

The Sun Has Won

Research Note: China Solar PV Installation Trends And Implications

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Summary: China dominates global solar photovoltaic (PV) manufacturing and domestic installation. China by itself installed an estimated 265 GW of PV, or 60% of the global total, in 2023. China's domestic installation is such a large fraction of the global market that changes in domestic demand may have increasingly important global consequences. Moreover, any uncertainty in China's domestic financing of manufacturing, or in government policy that influences manufacturing, could affect module availability worldwide. A contraction of domestic Chinese installation could result in a global glut of modules, and a contraction of Chinese manufacturing could result in tightening supplies, with either event influencing global prices. One ameliorating factor to emerge in the wake of the pandemic and war in Europe is the apparent rise of the warehousing of modules, which can buffer fluctuations in both supply and demand. Given China's present dominance in all phases of module manufacturing, I estimate it will be 5-10 years before domestic investment in new manufacturing in other countries will modulate China's impact on global supply and prices, a topic that I will cover in an upcoming report. This Research Note updates reporting on China from The Sun Has Won, Part 1.¹

1. The Sun Rises In The East

1.1 All solar is local...

The U.S. and Europe installed record amounts of solar in 2023, but even together these markets paled in comparison to China.² China by itself added an estimated 265 GW of PV, or 60% of the global total (see Figure 1).^{3,4} *Bloomberg News* recently noted that the additions last year in China were more than the cumulative installation that took place over four decades in the U.S.⁵ China has been aggressively expanding its rooftop solar capacity, which comprises a local, distributed energy production infrastructure that collectively now exceeds the total capacity of many nations.⁶

What will happen this year, and the next? We should take care not to conflate annual fluctuations with longer term trends. Twice previously, in 2013 and 2017, China's share of global installation peaked, only to contract significantly in succeeding years. These local fluctuations have increasing global impacts. Since 2013, China has accounted for at least a quarter of global annual installation, and in most years more than one-third. Consequently, in the years in which China's domestic installation experiences large increases or decreases, whether absolute or relative, global rates experience concomitant changes (Figure 1, Middle Panel). Going forward, small fluctuations in China's annual PV installation could create shortages, or oversupplies, that in absolute amounts are larger than the demand across entire regions ex-China.

1 The Sun Has Won, Part 1: Market Inevitabilities In Electricity Production, Robert Carlson, July, 2022, Planetary Technologies.

https://www.planetarytech.earth/s/The_Sun_Has_Won_Rob_Carlson_July2022.pdf

2 "Global PV Market Outlook, 4Q 2023", Jenny Chase, *BloombergNEF*, 29 November, 2023. <https://about.bnef.com/blog/global-pv-market-outlook-4q-2023/>

3 https://twitter.com/solar_chase/status/1752210574769799415?s=58&t=jVfElohOV0cSeAgVFLc6_Q

