Building a competitive solar-PV supply chain in Europe

December 13, 2022 | Report

Can European businesses achieve a competitive position in the global solar-PV supply chain and strengthen Europe's energy transition and resilience? It's challenging but a potential pathway exists.

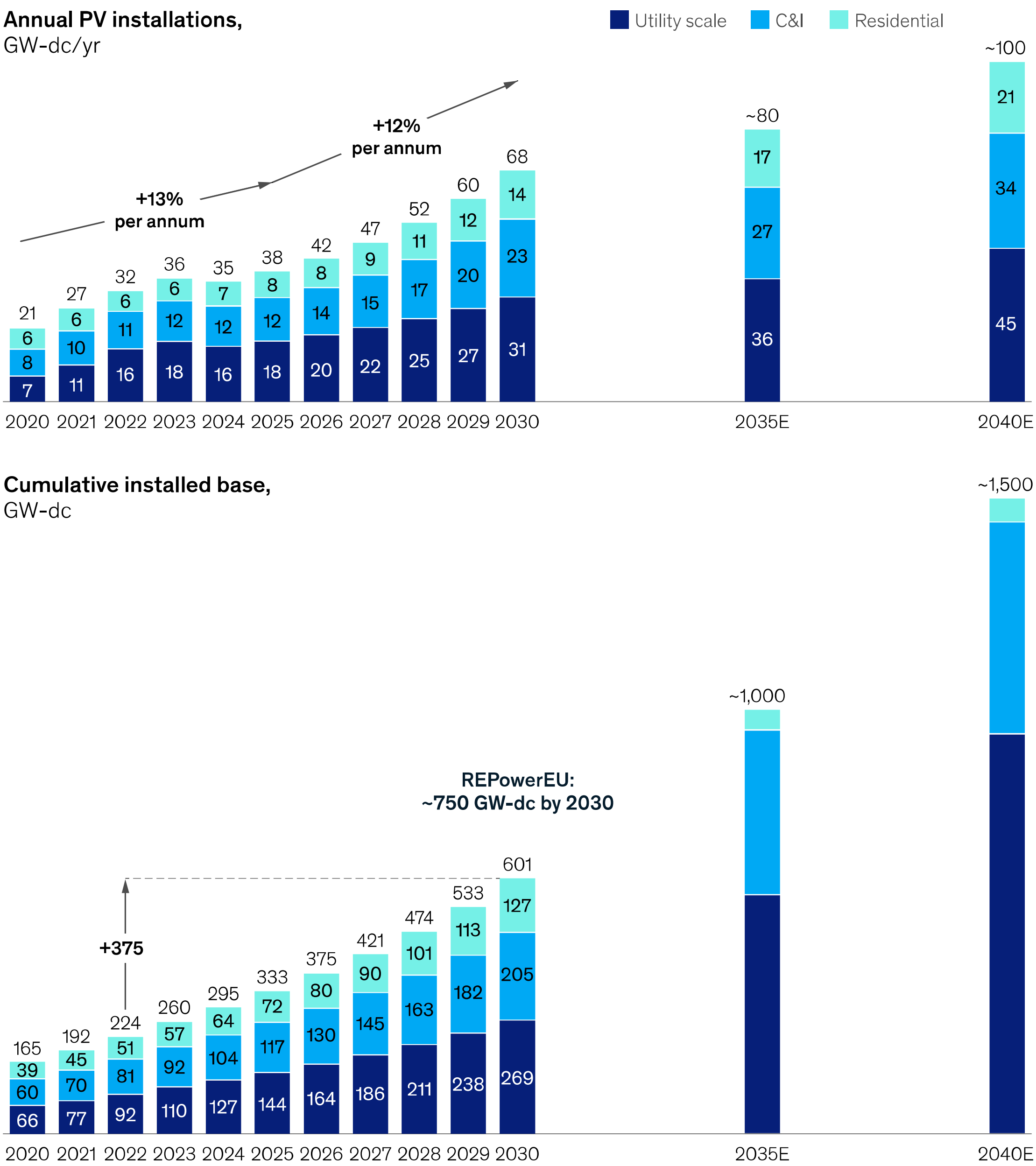
Europe has committed to being a climate-neutral society by 2050.[1] This is an ambitious target, which has been complicated by the energy crisis and the Ukraine conflict, as well as efforts to replace the import of Russian gas.

