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Transatlantic clean investment monitor 2: a solar PV snapshot

This analysis compares the state of play in solar capacity in both the US and Europe

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This is the second of a series of Bruegel-Rhodium Group quarterly briefings to compare clean tech deployment and manufacturing trends in Europe and the United States.

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*Click here to read the first piece **Transatlantic clean investment monitor.***

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Solar photovoltaic technology is set to be a critical enabler of the global energy transition, with mass deployment being enabled by a 90 percent drop in solar module costs over the past two decades. By 2025 more capacity to generate electricity from solar PV will have been deployed than any other generation technology (IEA, 2023a). A global solar manufacturing industry worth $90 billion has emerged, with China dominant. However, the market is marked by massive overcapacity, with global solar manufacturing capacity for modules in 2023 at 1,140 gigawatts (IEA, 2023b, 2024) compared to annual deployment of 345 GW (Ember, 2024).

Having kickstarted the solar industry with subsidies in the 2000s, Europe leads the United States in solar deployment. Yet, both regions generate similar amounts of electricity from solar, because of more sunshine in the US southwest. In the last few years, investment in US solar manufacturing has surged, spurred by the Inflation Reduction Act. This trend is not mirrored in Europe; the European Union imports almost all its solar cells and modules from China. Meanwhile, because of its trade policies limiting Chinese-origin imports, the US sources most of its solar equipment from Vietnam, Malaysia, Thailand and Cambodia.

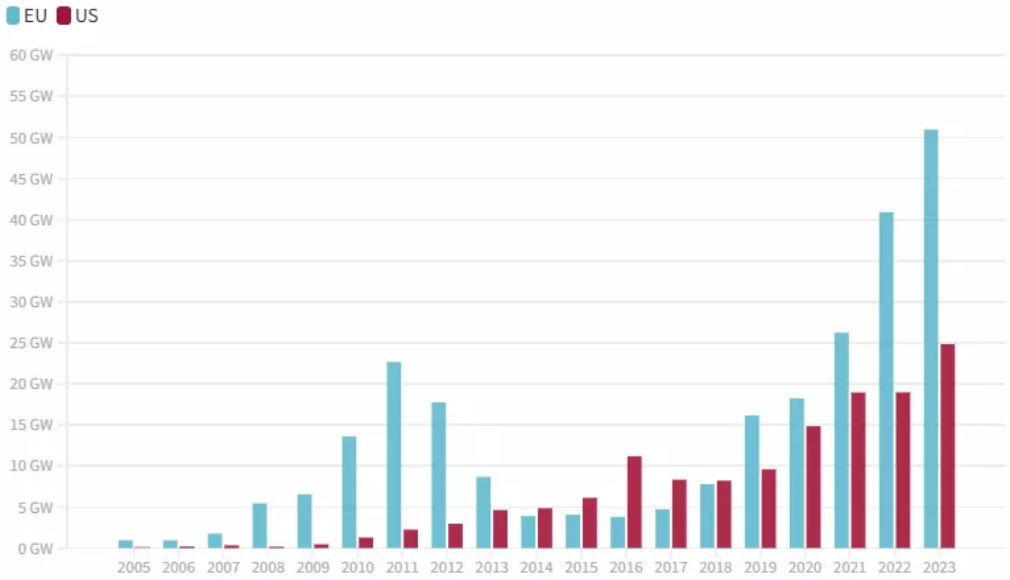
Deployment

The solar industry was boosted by generous European subsidies in the 2000s. From more or less zero in 2005, solar deployment in the EU accelerated rapidly, increasing by 2011 to more than 20 GW annually (Figure 1). As subsidy schemes were phased down, solar deployment slowed in the early 2010s.

The US, despite significant investments in solar R&D in the early stages of development, largely missed this 2000s solar deployment wave. The first federal tax credit for solar generation, introduced in the Energy Policy Act of 2005, plus state-level support, primarily in California, helped drive a steady increase in solar deployment. By the second half of the 2010s, as solar panel prices fell, EU and US deployment converged to similar rates of around 10 GW per year.