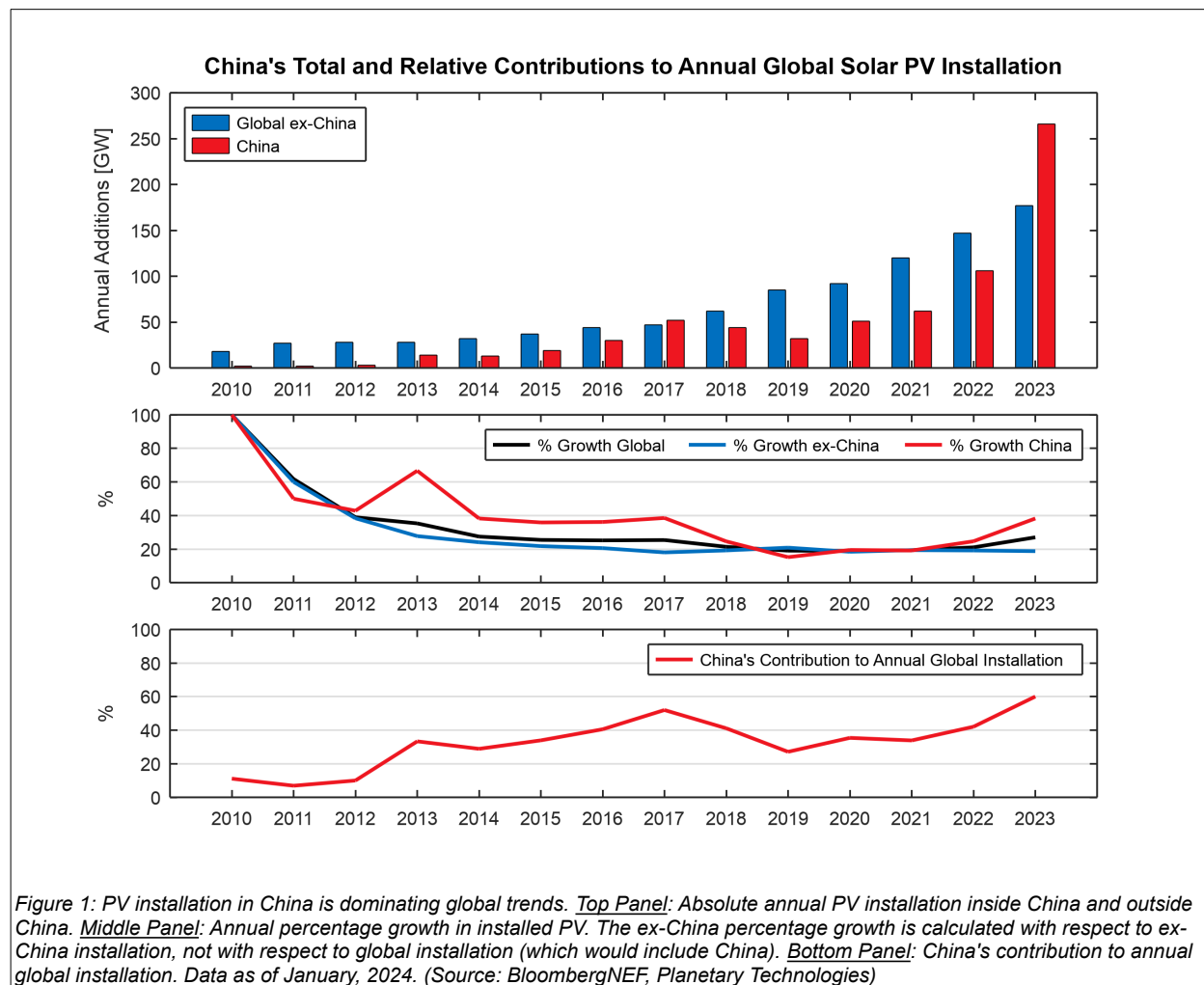
4 Annual total solar additions are typically not finalized by BloombergNEF until approximately Q2 of the following year.

5 "China Added More Solar Panels in 2023 Than US Did In Its Entire History", *Bloomberg News*, 26 January, 2024.

<https://www.bloomberg.com/news/articles/2024-01-26/china-added-more-solar-panels-in-2023-than-us-did-in-its-entire-history?sref=F2R0yNB0>

6 "China's New Solar Test Is Finding Enough Grid Space for Rooftop Panels", *Bloomberg News*, 9 January, 2024.

<https://www.bloomberg.com/news/articles/2024-01-10/china-s-new-solar-test-is-finding-enough-grid-space-for-rooftop-panels>



1.2 ...but everything depends on China...

Feeding both global and domestic markets, China accounts for more than 80% of all stages of the global solar manufacturing supply chain.⁷ India has recently been the largest customer of Chinese silicon PV cells, a demand attributed to stockpiling in advance of the implementation of the Approved List of Models and Manufacturers, which governs domestic content of solar projects in that country.⁸ Chinese module exports grew 34% in 2023, with 101.5 GW of the total 208 GW going to Europe.⁹ The EU import datum is intriguing because it is reported that “there are currently enough modules stockpiled in the EU for over a year’s worth of installations.”¹⁰ This stockpile creates a buffer in the market, potentially smoothing out fluctuations in Chinese manufacturing and in global shipping, which has seen recent disruptions due to the pandemic, maritime mishaps, and terrorism. Solar module distributors and

7 Solar PV Global Supply Chains, IEA, July 2022. <https://www.iea.org/reports/solar-pv-global-supply-chains>

8 “InfoLink Consulting Anticipates Restrained Chinese Imports In Q1/2024; European Warehouses Likely To Be Restocked In Advance”, 11 February, 2024, *Taiyang News*. <https://taiyangnews.info/china-exported-208-gw-solar-modules-globally-in-2023/>

9 *ibid.*

10 “Europe is importing a solar boom. Good news for (nearly) everyone”, 8 February, 2024, *The Economist*. <https://www.economist.com/europe/2024/02/08/europe-is-importing-a-solar-boom-good-news-for-nearly-everyone>

installers may be acting to ensure supply, even if it comes at the increased cost of warehousing, which may indicate a coming change in the structure of the solar industry.

The concentration of solar manufacturing in China enables powerful economies of scale, but this centralization also creates fragility in the global market. This dynamic of centralization and efficiency versus distributed production and resiliency is one that the global economy is struggling with whether the commodity is latex gloves or silicon cells. Because there is presently so little competition or alternative supply, hiccups in Chinese domestic component prices, as recently transpired with solar polysilicon, or in shipping capacity and prices, as happened during the pandemic, can have serious knock-on effects in global access to finished modules.^{11,12} Moreover, current manufacturing capacity appears to exceed demand, leading to a record low price per watt for silicon cells, in turn causing some Chinese wafer manufacturers to operate at only 40% capacity, while others operate at 95% capacity.¹³ A wave of bankruptcies and consolidation may be imminent.

