Spring 2025

Solar Industry Update

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Photo from Stacie Peterson, contestant in the U.S. Department of Energy's 2024 Hit Me With Your Sun Shot photo competition

Agenda

1. Global Solar Deployment
2. U.S. PV Deployment
3. PV System Pricing
4. Global Manufacturing
5. Component Pricing
6. Market and Policy
7. U.S. PV Imports

Executive Summary

Global PV Deployment

- In 2024, between 554 GW_{dc} and 602 GW_{dc} of PV were added globally, bringing the cumulative installed capacity to 2.2 TW_{dc}.
- China continued to dominate the global market, representing ~60% of 2024 installs, up 52% y/y. The rest of the world was up 11% y/y.
- The IEA reported Pakistan's rapid rise to fourth place in annual global PV deployment in 2024, with 17 GW_{dc} installed.
- At the end of 2024, global CSP capacity reached approximately 7 GW_{ac}, with virtually all installed CSP capacity (three projects, totaling 250 MW_{ac}) located in China.

U.S. PV Deployment

- EIA reported that the United States installed 36.2 GW_{ac} of PV in 2024—up 34% y/y. SEIA reported that the United installed 50.0 GW_{dc} of PV in 2024—up 21% y/y.
- At the end of 2024, solar was the second-largest source of U.S. generation capacity, though still a growing percentage of the U.S. electric generation mix.
- In 2024, solar represented 13.7% of net summer capacity and 6.9% of annual generation.
- EIA projects that PV's growth in 2023 (27 GW_{ac}) and 2024 (36 GW_{ac}) will continue in 2025 (39 GW_{ac}) and remain at similar levels in 2026 (36 GW_{ac}).
- In 2024, 24 states and territories generated more than 5% of their electricity from solar, with California leading the way at 32.4%.
- The United States installed approximately 31.1 GWh (12.3 GW_{ac}) of energy storage onto the electric grid in 2024—bringing cumulative capacity to 96.0 GWh (33.6 GW_{ac}).

A list of acronyms and abbreviations is available at the end of the presentation.

PV System and Component Pricing

- The median system price of large-scale, utility-owned PV systems in 2024 was \$1.51/W_{ac}—increasing about \$0.1/W since 2018.
- EnergySage reported that the median gross cost of stand-alone PV was \$2.65/W_{dc} in the second half of 2024.
- Module spot prices rose 2% in Q1 2025 and remained around \$0.09/W_{dc}.
- Global polysilicon spot prices rose 12% in Q1 2025, from \$5.54/kg to \$6.24/kg.
- In Q4 2024, the average U.S. module price (\$0.28/W_{dc}) was down 3% q/q and about three times higher than the global spot price.

Global Manufacturing

- SPV Market Research reported that 2024 global PV shipments were approximately 770 GW—an increase of 37% from 2023, with 90% of the increase coming from China.
- 98% of PV shipments were mono c-Si technology, with 58% TOPCon.
- Margins for the leading PV wafer, cell, and module manufacturers continued to decline through Q1 2025, due to record-low pricing.
- The United States manufactured approximately 12.0 GW_{dc} of PV panels in 2024 (+114% y/y).

U.S. PV Imports

- Q1 2025 module imports into the United States fell 14% q/q, hitting only 6.6 GW_{dc}—a level not seen since the first half of 2022.
- The United States imported 4.4 GW_{dc} of PV cells in Q1 2025, leveling off the meteoric growth from last 18 months. The United States is still projected to hit the current TRQ by midyear.

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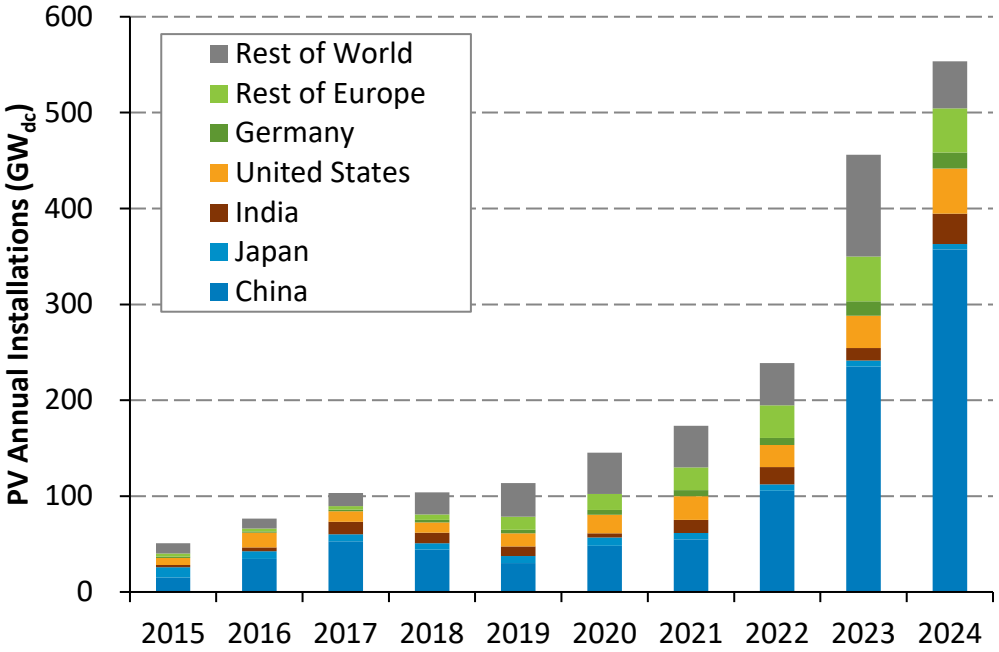
- **China continued to dominate the global market, representing ~60% of 2024 installs, up 52% y/y. The rest of the world was up 11% y/y.**
- **The IEA reported Pakistan's rapid rise to fourth place in annual global PV deployment in 2024, with 17 GW_{dc} installed.**
- **At the end of 2024, global CSP capacity reached approximately 7 GW_{ac}, with the virtually all installed CSP capacity (three projects, totaling 250 MW_{ac}) located in China.**

Global Annual PV Capacity Additions by Country



- From 2015 to 2024, global PV capacity additions grew from 50 GW_{dc} to 600 GW_{dc}.
  - In 2024, global PV installs increased 73%–91% y/y.
- The total cumulative installed capacity for PV reached 2.2 TW_{dc} at the end of 2024.
- China continues to dominate the global market, representing ~60% of 2024 installs, up 52% y/y. The rest of the world was up 11% y/y.
- 34 countries installed at least 1 GW_{dc} of PV in 2024, and 23 countries had installed at least 10 GW_{dc} of cumulative capacity.

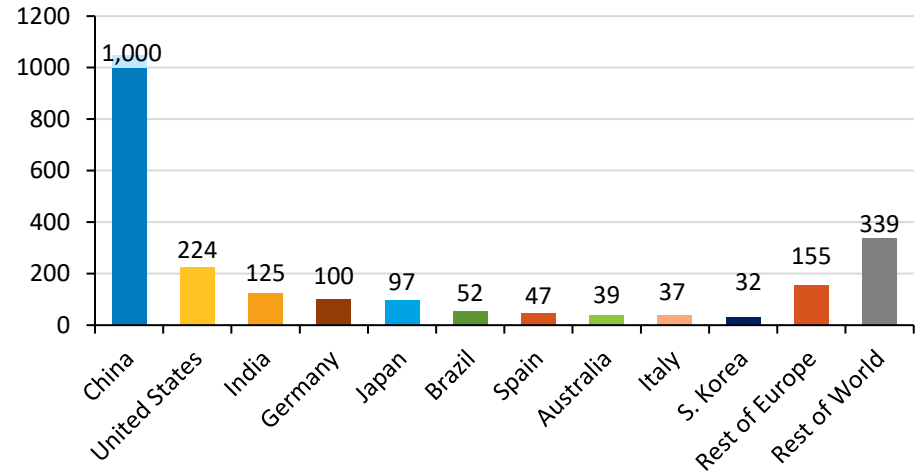
Note: China's National Energy Administration reports values in W_{ac}. Therefore, there is uncertainty in W_{dc} capacity due to differing assumptions on inverter loading ratio.