In 2019, European annual deployment again picked up. This was not matched in the US. Consequently, the gap between the EU and US in terms of deployed solar capacity is again widening. As of 2023, the EU has deployed 257 GW of solar capacity, generating 9 percent of total electricity. This compares to 139 GW solar capacity and 6 percent in the US[1]

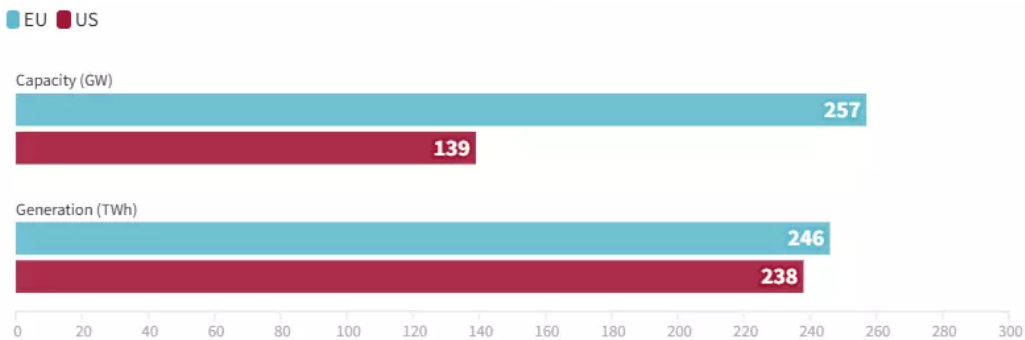
Figure 1: Annual solar PV deployment 2005-2023, GW



Source: Bruegel and Rhodium based on the Ember electricity dashboard.

In fact, despite the EU's much greater deployed solar capacity, the EU and US generated similar amounts of solar electricity in 2023 (Figure 2). This is largely a consequence of the US having on average more sunlight hours per year. Average numbers of sunlight hours vary widely across both the US and EU. The difference between the two in output per deployed gigawatt demonstrates the advantage of deploying solar in sunnier geographies. Germany – with relatively low average solar hours – dominates European solar deployment, with more than double the capacity of any other EU country as of 2023 (Keliauskaitė *et al*, 2024).

Figure 2: EU and US solar PV capacity (GW) and generation (TWh), 2023

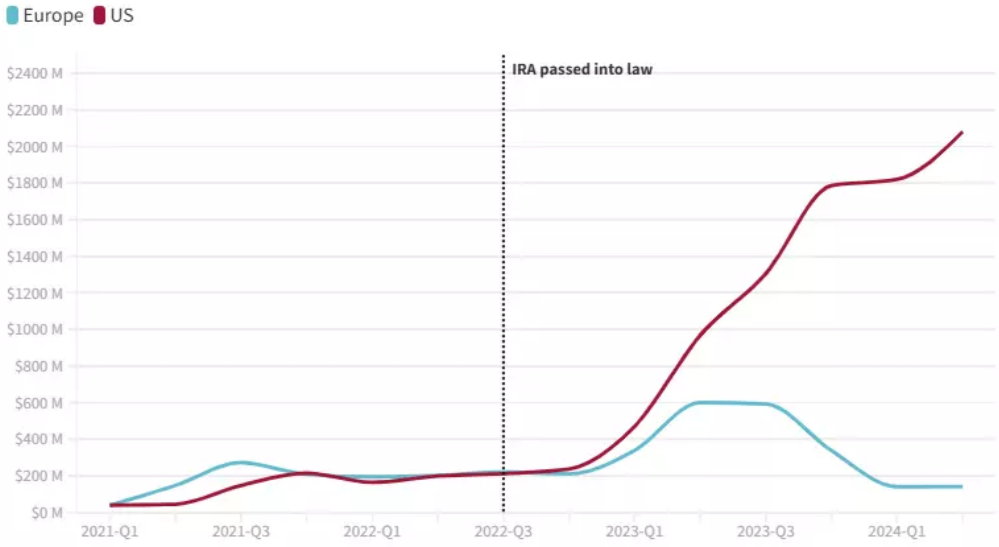


Source: Bruegel and Rhodium based on the Ember Electricity Dashboard.