China's domestic manufacturing and demand are both now so large that relatively small changes in that market have global consequences. As been seen previously in Spain, Germany, and California, recent policy changes that reduce electricity prices during peak solar production hours may lead to China's domestic installation slowing again.¹⁴ It is also possible that China's domestic market could experience a local contraction due to a changing financing environment, as might result from an increase in domestic interest rates, which could result in a global glut of modules. Conversely, over the course of just a year or two, a contraction of Chinese manufacturing could result in a tightening of global supplies. More vexing for analysts, even if Chinese-made modules fall in price due to a domestic slow down in installation, it is not clear that the rest of the world could absorb the extra supply and install it fast enough to maintain the current global rate of installation (Figure 1, Bottom Panel). The combination of concentrated manufacturing and large global consequences for even modest domestic market changes is creating increasing concern and uncertainty in energy markets, which together have implications for economic and physical security.

1.3 ...for now.

Secure energy supplies are a strategic goal of most nations. The concentration of PV manufacturing in China is thus often viewed as a risk. Countries around the globe, in particular the U.S., India, and the aggregate that is the EU, which together constitute the bulk of demand ex-China, have made policy decisions in recent years that in some combination require domestic manufacturing, penalize manufactured goods from China, or incentivize “friendshoring” of manufacturing to countries deemed less problematic than China for one reason or another.^{15,16} But these policies will take time to implement and it will be likely be 5-10 years before the resulting manufacturing capacity substantially displaces Chinese products. And not everyone is enthusiastic about policies that even out the distribution of solar manufacturing.

The Economist recently argued that the centralization of PV manufacturing in China, with its economies of scale and low prices, and despite the documented use of forced labor, is good for global consumers; we should all “stop worrying and love Chinese photovoltaic cells”.¹⁷ A counterargument is that many economists focus solely on prices and ignore what they consider to be externalities, such as national security and diplomacy. The government of China

11 “China polysilicon prices gain for the first time in 2024”, OPIS, *PV Magazine*, 9 February, 2024. <https://www.pv-magazine.com/2024/02/09/china-polysilicon-prices-gain-for-the-first-time-in-2024/>

12 “Solar and storage prices soared as a result of market disruptions, NREL reports”, Anne Fischer, 1 December, 2022, *PV Magazine*. <https://pv-magazine-usa.com/2022/12/01/solar-and-storage-prices-soared-as-a-result-of-market-disruptions-nrel-reports/>

13 “Solar Factories Slow Output as Overcapacity Weighs on Profits”, *Bloomberg News*, 25 January, 2024. <https://www.bloomberg.com/news/articles/2024-01-26/solar-factories-slow-output-as-overcapacity-weighs-on-profits>

14 “China’s Electricity Pricing Shifts in Blow to Solar Power, Boon for Batteries”, *Bloomberg News*, 10 December, 2023. <https://www.bloomberg.com/news/articles/2023-12-11/china-s-electricity-pricing-shifts-in-blow-to-solar-power-boon-for-batteries>

15 “EU Tries to Match US Green Subsidies With Its Clean Tech Deal”, John Ainger, 6 Feb, 2024, *Bloomberg*. <https://www.bloomberg.com/news/articles/2024-02-06/eu-reaches-clean-tech-deal-to-answer-the-us-tax-credit-system?sref=F2R0yNB0>

16 “India Plans Stricter Local Material Norm for Solar Module Makers”, Rajesh Kumar Singh, 20 October, 2023, *Bloomberg*. <https://www.bloomberg.com/news/articles/2023-10-20/india-plans-stricter-local-material-norm-for-solar-module-makers?>

has set a strategic goal of controlling certain industries, such as semiconductors and renewable energy materials and manufacturing, as a tool for projecting geopolitical power. Moreover, it has already utilized that tool on multiple occasions and with increasing frequency.^{18, 19, 20, 21} Historically, control of manufacturing, and of technical standards for manufacturing and use, are correlated with increased geopolitical influence, with the Internet being the most recent exemplar of this effect. Normalizing and accepting the policies of the government of China is a non-trivial externalized cost of ceasing to worry about how those policies enable and support the projection of power.

Beyond concerns of security, geopolitical power, and human rights, the primary driver for investing in domestic manufacturing ex-China is fundamentally the same as it is in China: economics. Given the ongoing and expanding boom in solar installations, the U.S., the EU, and India have set their sights on growing domestic jobs and revenues in renewable energy. Yet there is something more important going on here. Solar is far more capital efficient (that is, energy delivered per unit capital invested) than are fossil fuels.²² Because solar is still experiencing exponential decreases in cost, and fossil fuels are now increasing in cost, this advantage will only continue to grow, creating an ever greater impulse to shift investment from fossil fuels to renewable power generation. China is embracing that future; investment in PV power generating capacity grew by 61% in 2023 and investment in PV manufacturing capacity grew by 180%.²³ More broadly, the clean energy sector was the largest driver of GDP growth in China in 2023.²⁴ This investment will pay increasing dividends for decades.