Sources: IEA, Snapshot of Global PV Markets: 2025, April 2025; IEA, Trends in Photovoltaic Applications: 2024, October 2024

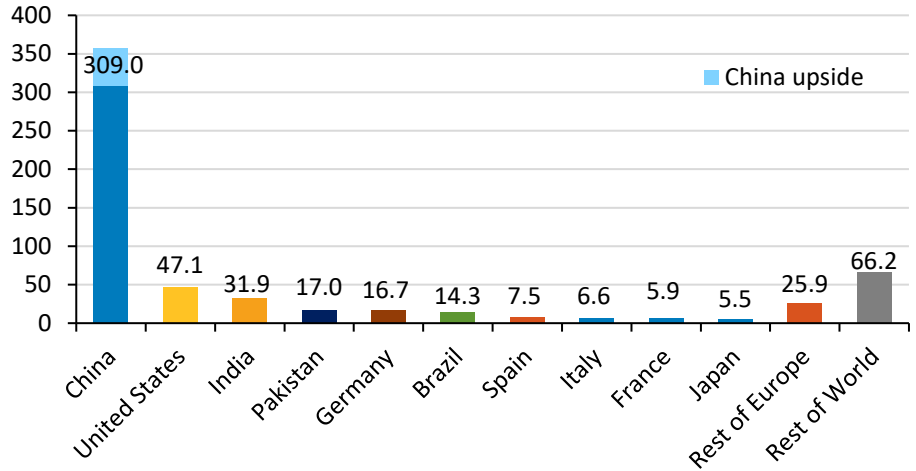
Top PV Markets

- In 2024, China, the EU, and the United States continued to represent more than 80% of annual PV installations.
- However, large growth occurred in other markets, particularly India (+92%) and Pakistan, benefiting from low-priced Chinese panels.
- The IEA reports that despite large growth in most major markets, the additional demand was not enough to absorb all new global manufacturing capacity.

Cumulative PV Deployment in 2024 (2.2 TW_{dc})



Annual PV Deployment in 2024 (554 GW_{dc} to 602 GW_{dc})



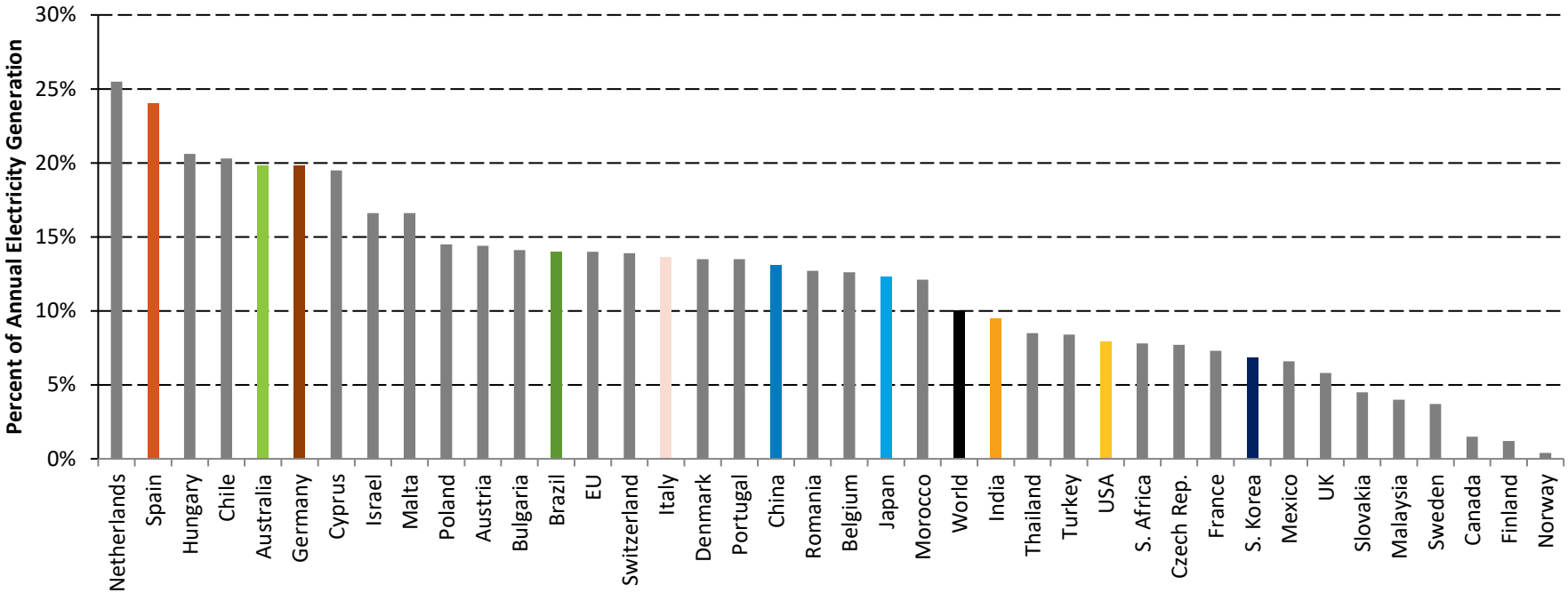
Note: China's National Energy Administration reports values in W_{ac}. Therefore, there is uncertainty in W_{dc} capacity due to differing assumptions on inverter loading ratio. The "upside" reflects a higher inverter loading ratio.

Sources: IEA, Snapshot of Global PV Markets: 2025, April 2025; IEA, Trends in Photovoltaic Applications: 2024, October 2024

Global PV Penetration

- The IEA estimates that in 2024, over 10% of global electricity generation came from PV.

- The United States, despite being a leading PV market, is below the global average of other leading markets in terms of PV generation as a percentage of total country electricity generation, with 8% of total generation represented by PV.
  - If California were a country, its PV contribution (32%) would be the highest.



Sources: IEA, Snapshot of Global PV Markets: 2025, April 2025

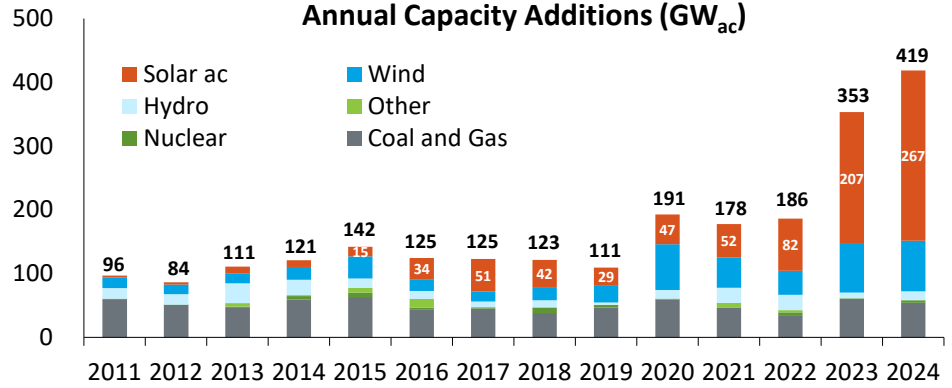
Chinese Generation Capacity Additions by Source

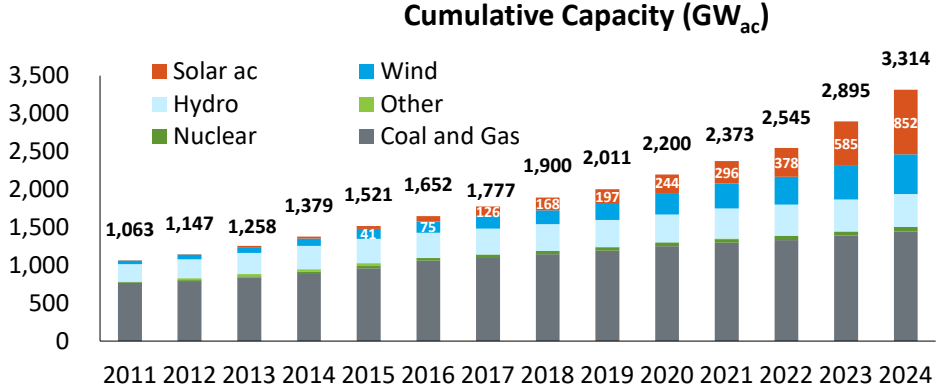
- In 2024, solar contributed 267 GW_{ac} (309–357 GW_{dc}), or 64% of new generation capacity, in China, and cumulative solar capacity reached 852 GW_{ac} (1,000–1,048 GW_{dc}), or 26% of total cumulative capacity.
  - In 2024, 40% of new PV was distributed, and 60% was utility scale.
  - Wind and solar accounted for 83% of capacity installed in 2024; together, they have constituted the most capacity installed for 9 years running.
  - Annual coal and gas additions fell 10% in 2024.
  - In Q1 2025, solar accounted for 10% of China's total energy generation.