Europe is planning a major ramp-up of solar-photovoltaic (PV)-based electricity to address its energy challenges, which include meeting its climate ambitions, managing a large part of its electrification, decarbonizing the electricity grid, and becoming less reliant on others. As part of its "EU solar energy strategy," the region has announced a 750 GWDC target of installed solar-PV capacity by 2030—up from 224 GW of installed capacity in 2022 (Exhibit 1). This represents a considerable step up in annual installations, going from some 26 GW in 2021 to around 70 GW a year in the second half of this decade. Germany alone aims to install 215 GW by 2030, adding

160 GW of new capacity on top of the current 58 GW, almost scaling the market by a factor of four.[2]

Exhibit 1

Europe is a major solar market with increasing step-up ambitions toward 2030.



Source: : "EU solar energy strategy," Bloomberg; "REPower EU with solar: The 1TW EU solar pathway," SolarPower Europe, March 8, 2022; McKinsey analysis

McKinsey & Company

With these ambitions in place, Europe would maintain its position as one of the major solar-PV markets in the world, alongside China, India, and the United States.

Europe's supply challenge: It's all imported

This ambition faces a potential supply resilience risk: Europe currently relies almost entirely on imports from one country for the solar PV panels it needs. China dominates the solar-PV supply chain with almost 95 percent of the world's wafer production (Exhibit 2). It is home to the top five companies across each step of the value chain, except Germany's Wacker Chemie EG in PV grade polysilicon. [3]

Exhibit 2

Chinese solar companies have leading large-scale positions and share of market across the entire value chain.

	Solar polysilicon	Ingot and wafer	Solar cell	Solar module
Share of global capacity per region, 2020, % — Rest of world	21	5	24	32
Share of global capacity per region, 2020, % — Greater China region	79	95	76	68
Industry capacity	**~210 GW**	**~300 GW**	**~270 GW**	**~250 GW**
Share of top five manufacturers	**~64%**	**~92%**	**~70%**	**~78%**

Source: "Solar manufacturers 2019 production," BNEF, May 27, 2020; "PV supply chain tracker Q2 2020," IHS Markit, 2020; "PV installations tracker Q3, 2020," IHS Markit, 2020

McKinsey & Company

China's solar-PV industry's scale-up has been rapid—from zero to 300 GW capacity in some 15 years.[4] While European companies initially led the industry, Chinese solar-PV companies, in many regards, today dominate both manufacturing at scale and deploying new technologies, supporting major solar-PV ecosystems built around industry hubs. Specialized companies deliver everything from ingot pullers to diamond wire saws and solar PV glass to aluminum frames. In this way, the Chinese solar-PV industry has made the technology the cheapest renewable energy source in many markets.[5] Prior to recent price increases (due to the effects of the COVID-19 pandemic and supply-chain bottlenecks), the price of solar PV only went one way—down. The levelized cost of energy (LCOE), a measure for the lifetime cost of solar PV including both capital and operating expenditure, has fallen some 80 percent since 2010.[6]

While European markets have enjoyed the benefits of falling solar-PV costs, the geopolitical context is evolving. The Ukraine conflict has exposed the risk of relying on imports for critical energy, and Europe is becoming increasingly sensitive to the potential supply-chain risks for solar-PV products. Labor concerns in the production of polysilicon have created additional worries for European customers, particularly with regard to ESG and human rights' issues.

In response to these rising challenges, the EU has begun its solar-PV strategy to reestablish a viable PV manufacturing industry, with the EU's Energy Commissioner stating that the EU will do "whatever it takes" to succeed.[7] In light of this, the Commission formally launched the Solar Photovoltaic Industry Alliance in December 2022 to develop a European solar-PV ecosystem that will secure and diversify supplies of solar PV products. The EU has already defined a target of 30 GW a year of PV manufacturing across the entire supply chain by 2025.[8]

But, in reality, what will this take—and can European companies really be competitive with the industry leaders?