Manufacturing

While Europe leads the US in deployment, growth in solar manufacturing capacity is far faster in the US. Investments in the PV manufacturing supply chain were largely on par in the EU and US in 2021 and the first half of 2022 (Figure 3). US investment then started to accelerate in Q3 2022, coinciding with the enactment of the Inflation Reduction Act (IRA), which incentivises advanced manufacturing and clean electricity[2]. These subsidies come on top of US tariffs that essentially block all solar imports from China.

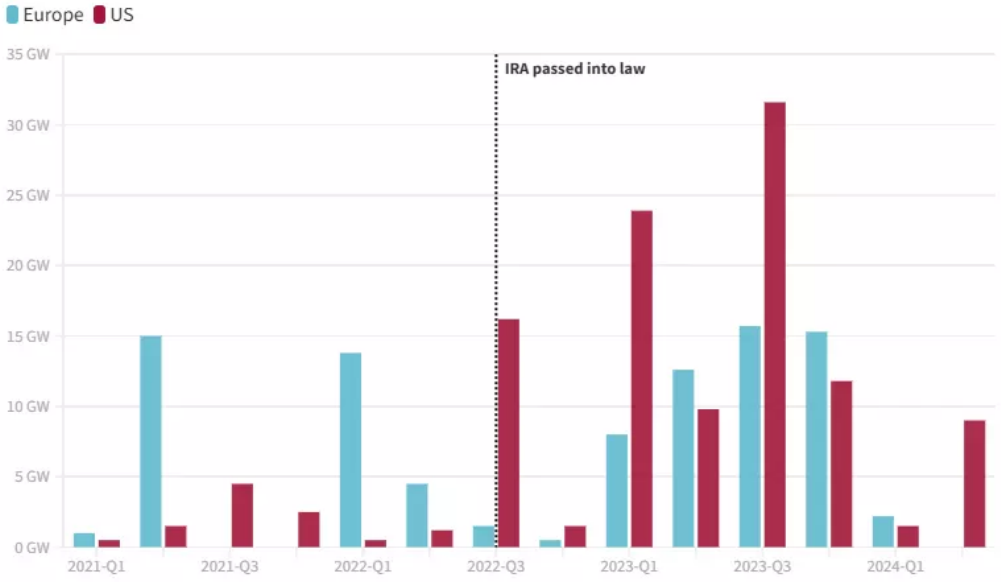
Figure 3: Quarterly investments in the solar manufacturing supply chain, US and Europe, 2021 Q1 onwards, $ millions (2023)



Source: Bruegel European Clean Tech Tracker, Rhodium Group – MIT CEEPR Clean Investment Monitor. • Note: Europe figure includes EU, Norway, Switzerland, Serbia, North Macedonia and Kosovo.

Companies invested more than $2 billion in US solar manufacturing in Q2 2024, a tenfold increase compared to the $198 million invested in Q2 2022. In Europe, investments in 2024 were at their lowest level ($281 million for the first half of the year) since 2021. A substantial volume of investment has been announced for Europe (Figure 4) but final investment decisions have been taken or construction started for only a small fraction. Since the IRA passed, the US has seen substantial growth in announcements.

Figure 4: Quarterly announcements in new solar manufacturing capacity, GW



Source: Bruegel European Clean Tech Tracker, Rhodium Group – MIT CEEPR Clean Investment Monitor. • Note: Europe figure includes EU, Norway, Switzerland, Serbia, North Macedonia and Kosovo.

This sharp rise in solar manufacturing investment in the US is materialising into growing manufacturing capacity along the value chain (Figure 5). This can be seen by looking at three blocks of the solar value chain:

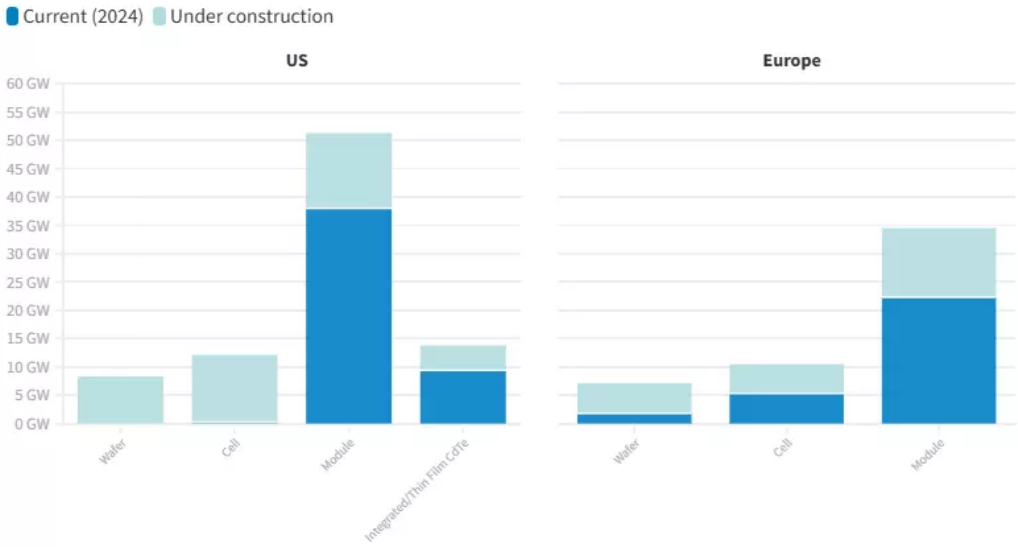
- Wafers are sliced from blocks of melted polysilicon;
- Wafers are then treated to create solar cells that convert sunlight into electricity;
- Solar modules are assembled from many cells wired in parallel.

In the US, the installed capacity of module assembly almost doubled between 2023 and 2024 reaching 38 GW. Growth in earlier value chain stages has also been notable, with 8 GW of wafer production capacity under construction and 12 GW of solar cell manufacturing capacity[3]. The US also has around 10 GW capacity for the production of integrated thin film solar panels produced from cadmium telluride (CdTe; Figure 5). This supply route is completely independent of our main focus on silicon-based solar panel production.

In comparison, Europe's current manufacturing capacity, while also dominated by modules, is slightly more diverse, with 22 GW of operational solar module manufacturing capacity, 2 GW of wafer and 5 GW of cell manufacturing. Despite lower

investment levels, Europe has capacity in the construction pipeline, with 12GW of module manufacturing capacity and 5 GW of both wafer and cell manufacturing.

Figure 5: Operational and under construction capacity for different elements of the supply chain, GW

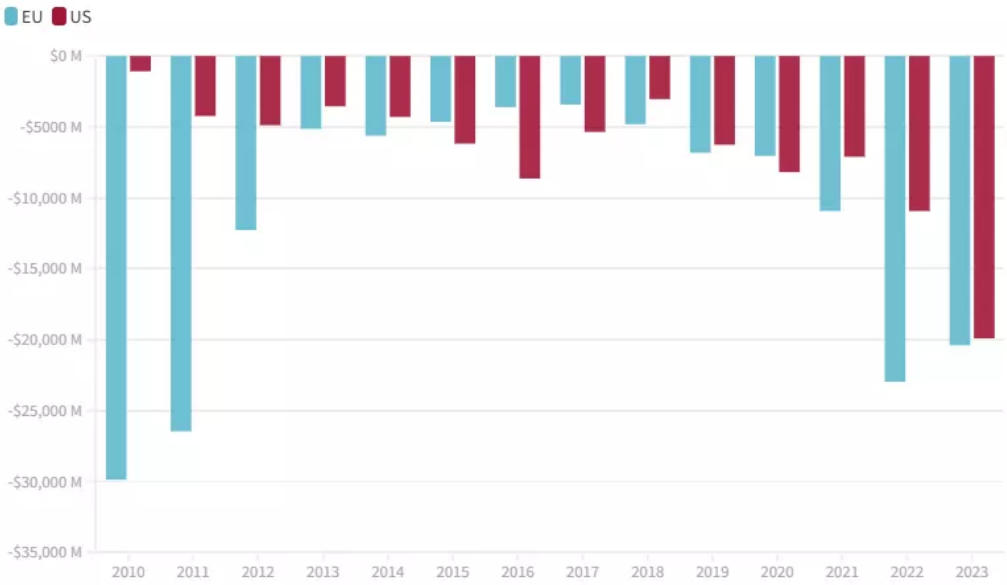


Source: Bruegel European Clean Tech Tracker, Rhodium Group – MIT CEEPR Clean Investment Monitor. • Note: Europe figure includes EU, Norway, Switzerland, Serbia, North Macedonia and Kosovo.