Note: Annual and cumulative solar values assume that China's NEA reports distributed PV in dc terms and utility-scale PV in ac terms. The NEA reported 159 GW of utility-scale PV and 118 GW of distributed PV for 2024. On this slide, ac/dc conversions assume a dc-to-ac ratio of 1.1 for distributed PV. We use the IEA-reported total capacity for W_{dc}.

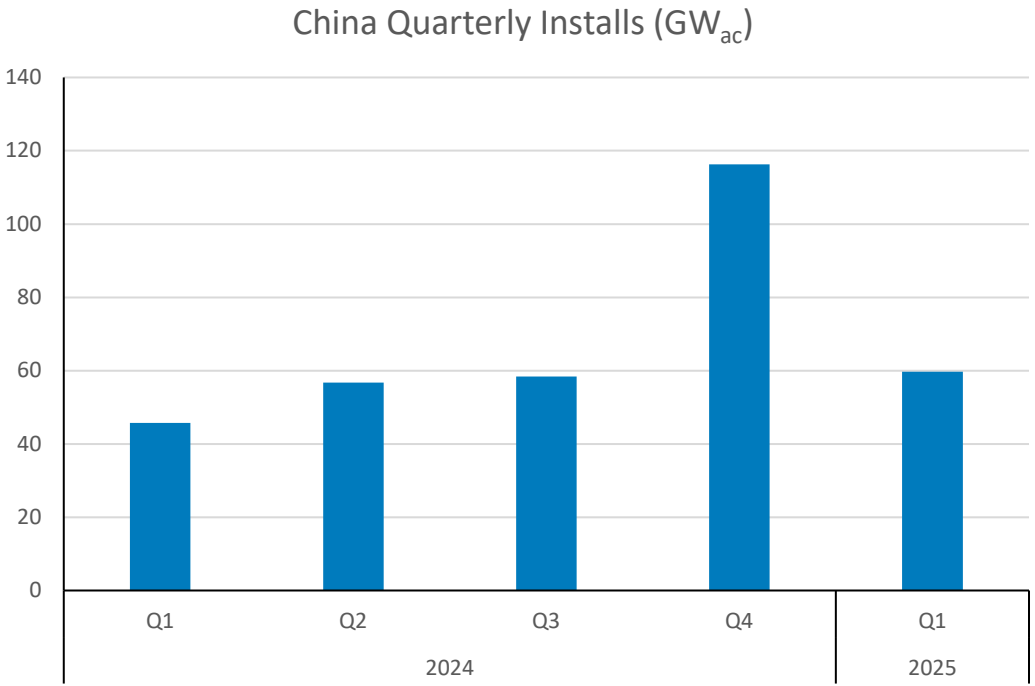
Sources: China Photovoltaic Industry Association, NEA results, February 2025; Climate Energy Finance, Monthly China Energy Update, February 2025; IEA, National Survey Report of PV Power Applications in China: 2021, November 2022; Reuters, China sets new clean electricity milestones during Q1 2025, April 2025.

- Renewable sources continue to capture a larger share of China's growing electric capacity.
  - In 2011, renewables made up 26% of the 1.1 TW_{ac} of total capacity.
  - In 2024, renewables made up 55% of the 3.3 TW_{ac} of total capacity.





Chinese PV Installation Breakdown



- China's NEA reported that 59.7 GW_{ac} of PV were installed in the first quarter of 2025—a 31% increase y/y.
  - China also installed 14.6 GW_{ac} of wind in Q1 2025.
- Despite the increase in installations in Q1, China's PV industry association projects that solar installations in 2025 will drop y/y to between 215 GW_{ac} and 255 GW_{ac}, due to the introduction of market-based pricing reforms.
  - BNEF, however, projects China's market to grow by 9%.

Sources: BNEF, 1Q 2025 PV Market Outlook, February 2025; Mercom, China's Solar Growth to Dip in 2025 Post Market-Aligned Pricing Reforms, March 2025; Mercom, April 2025; NEA, The National Energy Administration released the national power industry statistics from January to March 2025, April 2025

Chinese Market and Policy Update

Sources: BNEF, China's CfD Scheme No Panacea for Renewables Developers, March 2025; BNEF, China Market Outlook 1H 2025: Moving Through Reform Tumult, April 2025; BNEF, China Policy Bulletin: It's Reform Time, April 2025; BNEF, China Spurs Rush to Build with Commercial Solar Pricing Change, May 2025; PV Magazine, Digging into China's solar capacity numbers, March 2025; PV Tech, Rising module prices and a rush to complete projects – welcome to China's PV 'Hunger Games,' April 2025

Beginning June 2025, compensation for new wind and solar energy will switch from fixed to market-driven pricing.

- The proportion of wind and solar traded in wholesale markets will jump from 52% in 2024 to ~100% in 2025.
- The resulting revenue uncertainty—which may slow PV growth after 2025—will be greater for small-scale solar than for utility-scale solar, because small-scale projects had benefited more from fixed pricing.
- A transitional contract-for-difference scheme is meant to provide some revenue certainty to renewable projects; developers also receive revenue through power market trading.
- This policy, a strong project pipeline, and 2025 installation goals caused PV deployment to surge before June.

Beginning May 2025, China will implement additional rules to shape commercial and industrial PV deployment.

- Systems that export all their electricity to the grid will be prohibited.
- Systems larger than 6 MW will receive local spot market prices rather than fixed rates to promote development where on-site power demand is stable and retail prices are high.
- BNEF expects growth in this sector to slow in 2025 after rapid growth in 2024.

The new pricing policy adds to headwinds faced by China's already-stagnating residential PV market.

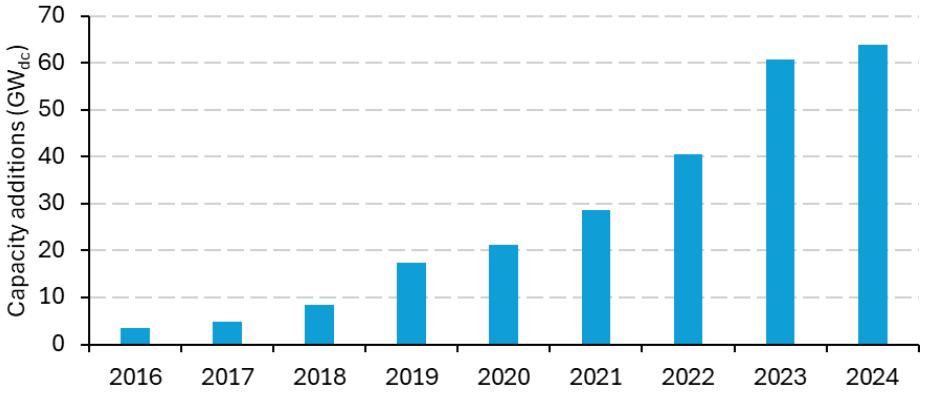
- Residential installation growth dropped 32% in 2024 due to policy uncertainty, concerns about interconnection limits, rising curtailment rates, and provincial policies that make distributed PV less economically attractive.
- Developers are exploring options like boosting on-site consumption and creating distributed energy aggregators.