European companies are starting to respond

Although it is currently small, the European solar PV industry does not have to start entirely from scratch (Exhibit 3). Europe has some 6 to 8 GW of module capacity, and approximately 1 GW of cell and 2 GW of wafer capacity—however, this is still less than 1 percent of global capacity.[9] Wacker in Germany is the only European top-five global company with approximately 20 GW of polysilicon production in Europe.[10]

Exhibit 3

European companies have announced expansion plans of around 20 GW, but with uncertainty and modest scale.

On par | Lagging | Current market share | Expected market share by 2025

	Solar polysilicon	Ingot and wafer	Solar cell	Solar module
Expertise	On par	Lagging	On par	Lagging
Market share	~11% / ~12%	~1% / ~4%	<1% / ~4%	~3% / ~5%
Expansion projects until 2025—scale-ups	Wacker: 53 GW by 2025 (+25.4)	NorSun (Ingots and wafer): 5 GW by 2025 (+4) Norweigan Crystal (Ingots): 4.1 GW by 2025 (+3.6) Nexwafe (Wafers): 3 GW by 2025 (+2.8)	Meyer Burger: 4.2 GW by 2025 (+3.8) Enel: 3 GW by 2024 (+2.8) Oxford PV: 2 GW by 2024 (+1.8) Valoe: 0.1 GW by 2024 (+0.1)	Meyer Burger: 4.1 GW by 2025 (+3.8) Enel: 3 GW by 2024 (+2.8) Oxford PV: 2 GW by 2024 (+1.8) Voltec Solar: 0.5 GW by 2023 (+0.3) SoliTek: 0.6 GW by 2023/2024 (+0.4) SolarWatt: 2 GW by 2023 (+1.7) FuturaSun: 1 GW by 2023 (+1)
Expansion projects until 2025—start-ups		CARBON (Ingots and wafers): 5 GW by 2025 (+5) Astrasun Solar (Ingots and wafers): 1.8 GW by 2025 (+1.8)	CARBON: 5 GW by 2025 (+5) Astrasun Solar: 1.8 GW by 2025 (+1.8) MCPV: 5+ GW by 2025 (+5)	CARBON: 3.5 GW by 2025 (+3.5) Astrasun Solar: 3.5 GW by 2025 (+3.5) MCPV: 5+ GW by 2025 (+5)
Total announced	~30 GW	~15–20 GW	~20 GW	~20 GW
Capex needs	~€3bn / ~€120m/GW	~€0.8bn / ~€55m/GW	~€1.7bn / ~€85m/GW	~€1.9bn / ~€80m/GW

Source: Fraunhofer Institute for Solar Energy Systems IES; Intersolar Europe, 2022

McKinsey & Company

Many European companies have started ramping up or have expansion plans in motion. In Turkey, Kalyon PV has boosted its 1.2 GW integrated ingot-to-module facility.[11] In Sicily, Enel's 3Sun is building a 3 GW facility that will produce heterojunction (HJT) cell technology modules and, over time, tandem cells (traditional polysilicon-based PV cells coupled with so-called perovskite solar-PV cells), with a roadmap to more than 30 percent cell efficiency.[12] Similarly, Meyer Burger in Switzerland, the former equipment manufacturer, is aiming for 4.2 GW by 2025 (also using HJT cell technology), and Norwegian ingot and wafer producers, NorSun and Norwegian Crystals, plan around 4 GW new capacity.[13] New technology companies like Nexwafe and Oxford PV also aim to have GW-sized capacities by 2024 to 2025.

So far there are few current Chinese solar PV companies that have decided to establish manufacturing in Europe—Chinese leading companies would likely consider doing so if it supported their market positions. These companies would bring both capabilities and already-scaled production systems. However, given the strong platforms in China, they may enter with a minimal approach, limiting European production to modules, or cells and modules, and source as much as possible from their existing Chinese-supplier networks. Further, given their limited experience in building and operating factories in Europe, they may look for European partners and also face many of the same scaling and ramp-up challenges as European companies do.