Trade

Both the EU and the US are heavily reliant on imports to meet solar PV demand, each running a trade deficit for solar PV modules and cells of about $20 billion in 2023 (Figure 6). In the face of threats to EU industrial capacity, the European Commission in 2012 investigated Chinese companies selling solar panels in Europe at far below market prices and subsequently imposed antidumping duties on Chinese solar panels in 2013. These tariffs reduced imports until 2018, when the tariffs were lifted amid fears that they undermined progress towards renewable energy deployment goals. EU imports of solar panels have increased markedly since then, most notably more than doubling from 2021 to 2022 as prices collapsed (McWilliams *et al* 2024).

Figure 6: Trade deficit of PV modules and cells, $ millions (2024)

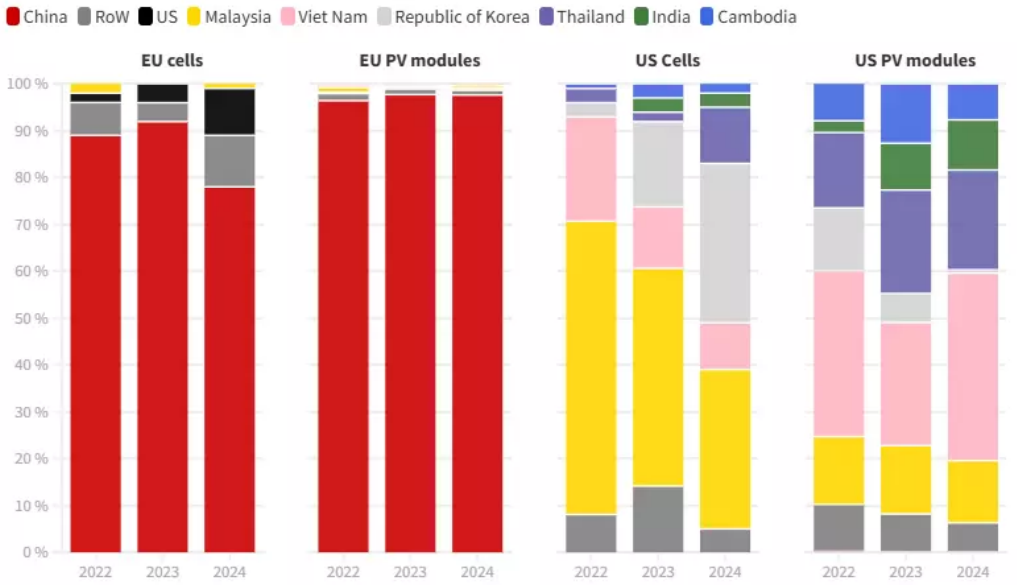


Source: UN Comtrade, Imports and Exports of HS product codes 854140 (until 2021), and 854142 & 854143 post-2022, due to the amendments to the Harmonization System, accessed on September 9, 2024.

The US also imposed anti-dumping duties on solar panels from China in the early 2010s under the Obama administration, despite not facing large trade deficits like the EU. In 2018, the Trump administration imposed additional tariffs to protect the small US domestic solar manufacturing sector against low-priced imports. These policies shifted US imports away from China to four countries particularly (Vietnam, Malaysia, Thailand and Cambodia) which accounted for more than 75 percent of total US PV module imports and 64 percent of cell imports in 2023 (Figure 7a).

The Biden administration granted an exemption from tariffs to those four countries in 2022 to mitigate supply risks, while it attempted to bolster domestic clean technology manufacturing. From 2022 to 2023, the US solar trade deficit increased by 82 percent. In May 2024, following an investigation, the administration allowed the exemption to expire. By September, it had increased tariffs on solar cells imported from China.