EU Market

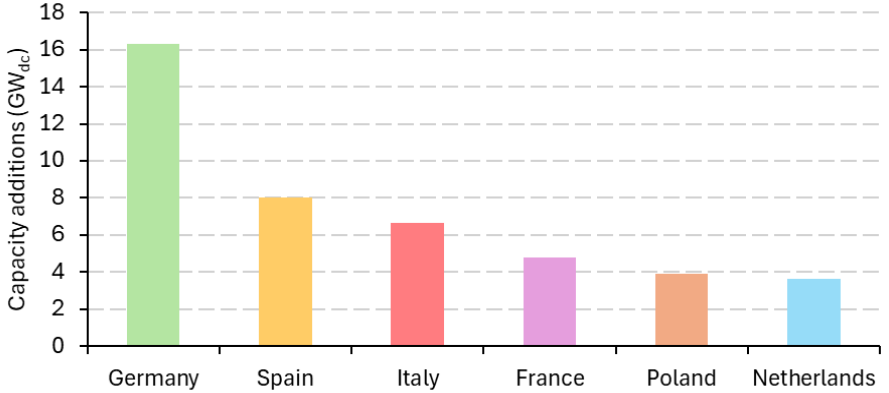
- The EU's annual PV additions reached a record of nearly 64 GW_{dc} in 2024, up 5.3% from 2023.
  - In the EU, utility-scale PV made up 42% of new additions (up 6% from 2023), commercial and industrial PV made up 39% of new additions (up 3% from 2023), and residential PV made up 20% of new additions (down 8% from 2023).

- As the energy crisis fueled by Russia's invasion of Ukraine has subsided, demand for residential solar systems in the EU has declined and several residential solar incentive schemes have begun to phase out.
- Utility-scale PV (UPV) had its largest-ever market share of new capacity additions in 2024, but deployment of UPV is expected to slow down due to grid congestion, curtailment, and interconnection issues.

EU Annual PV Capacity Additions (GW_{dc})

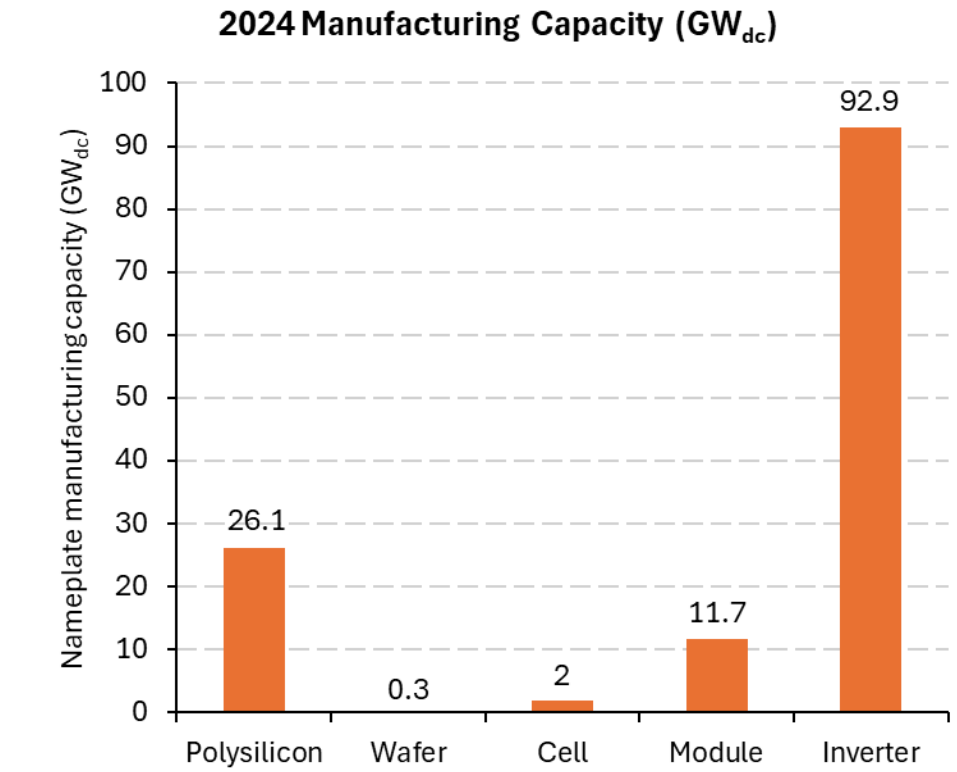


Top 6 Countries by 2024 PV Capacity Additions (GW_{dc})



Sources: BNEF, 1Q 2025 Global PV Market Outlook, February 2025; Wood Mackenzie, Global Solar PV Market Outlook Update: Q1 2025, March 2025; Solar Power Europe, EU Market Outlook for Solar Power 2024-2028, December 2024

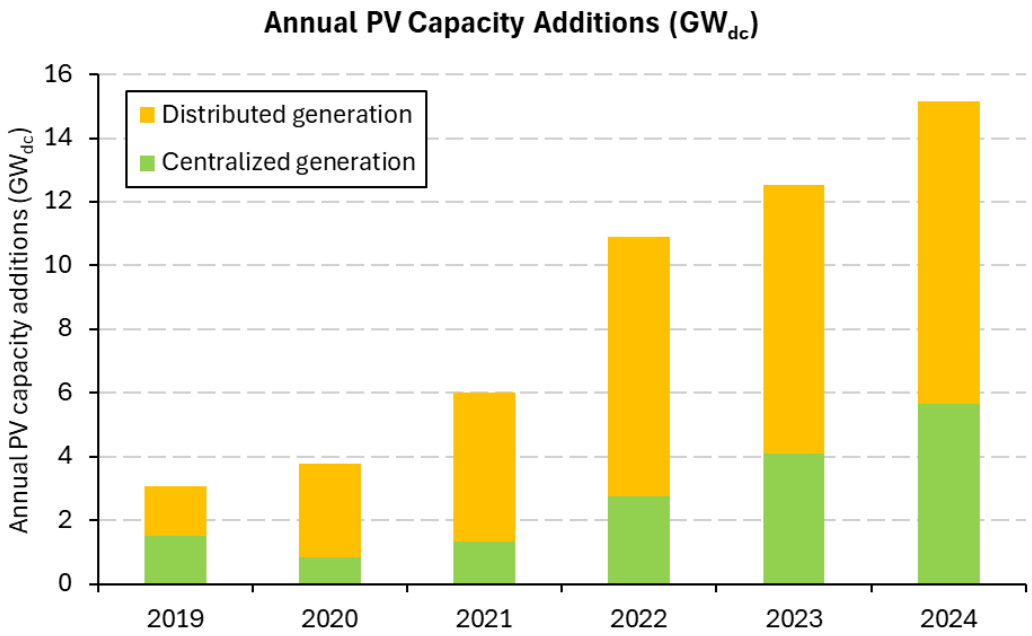
EU Manufacturing



- In the EU, polysilicon and cell capacity stayed the same from 2023, module capacity decreased by more than 14%, and inverter capacity increased by 12%.
- Wacker Chemie is currently the only polysilicon producer in the EU. They produce 60,000 metric tons per year in Germany, though not all their capacity goes toward polysilicon for solar purposes, and they plan to shift more of their production toward use in semiconductors.
- There is virtually no ingot/wafer production in the EU, although German startup NexWafe expects to begin production on its 250-MW pilot line in 2025.
- Solar cell capacity in the EU remains unchanged from 2023, with seven active companies in this segment.
- Module production has decreased in the EU following several closures and bankruptcies, notably including the closure of Meyer Burger's 1.4-GW facility in Germany.
- There are also several mounting, tracking, cable, and connector companies manufacturing in the EU.