A path to competitiveness

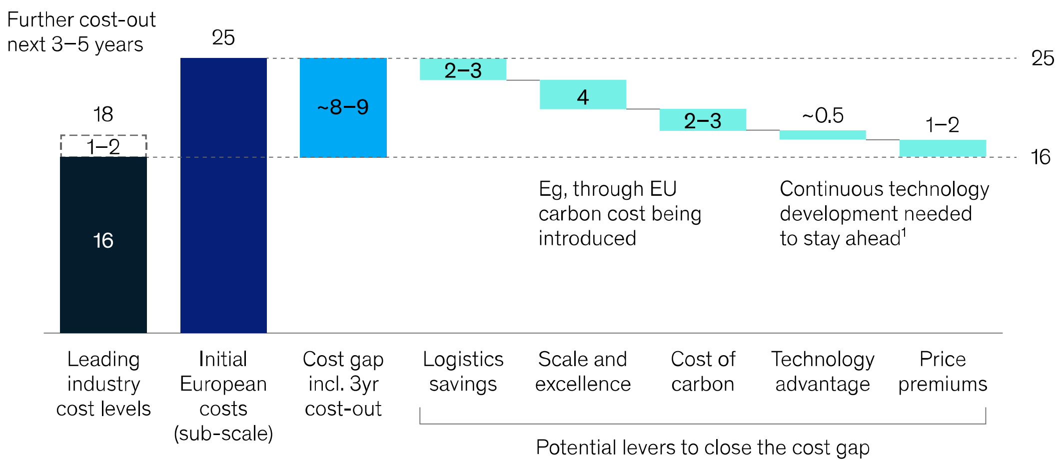
Our analysis suggests that the costs of solar-PV manufacturing in Europe at scale for the full value chain will be at a 20 to 25 percent disadvantage against current lowest cost levels—if scale and excellence effects have been achieved. When assuming that large scale is achieved, European companies will still be structurally disadvantaged by higher labor, material, utilities, and capital costs. This is based on the cost of power before the price hikes that European industrial players have experienced over the past year—this means that the current power prices in Europe further lower their cost competitiveness, especially in the energy-intensive upstream parts of the value chain.

However, there are several factors that point to a potential path to competitiveness for leading European solar-PV companies (Exhibit 4).

Exhibit 4

There is a potential pathway to competitiveness for ambitious European companies, with scale and excellence as the main drivers.

Manufacturing costs comparison in EU and imported from China, $c/W



[1]~0.5–1.0% higher cell efficiency leads to ~0.5–1.0c/W cost advantage.
Source: BNEF; DP World; Eurostat; Fraunhofer IES; NREL; Our World in Data; RCT Solutions; Trading Economics

McKinsey & Company

Scale and excellence: European companies (or companies that are setting up manufacturing capacity in Europe) will only succeed if they are able to grow fast to reach large scale, while at the same time being highly stringent in capital and operational excellence. While pinpointing exact scale thresholds is difficult, on plant level we observe that leading players typically have 3 to 5 GW at cell and module level, and around 10 GW for ingot and wafer, and polysilicon.[14] The scale levels have consistently increased over time as the industry has matured. Further, the leading players have production systems consisting of close to 100 GW capacity on company level, and operate more than ten plants across their production systems.[15] In short, without large scale, European players will have a hard time to succeed in being competitive. Our analysis show that around half the initial cost gap (about 4 c/W) to Chinese companies will depend on reaching sufficient scale.

A key factor in scaling the industry is also to build a viable ecosystem of suppliers and equipment providers. Without sufficient scale, the industry will not spur the necessary investments and competition among sub-suppliers and technology partners.

Similarly, leading players will need to have laser-sharp focus to ensure cost out and implement continual improvements to build viable long-term competitiveness. This includes higher levels of automation and building a competitive supplier network that shares the same commitment to aggressive scaling and cost competitiveness.

Deployment of leading technology: European players could enhance their competitiveness by being early adopters of new technologies. Most importantly, higher cell efficiencies and more power per module could drive down the cost per watt correspondingly. And, as many cost drivers are linked to units produced, higher efficient cells will lower the structural cost disadvantages that European companies face—Enel and Meyer Burger are already leading the way to implement HJT and also develop tandem cell technologies.[16] In addition, European companies have the opportunity to be leaders in implementing new production processes and product technologies and, in this way, will likely build long-term competitiveness. However, as the ramp-up is needed on relatively short notice, it is unlikely that next generation technologies alone will close the gap.