As I noted in Part 1 of this series, it is clear that there is a virtuous feedback loop emerging in which lower cost renewable electricity from solar and wind is used to manufacture the next generation of solar and wind power components. Those components will be manufactured at lower cost than identical units manufactured using more expensive fossil fuel electricity. This transition is divorcing the future of energy production from the price floor set historically by the need to purchase and burn fossil fuels, and from the historical price fluctuations created by machinations of oil producers and traders, by war, or by other regional and global events. Nations that invest in this feedback loop, and particularly those that invest in its acceleration, will reap the benefit of a structurally more efficient and productive economy. There is an obvious competitive advantage to be had for nations that make the transition quickly. Nations that fail to invest will be left behind, and nations that continue to rely on influence developed during the 20th century—whether through controlling petroleum production or markets, or through powering a manufacturing base with combustion—will be imperilled. Just as the economic advantage of renewables and electrification is leading to petroleum investment that comprises “stranded assets”, so too will it that advantage lead to stranded influence.

Among the geopolitical consequences of the shift from fossil fuels to renewable electricity is that no international hegemony will be needed to police and stabilize trade in oil. A consequent reduction in the trade volume of oil may in turn reduce the importance of any currency used to denominate that trade. A global economy in which most energy is produced locally rather than being shipped in chemical form for thousands of kilometers will look very different than the economy does today. However, although it currently dominates the materials and manufacturing sectors related to the new energy economy, China has not necessarily built a tool of lasting geopolitical control. This dragon is not yet fully grown, and there are gaps between its armored scales.

17 “Europe is importing a solar boom. Good news for (nearly) everyone”, 8 February, 2024, *The Economist*.
<https://www.economist.com/europe/2024/02/08/europe-is-importing-a-solar-boom-good-news-for-nearly-everyone>

18 Hopkins decoupling report.

19 “China, world’s top graphite producer, tightens exports of key battery material”, Siyi Liu and Dominique Patton, Reuters, 20 October, 2023.
<https://www.reuters.com/world/china/china-require-export-permits-some-graphite-products-dec-1-2023-10-20/>

20 “China to restrict exports of chipmaking materials as US mulls new curbs”, Reuters, 3 July, 2023.
<https://www.reuters.com/markets/commodities/china-restrict-exports-chipmaking-materials-us-mulls-new-curbs-2023-07-04/>

21 “China’s rare earths dominance in focus after it limits germanium and gallium exports”, Mai Nguyen and Eric Onstad, Reuters, 21 December, 2023. <https://www.reuters.com/markets/commodities/chinas-rare-earths-dominance-focus-after-mineral-export-curbs-2023-07-05/>

22 The Sun Has Won, Part 1, Carlson, 2022.

23 “Analysis: Clean energy was top driver of China’s economic growth in 2023”, Lauri Myllyvirta, et al, *Carbon Brief*, 25 January, 2024.
<https://www.carbonbrief.org/analysis-clean-energy-was-top-driver-of-chinas-economic-growth-in-2023/>

24 “China clean energy sector was biggest driver of 2023 GDP growth -research report”, Andrew Hayley, *Reuters*, 25 January, 2024.
<https://www.reuters.com/markets/commodities/china-clean-energy-sector-was-biggest-driver-2023-gdp-growth-research-report-2024-01-25/>

Over-investment, price wars, and periods of retrenchment are features of every market and act together to create short-term surges and lags in technology deployment. These fluctuations will play out on short time scales even while the long-term trend of maximizing solar deployment continues globally. Over the next 25 years, the globe will install 10–100X as much solar as we have cumulatively today, as I will cover in a future installment of this series. That volume of manufacturing, combined with a competitive lifetime for any given installation of PV manufacturing tools of just 3–5 years, means that any nation that wishes to develop its own manufacturing base can plausibly make the attempt. Success in developing this capital- and energy-efficient economy will deliver a competitive advantage for the remainder of the 21st century.

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About Planetary Technologies, LLC

Planetary Technologies, LLC identifies and builds scalable technologies that will enable the world to mature beyond fossil fuels at the pace necessary to avoid unsustainable warming. The Planetary Technologies team has a combined five decades of experience in startup operations, engineering, product development, science, strategy, techno-economic analysis and forecasting, and venture capital. Our strategic analysis and quantitative research is cited prominently by governmental policies and roadmaps in the United States, Great Britain, the European Union, the OECD, and the UN; we directly advise the U.S. government on matters of economics, security, and regulatory policy.