Sources: BNEF, 1Q 2025 Global PV Market Outlook, February 2025; Solar Power Europe, EU Market Outlook for Solar Power 2024-2028, December 2024; Megasol, Megasol Energie AG, accessed April 2025; PV Magazine, 3S Swiss Solar Solutions completes 250 MW module factory in Switzerland, January 2024

Brazil Market Update

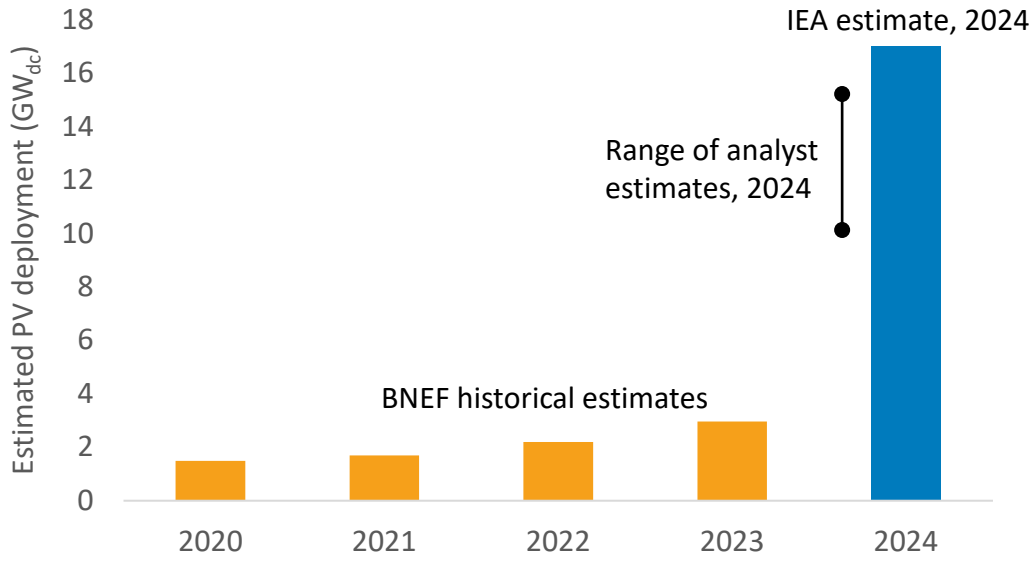


- The Brazilian Association of Photovoltaic Solar Energy (ABSOLAR) and the Brazilian Energy Regulatory Agency (ANEEL) reported that Brazil installed over 15 GW_{dc} of PV this year (the IEA reported more than 14 GW_{dc}). This is more than Brazil's entire cumulative capacity in 2021 and brings their current cumulative capacity to over 53 GW_{dc}.
- Growth in deployment was driven mainly by distributed solar systems, which are eligible for net-metering benefits. Distributed generation made up nearly 63% of new solar PV capacity in 2024.
- In 2024, Brazil increased tariffs on imported solar modules to 25% to shield their 5 GW of local manufacturing from low-cost Chinese modules.
- BNEF expects another 14.4–17.6 GW_{dc} (approximately 11.5–14 GW_{ac}) of solar installations in 2025.

Sources: ABSOLAR, Panorama of solar photovoltaic in Brazil and in the world, accessed April 2025; IEA, Snapshot of Global PV Markets: 2025, April 2025; BNEF, 1Q 2025 Global PV Market Outlook, February 2025

Pakistan Market Update

Estimates of Pakistan's Annual PV Deployment

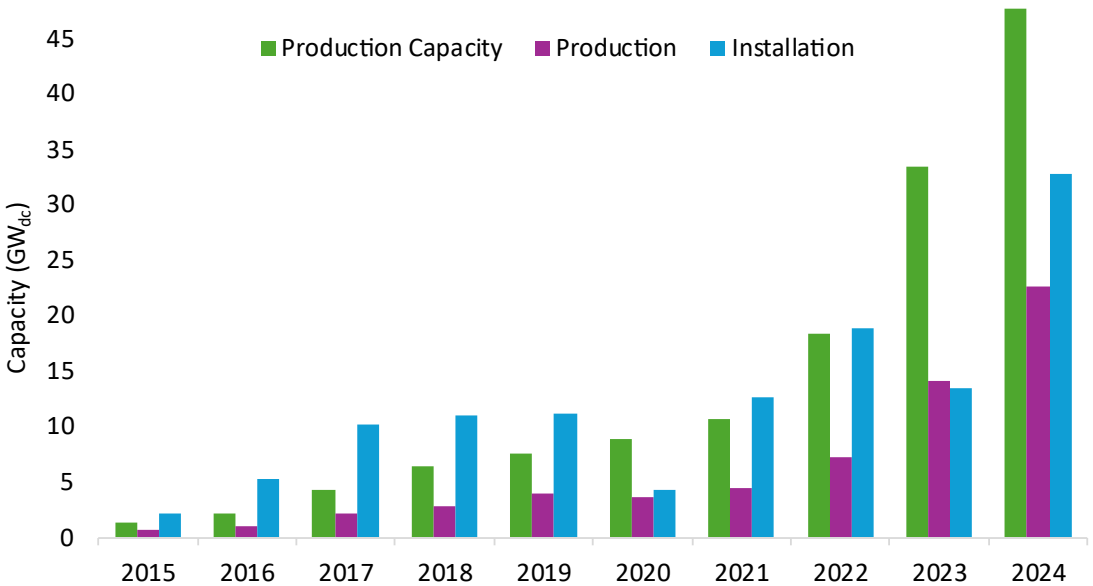


Sources: BNEF, 1Q 2025 Global PV Market Outlook, February 2025; BNEF, Pakistan Cuts Solar Buyback Price After Chinese Panel Boom, March 2025; BNEF, Pakistan's Unrecorded Solar Boom Shows Up From Space, April 2025; BNEF, Surprise Solar Boom in Pakistan Helps Millions, But Harms Grid, November 2024; IEA PVPS, 2025 Snapshot of Global PV Markets, April 2025; InfoLink, Solar Energy in Pakistan: A Growing Market, November 2024; PV Magazine, Pakistan's Net-Metering Solar Capacity Hits 4 GW, March 2025; Wood Mackenzie, The mystery of Pakistan's sudden solar boom, December 2024

- The IEA reported Pakistan's rapid rise to fourth place in annual global PV deployment in 2024, with 17 GW_{dc} installed.
  - The IEA emphasized the uncertainty in the data, saying that Pakistan imported 24 GW_{dc} of modules across 2023 and 2024 (per China's Chamber of Commerce).
  - Industry analysts developed a range of estimates.
- Drivers of this growth include high and rising electricity costs, unreliable grid electricity, availability of imported modules at record-low prices, and the proliferation of module importers and resellers.
- Policies have also driven PV deployment.
  - Favorable net-metering terms were available until March 2025.
  - Provincial policies have subsidized residential PV installations.
- The vast majority of Pakistan's PV installations are in the residential and commercial/industrial sectors, including on- and off-grid systems.
- The rapid PV growth is raising concerns about the stability and financial viability of the traditional grid in Pakistan, which is burdened by high borrowing costs.
  - Energy storage may play a critical role in sustaining the PV market.

Indian Market Update

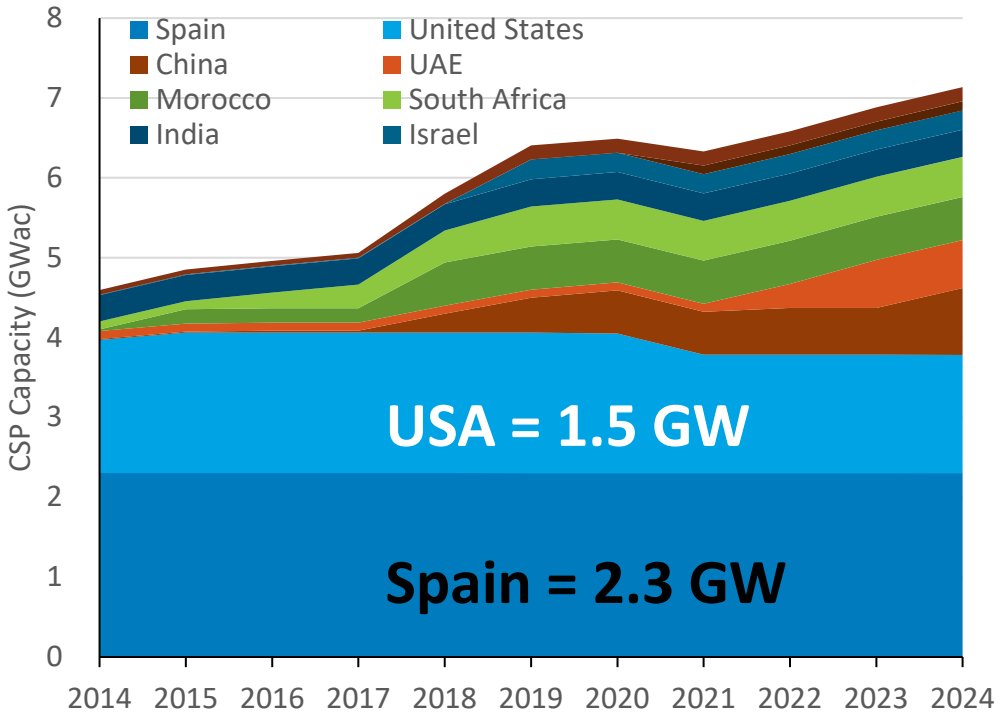
India's Annual PV Installations, Module Production, and Module Production Capacity



- India installed about 6 GW_{dc} of PV in Q4 2024 and 32.9 GW_{dc} in all of 2024.
  - This represented a 74% increase over the previous high of 18.9 GW_{dc} installed in 2022.
- Between 2022 and 2024, India's domestic module production and production capacity roughly tripled.
- India uses tariff and non-tariff barriers to balance domestic manufacturing goals with installation goals.
  - Imported modules are subject to a 40% tariff, and cells are subject to a 25% tariff.
  - Modules used in many projects must be on the government's Approved List of Models and Manufacturers (ALMM), which contains only Indian products.
- India imported 24 GW_{dc} of modules in 2024.
  - These were mostly Chinese modules, which cost less than Indian modules, even after tariffs.
  - The ALMM was suspended between April 2022 and April 2024, which promoted the influx.
- 5 GW_{dc} of modules were exported, mostly to the United States.
  - Excess production capacity could be leveraged to support domestic installation as well as exports.