Consumers' willingness to pay: European customers will, to some degree, likely be prepared to pay a premium for European-made panels. From interviews conducted over the last six months and from comparing prices, customers show a willingness to pay 10 to 20 percent premiums for European-made products with full traceability. Statements from industry leaders include, "There is a premium for better ESG. We have seen players pay 2 to 3 c/Wp." And, "If European players can offer PV modules with good warranties, a lower carbon footprint, and delivery security, I think that utilities would pay about a $2 c/Wp premium."

In future, this trend is likely only to strengthen. As one expert put it, "The importance of ESG is picking up, especially when banks are involved. There is a cost difference in complete ESG transparency of 1.3 to 1.5 c/Wp." Successful European companies will need to build quality products with strong brand positions for which customers are willing to pay premium prices. These companies could develop compelling value propositions that include sustainability and low-carbon footprint, full value-chain traceability, as well as excellent product quality, output performance, and bankability. Further, as the costs of solar PV have come down as far as they have, the marginal extra cost of paying a premium will, for many customers, be secondary to other purchasing factors. However, energy-intensive players, especially large ones, will still potentially be sensitive to these smaller differences, which emphasizes the need to close the structural gap as much as possible.

The cost of carbon: European companies can achieve a lower embedded carbon footprint than the current supply chain—around 40 percent lower in the EU compared to modules produced in China. [17] Europe is in the process of implementing carbon border mechanisms to avoid carbon leakage, as well as considering carbon contracts for difference. Assuming a carbon price range of $60-90 per ton and 330kg CO_2 equivalent per kilowatt peak lower emissions for an EU made panel, the impact would be 2.0 to 3.0 c/W, with potential higher range impact in markets with CO_2-linked incentives like France.

These levers point to a potential pathway toward competitiveness for European businesses with the right approach and mindset. Yet, while the direction of the pathway is clear, there are multiple challenges to overcome. Rebuilding an end-to-end European supply chain including material suppliers and equipment providers will not be easy (Exhibit 5). Module manufacturers will likely be hard pressed to find capable and cost-competitive regional suppliers of glass, backsheets, junction boxes, and frames—at least in the near term. Similarly, finding European manufacturing equipment suppliers and technology partners is possible but will require additional effort to scale and higher initial costs as the industry is currently sub-scale. For ingot and wafer, the dependency on non-European supply is even more pronounced, and key components such as ingot pullers and suppliers of crucibles, hot zones, and diamond wire saws are today entirely sourced from Asia. Any fast scaling of a European industry, by necessity, requires close collaboration with global suppliers.

Exhibit 5

European companies rely on imported materials and components, especially ingot, wafer slicing, and module components.

Availability of key production materials/components

Availability in Europe
Good Medium Challenged

	Solar polysilicon	Ingot and wafer	Solar cell	Solar module
Availability of key production materials/ compo-nents	MG Silicon TCS/silane gas	Hot zones Crucibles Argon Chemicals Diamond wire consumables Slurry component Wafer production	Silver paste Aluminum paste Anti-reflection coating Doping chemicals, deposition gases	Aluminum Glass Backsheet Junction box EVA POE
Rationale	**No open market for TCS/silane gas** at large volumes, requires dedicated integrated production capacity MG Silicon more readily available including in Europe	**Hot zone** materials currently produced predominately in China with long lead times (baking time to customer recipe) **Crucibles** at competitive cost predominantly supplied from China Diamond wire produced in China Gases/chemicals typically more global markets	Relatively **standard products** available	**Chinese-dominated supply of glass** with spe-cialized PV glass sites at large volumes—lack of European supplier at scale/cost Backsheet and junction boxes **not available in Europe at competitive costs;** need to be sourced from China

Source: McKinsey analysis

McKinsey & Company

A level playing field in an uneven world

As European companies look to invest in rebuilding solar-PV manufacturing, the market design and framework within which it can operate is vital. Indeed, the market design is evolving fast in other regions. There are significant structural differences between the key solar-PV regions—China, Europe, India, and the United States. In particular, the United States recently passed the Inflation Reduction Act (IRA) in August 2022, which includes tax incentives for solar-panel manufacturers.[18]

