rapidly from 2019-23, with engineering wages leading the way at a 7% average increase over the period.

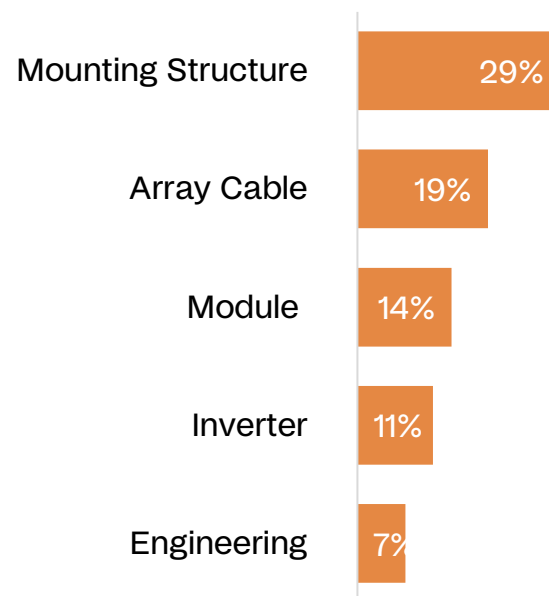
## Service price inflation

Indexed to 2019 = 100



## Underlying cost drivers

EU, 2019-2023



Source: Rystad Energy Price Inflation Solution - Low Carbon, May 2023

# Solar PV price inflation is expected to fall towards pre-pandemic levels by 2025

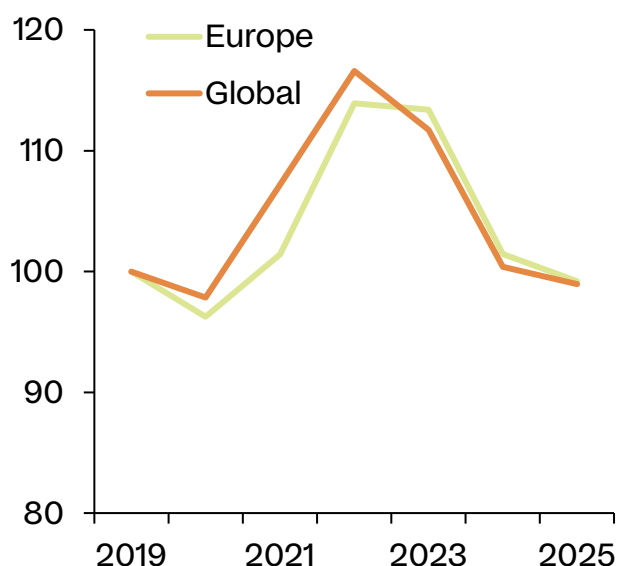
Up to 2025, European solar projects are likely to see reduced costs as service price inflation decreases towards 2019 levels. As more Chinese polysilicon, cell and wafer supply is onshored, module prices are likely to fall by at least 25% with Europe expected to continue depending on Chinese module imports. Prices for key raw materials such as aluminium, steel and copper are expected to decrease, which may help stabilize prices for key balance-of-system components such as mounting structures and cables.

Supply chain bottlenecks associated with increasing lead times for inverters are also expected to ease, leading to inverter prices lowering from 2023 onwards as more supply is onshored.

Lastly, increased average project sizes will contribute to boost economies of scale, helping reduce the costs of labor-intensive segments as ease of installation increases with more standardised systems.

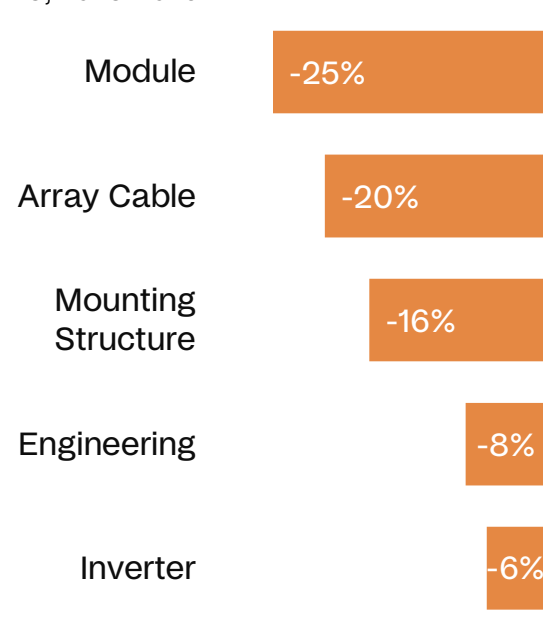
## Service price inflation

Indexed to 2019 = 100



## Underlying cost drivers

EU, 2023-2025



Source: Rystad Energy Price Inflation Solution – Low Carbon, May 2023

## Would you like to learn more?

Rystad Energy's **Solar Solution** provides in-depth analyses of the solar market on different levels, from utility-scale through commercial and industrial to rooftop installations, and a complete overview of supply and demand for key raw materials.

If you would like to discuss any topics covered in the whitepaper or learn more about all features of our **Solar Solution**, scan the QR code to book a meeting with one of our experts, or contact Anja Gudbrandsen directly.



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