Sources: BNEF, 1Q 2025 Global PV Market Outlook, February 2025; PV Tech, PV Manufacturing & Technology Quarterly Report - Release 35, March 2025; Mercom India, State of Solar PV Manufacturing in India: 2025, April 2025

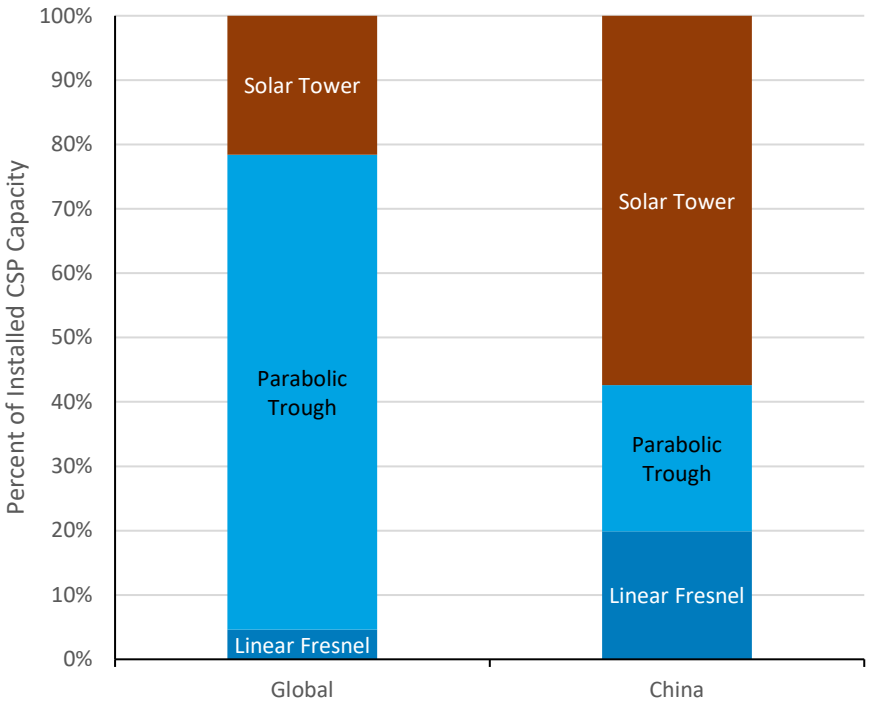
Global CSP Capacity (Operational)



- At the end of 2024, global CSP capacity reached approximately 7 GW_{ac}, with virtually all the installed CSP capacity (three projects, totaling 250 MW_{ac}) located in China.
- Spain continued to have the largest installed CSP capacity, at 2.3 GW_{ac}, followed by the United States, with 1.5 GW_{ac}.
- CSTA reports that there are approximately 34 additional CSP projects in China, totaling 3.3 GW_{ac}, most of which are expected to be completed in 2025.

Sources: International Renewable Energy Agency (IRENA), Renewable Capacity Statistics 2025, March 2025; Chinese Solar Thermal Alliance, Blue Book of China's Concentrating Solar Power Industry 2024, February 2025

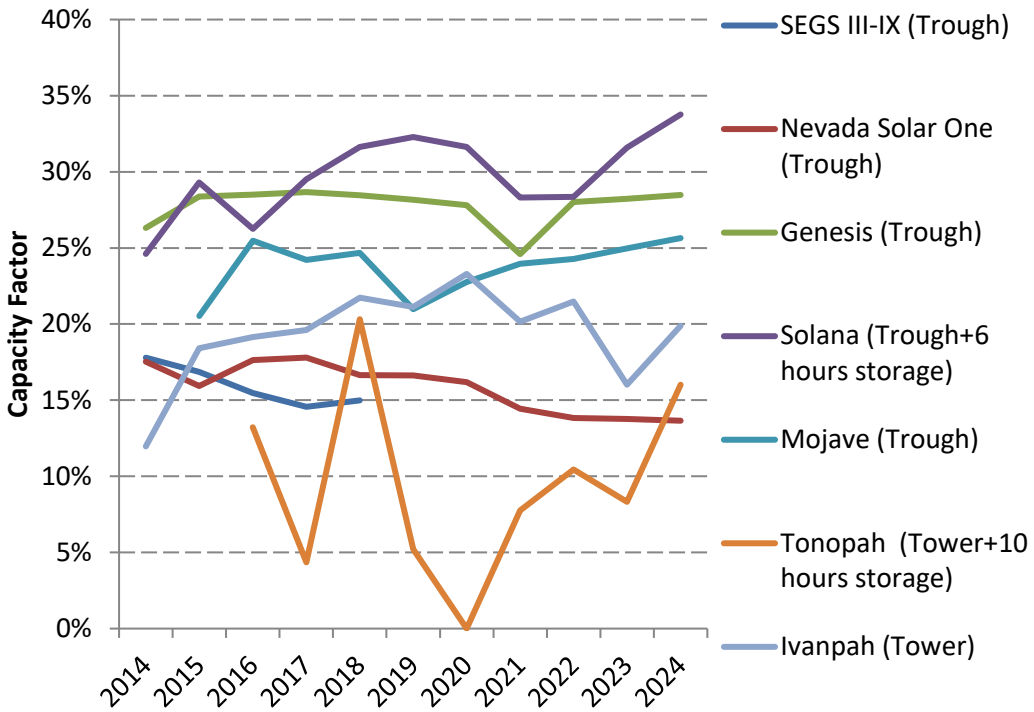
Global CSP Capacity Technology



- Globally, most CSP plants use parabolic trough technology (74% of CSP plants worldwide). CSTA reported that the United States brought the CSP technology to scale in the 1980s using parabolic troughs. When Spain began its build-out of CSP, financiers required reference cases to improve the creditworthiness of the technology, so almost all of Spain's 2.3 GW_{ac} of CSP plants also use parabolic troughs.
- Since then, countries have supported innovation to lower CSP costs (including the United States through the Loan Programs Office).
- China, which has only begun to build out CSP capacity in the last 7 years, now relies more heavily on other technologies—particularly solar towers.

Source: Chinese Solar Thermal Alliance, Blue Book of China's Concentrating Solar Power Industry 2024, February 2025

U.S. CSP Project Generation Performance, 2014–2024



- Over the past decade, since the LPO-funded CSP plants came online, performance has generally been more consistent for the trough plants than for those using tower technologies.
  - The two U.S. tower plants had improved performance in 2024, with Tonopah's annual production its second highest on record (though all the LPO-funded trough plants also had their highest or second-highest performance on record).
  - Annual weather variation can cause some of the differences in annual production.
- Absolute capacity factor is not necessarily the best metric for performance, as plants can be designed and operated differently.

Source: EIA, Form 923, May 2025

CSP Update

- SolarPACES reported that PG&E's decision to end its 25-year contract with the Ivanpah CSP tower facility early was because it did not include energy storage, instead using water for heat transfer, and so is not dispatchable for long periods of time (unlike Crescent Dunes tower plant in Nevada, with 10 hours of storage).
  - PG&E was confident it would have enough storage at the Hetch Hetchy pumped-hydro facility; however, droughts have cut into the facility's ability to provide storage.
  - The water-based design has not allowed the plant to operate optimally.
  - Since Ivanpah was installed, all CSP tower plants installed globally have included storage, using molten salt or other non-water thermal energy storage media.
- A new study from Spain has introduced the application of AI to improve the efficiency and safety of CSP towers by dynamically adjusting the position of heliostats to changing solar conditions automatically. To date, the system has not been used on an operating facility.