This United States support scheme is focused on encouraging investment in new solar-PV manufacturing capacity. On a fully localized basis (the IRA plus other local incentive programs), the direct production support is around 12 to 20 c/W until 2030, after which it reduces by 25 percent per year—in other words, federal government covers a large share of the cost, and will hypothetically make the US the cheapest cost region for solar PV in the world. In addition, the United States already puts import tariffs on cells and modules made in China, and partially extended these in December 2022 to manufacturing hubs in Cambodia, Malaysia, Thailand, and Vietnam to select suppliers. The United States is also considering extending these tariffs to put special duties on the import of Chinese wafers—alongside the existing rules that ban the import of Chinese forced-labor products, which are already creating high barriers for Chinese solar-PV companies to sell in the United States.

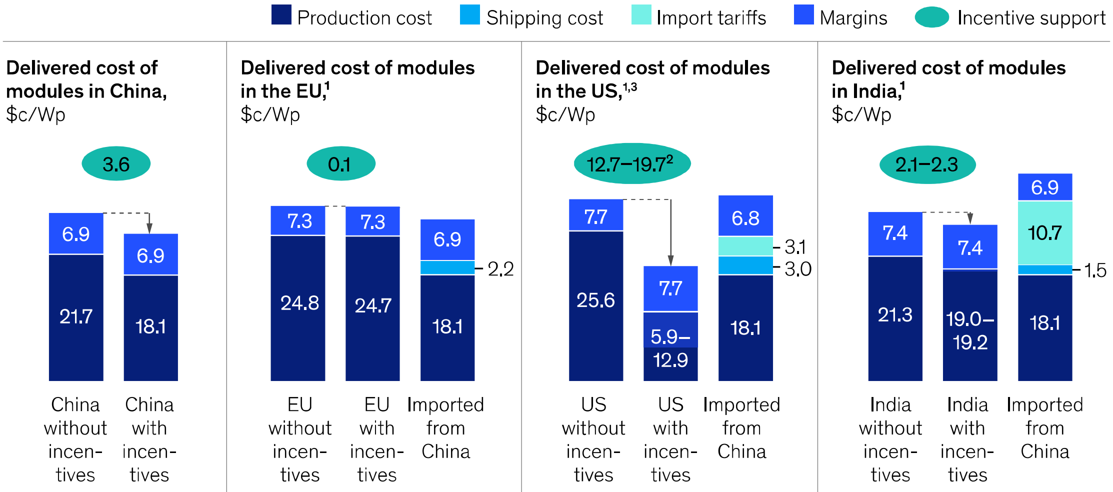
The overall effect of these measures has been immediate, with more than 30 GW of new capacity revealed across more than ten new announcements in the short time since the IRA was passed.[19]

In Europe, the EU Innovation Fund and regional programs can provide grants and recently reopened for bids to allocate €25 billion toward 2030 to low-carbon projects. Traditionally the fund focuses on innovative projects at pre-commercial scale, which are not entirely fit for the purpose of stimulating scaling of a relatively mature solar-PV industry.[20] However, flagship projects, like Enel's 3Sun, have so far received €118 million in EU grants (in addition to national grants), covering some 20 percent of the overall capital cost.[21] Still, the impact of such upfront grants is relatively modest, especially when compared to the IRA, since depreciation costs for cell and module plants are less than 10 percent of unit costs (Exhibit 6).

Exhibit 6

The direct support mechanisms for supply chain investments in Europe are limited, particularly in comparison to the United States.

Impact of incentives on local solar manufacturing cost across the regions, estimates



Key policy actions	Key policy actions	Key policy actions	Key policy actions
Capital subsidies: cheap/free land, subsidized loan rate Impact: 2/cWp **Utility subsidies** on electricity and water Impact: 0.9 c/Wp **Indirect supply incentives:** relaxed labor laws, no input credits Impact: 0.7 c/Wp	**Capital subsidies and grants** (such as EU Innovation Fund,[1] regional programs) Impact: 0.1 c/Wp	**Inflation Reduction Act incentives:** $48bn till 2032; primarily production linked Impact: 11–18 c/Wp[4] **State-level investment incentives** (eg, Arizona's Jobs Credit Schemes) Impact: 1.7 c/Wp **Section 201 import tariffs** Impact: 14.5%	**Production-linked Incentive (PLI) Scheme:** $3bn for solar mfg Impact: 2.1–2.3 c/Wp[5] **Import tariffs:** Make-in India safeguard duty (14.5%), basic customs duty (25–40%) Impact: 40–55%