Figure 7: Share of imports by partner country



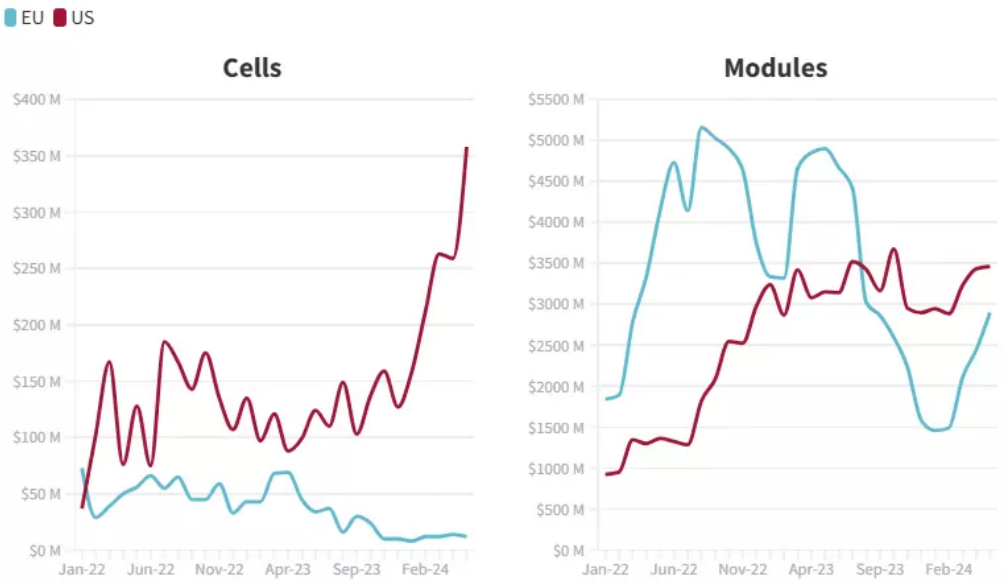
Source: UN Comtrade, Imports and Exports of HS product codes 854140 (until 2021), and 854142 & 854143 post-2022, due to the amendments to the Harmonization System, accessed on September 9, 2024.

For the US, there are signs of supply chain diversification. The share of supply from India in US module imports increased from 2.5 percent in 2022 to 10.7 percent in 2024 (to time of writing; Figure 7a). For solar cells, Vietnam's and Malaysia's shares of US imports in 2024 are significantly reduced compared to 2022, falling from 22 percent to 10 percent and 62 percent to 34 percent, respectively. South Korea has filled this gap, supplying 34 percent of total imports in 2024 to date.

US cell imports rose significantly between 2022 and 2024 (Figure 8a). This was necessary because domestic solar module manufacturing growth has not been so far matched by operational domestic solar wafer or cell manufacturing. Imports from South Korea and India have increased significantly to meet this demand.

For Europe, China accounts for almost all solar module imports (96 percent to 98 percent in the past few years). In 2022 and 2023, imports of solar cells to the EU were almost exclusively from China. In 2024 to date, China's share of solar cells imported to the EU has fallen by around 20 percent. Over the same period the value of solar cells imported into the EU has dropped significantly (Figure 8a).

Figure 8: Monthly imports EU/US, $ millions



Source: UN Comtrade, Monthly imports of HS product codes 854142 & 854143, based on monthly exports values, 2024 data only available until June 2024, accessed on September 9, 2024.

Looking ahead

With a rapidly changing manufacturing investment and trade policy landscape in the US, and Europe largely maintaining the status quo, it is likely that they will continue to experience diverging trends. In terms of PV supply chains, the current US approach is to aim for more domestic supply and less China-linked supply, whereas Europe prioritises fast-paced deployment of the technology in electricity generation. Our next Bruegel/Rhodium briefing notes will explore how these deployment and manufacturing trends materialise for other clean energy technologies.

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Endnotes

1 Substantial capacity does not imply substantial generation of electricity because of different capacity utilisation (hours in which capacity operates). Solar PV has low capacity utilisation relative to other electricity generation technologies.

2 The IRA gave two tax credits to solar manufacturers in the US. Manufacturers can claim a newly introduced Advanced Manufacturing Production Tax Credit, which subsidises the production and sale of solar manufacturing components until 2032. Alternatively, they can claim the expanded Advanced Energy Project Investment Tax Credit, an upfront tax credit that finance up to 30 percent of the investment to establish, re-equip or expand a renewable component manufacturing facility, including solar.

3 Further descriptions of the solar manufacturing value chain are available in Keliauskaitė et al (2024).

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