CSP Update (Solar Industrial Heating)

- The solar heat in industrial processes (SHIP) market is reportedly growing globally, with more than 100 projects installed each year from 2022 to 2024.
  - Solarthermalworld.org reported that 120 MW of solar industrial heat projects were installed in 2024, up from 94 MW in 2023.
  - 125 MW of projects were under construction at the end of 2024.
- Most of the SHIP projects are small projects in Europe; however, by capacity, the industry is dominated by several large-scale projects.
  - An 80-MW parabolic trough field was installed in China in 2024, supplying snow to an indoor ski hall.
  - Three Chilean mining projects using flat-plate collectors, totaling 154 MWth, are scheduled to be commissioned by 2027.
  - The 1-GW Glasspoint parabolic trough at an aluminum production facility in Saudi Arabia has been delayed, with a 9-MW demonstration project scheduled instead for 2026.

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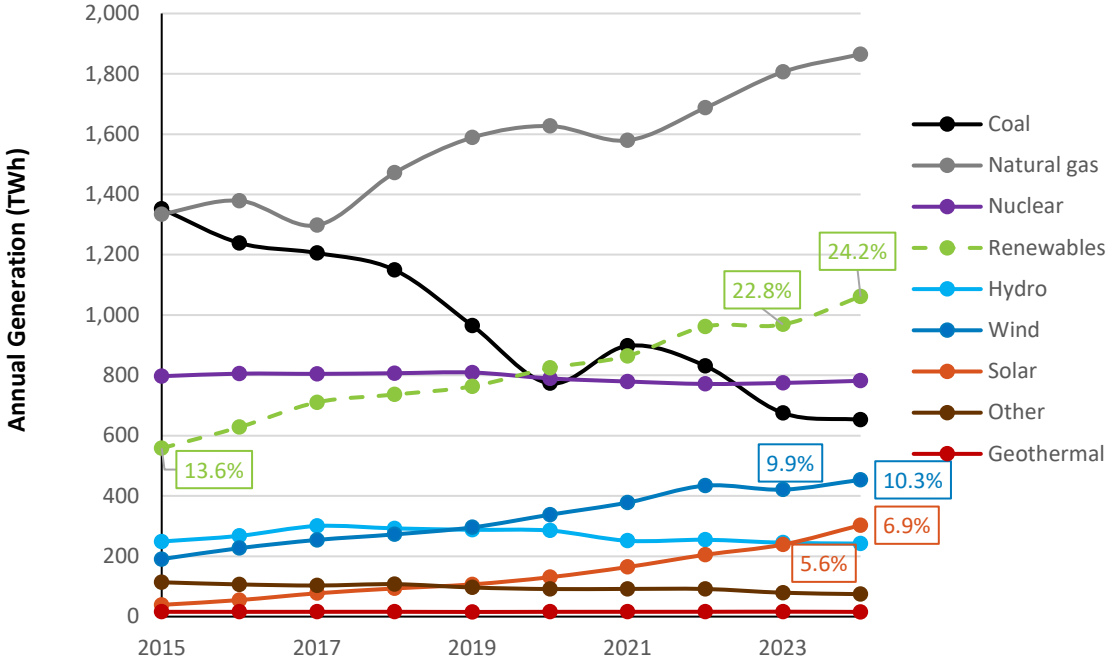
U.S. Generation, 2015–2024



- In 2024, the United States generated 4,389 terawatt-hours (or 4.4 petawatt-hours) of electric power.
- Energy generation from renewables continued its steady upward trend, mostly because of increases in solar generation.
  - Together, utility-scale solar and wind generation accounted for more power than coal generation.
  - Solar overtook hydropower to be the second-largest source of renewable energy generation in the United States.
- The percentage of electricity generated by fossil fuels in the United States dropped from 67% in 2015 to 58% in 2024, while the percentage of electricity generated by renewable energy sources increased from 14% to 24% over the same period.
- In 2024, renewable energy facilities continued to produce more electricity than both nuclear and coal sources, despite hydropower generating its lowest level of power since 2001.
  - Drought conditions in the western United States continued to hamper hydropower generation.

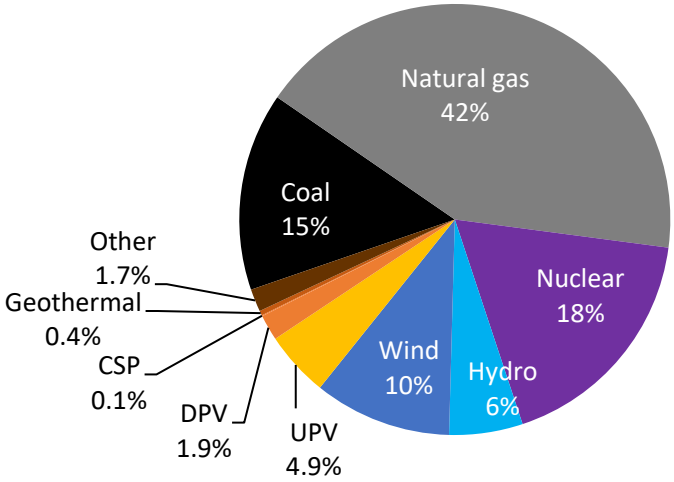
Sources: EIA, Electric Power Monthly, forms EIA-023, EIA-826, and EIA-861, February 2025; EIA, Drought conditions reduce hydropower generation, particularly in the Pacific Northwest, November 2024

2024 U.S. Generation and Capacity

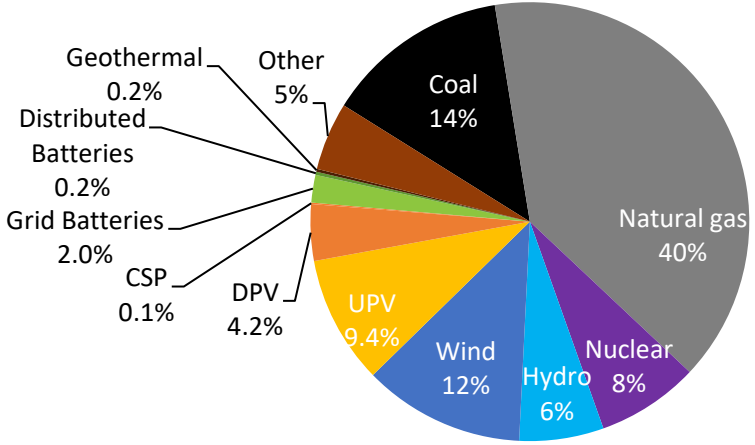
- Renewables are becoming an increasingly large part of the U.S. electric generation mix, representing 33% of capacity and 24% of generation in 2024.
  - All non-carbon energy sources—including solar, wind, nuclear, hydropower, and geothermal—represented 41% of capacity (excluding storage) and 40% of generation in 2024.

- At the end of 2024, solar was the second-largest source of U.S. generation capacity, though still a growing percentage of the U.S. electric generation mix.
  - In 2024, solar represented 13.7% of net summer capacity and 6.9% of annual generation.
- Capacity is not proportional to generation, as certain technologies (e.g., natural gas) have lower capacity factors than others (e.g., nuclear).