[1]Assumption: shipping cost = 0 for locally manufactured solar modules.
[2]For EU, incentive impact (depreciation spend saved) corresponds to Enel's (€118 million) received for 3 GW HJT solar manufacturing unit through the EU Innovation Fund.
[3]Impact range (including state incentives) depends on partial localization (cells and modules):12.7 c/Wp vs for full localization: 19.7 c/Wp.
[4]IRA to provide 100% of the proposed incentive till 2029, phased out linearly by 2033. Incentive breakdown: p-Si (1.5 c/W), wafers (5.5 c/W), cells (4 c/W), and modules (7 c/W). IRA's impact (avg NPV) range: 8.8 c/W (US cells and modules)—14.4 c/W (full US localization) till 2033.
[5]PLI incentive value (range) primarily depends on module efficiency: 0 (< 19.5%), 2.25 INR/Wp (19.5–20%), and 2.75 INR/Wp (>20%).
Source: Expert interviews, McKinsey analysis

McKinsey & Company

Creating a level playing field is challenging under these shifting circumstances. The EU is developing measures such as a CO_2 tax and eco-labeling that are expected to be favorable for European-based companies. To trigger broad and large-scale investments, however, further targeted market design measures may be required to entice investments. Indeed, there are already indications of solar-PV companies refocusing investments from Europe to other regions —REC Solar recently announced it is canceling its plans for a 4 GW

French plant, despite being selected in July to receive an EU grant. [22]

Potential unlocks

For European-based companies to succeed in building feasible, long-term competitive positions in the global solar-PV supply chain and enable a viable European industry, the success formula will likely combine highly ambitious and cost-competitive players, supported by the right market design especially in the critical scale-up phase. With this in mind, we have identified six potential unlocks:

1. Leading ambitious industrial frontrunners who are willing to move first and deploy risk capital at pace, using the best available technology across the value chain and with long-term global ambitions to succeed.

2. A laser-sharp focus on cost-out performance through accelerated scale-up and world-leading ambitions for capital and operational excellence, combined with a compelling customer value proposition (especially cost, quality, and sustainability).

3. A sophisticated industrial approach to continually implement new technologies to enable and build competitive leadership. This will involve close collaboration with technology companies, equipment providers, and technical research institutes.

4. An orchestration and coordination across the value chain to de-risk investment cases and scale in lock-step. Leading downstream customers need to be prepared to de-risk upstream investments (and unlock financing) by committing demand at the right price signal to spur investments across the value chain—with a high degree of transparency on plans and the need to scale in tandem.

5. Systematic efforts by companies to build a competitive ecosystem of sub-suppliers and equipment partners in coordination with others to support new investments. Such an ecosystem of suppliers should be able to extract cost synergies and drive down input costs to support a viable industry.

6. National- and EU-level regulators that create a market design framework that encourages and de-risks early investments in Europe, especially until minimum scale thresholds are achieved, and with a scale and scope that attracts the necessary investments in a global context.

European solar-PV companies have been through a solar-PV boom and bust before that makes many stakeholders wary. While there is a potential pathway to competitiveness, companies producing solar-PV products in the region will need bold aspirations and to turn every stone to become competitive. European companies will need to build an entire industry ecosystem to be truly viable in the global market in the long term—as Chinese companies have done. This will require major efforts by industry leaders, supported by customers, end users, and policy makers.

ABOUT THE AUTHOR(S)

Alberto Bettoli is a senior partner in McKinsey's Rome office, **Tomas Nauclér** is a senior partner in the Stockholm office, **Thomas Nyheim** is a partner in the Oslo office, **Andreas Schlosser** is a partner in the Munich office, and **Christian Staudt** is an associate partner in the Washington office.

The authors wish to thank Kevin Anneken, Rogier Buck, Stefan Burghardt, Bas Dijkstra, Aman Gupta, Lawrence Heath, Humayun Tai, Bram van der Horst, and Shivaji Yadav for their contributions to this article.