2024 U.S. Generation (Total 4,389 TWh)

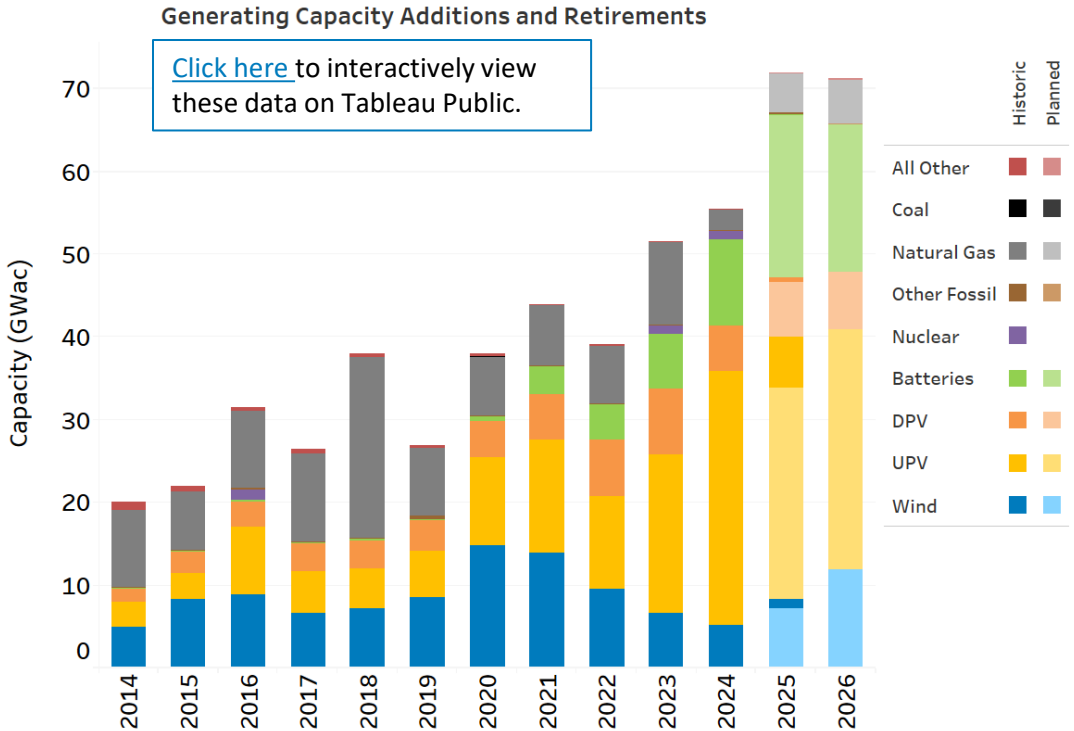


2024 U.S. Generation Capacity (Total 1.3 TW)



Sources: EIA, Electric Power Monthly, forms EIA-023, EIA-826, and EIA-861, February 2025

U.S. Generation Capacity Additions and Retirements by Source: 2013–2024 and Planned 2025–2026

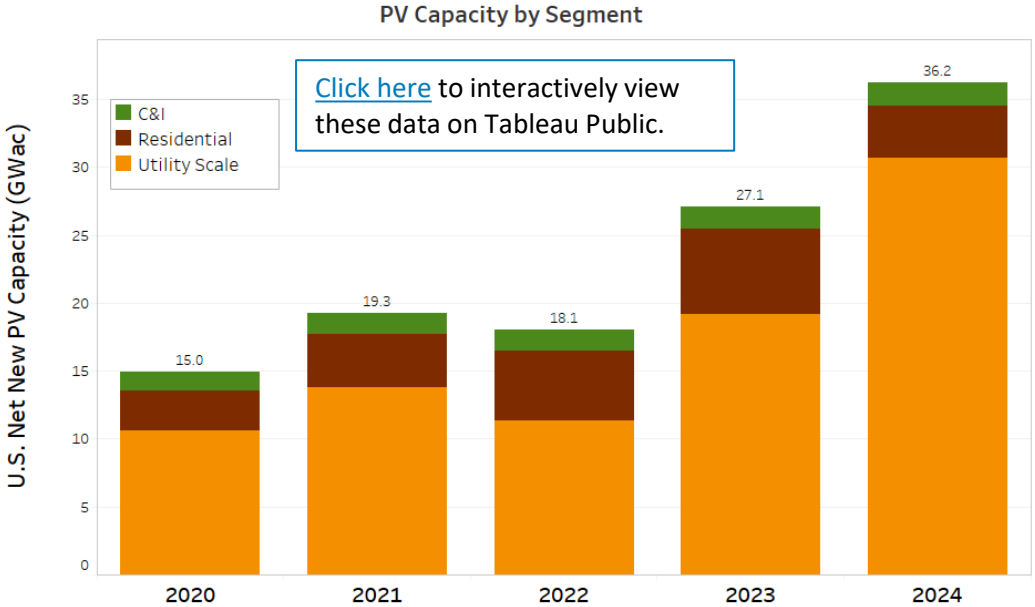


- EIA projects that PV's growth in 2023 (27 GW_{ac}) and 2024 (36 GW_{ac}) will continue in 2025 (39 GW_{ac}) and remain at similar levels in 2026 (36 GW_{ac}).
  - At the end of 2024, solar was the second-largest source of electricity generation capacity in the United States.
- Over the next 2 years, virtually all new electric generation capacity will be PV, batteries, and wind.
  - 10 GW_{ac} of natural gas additions are also projected over that time.

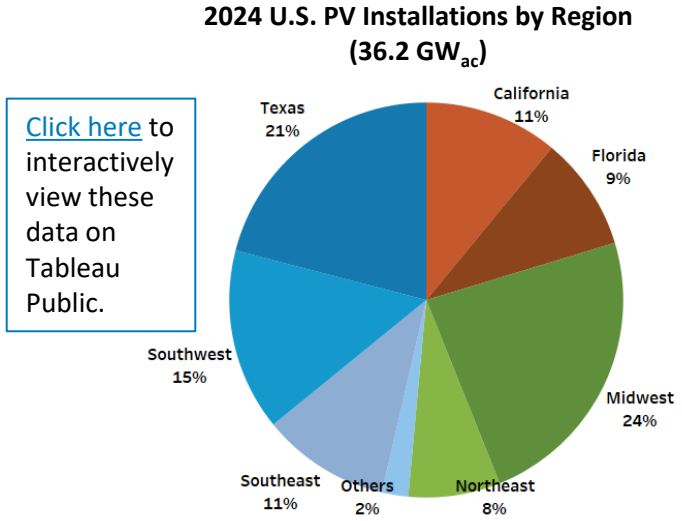
Sources: EIA, EIA Form 860M/Preliminary Monthly Electric Generator Inventory ("Planned" and "Operating") and EIA Short-Term Energy Outlook, Table 7e, downloaded February 2025

U.S. Installation Breakdown Annual: EIA (GW_{ac})

- The United States installed 36.2 GW_{ac} of PV in 2024—up 34% y/y.
  - In 2024, utility-scale (30.6 GW_{ac}) and C&I (1.7 GW_{ac}) PV were up 60% and 5%, respectively, while residential (3.9 GW_{ac}) PV was down 39%.



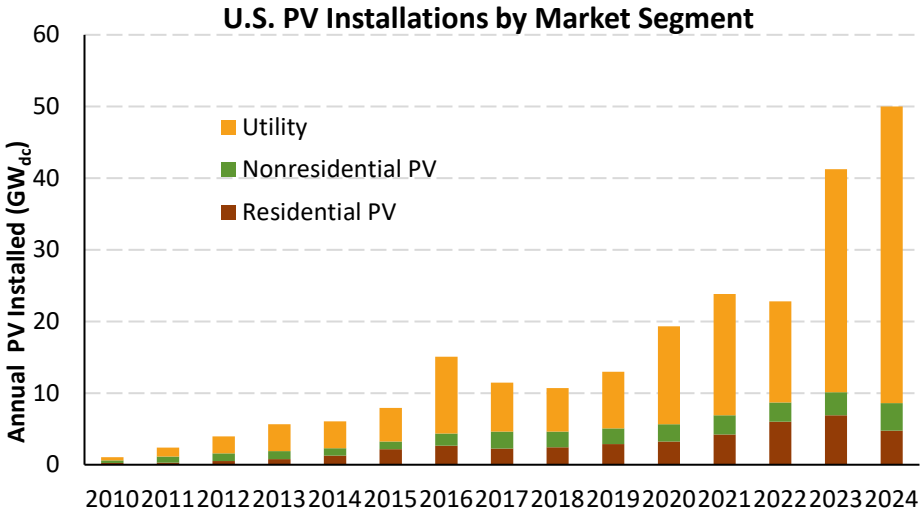
- Approximately 41% of U.S. PV capacity installed in 2023 was in Texas, Florida, and California.
- Despite a concentration of PV installations in the top three markets, diversification of growth continues across the United States.
  - 39 states installed more than 100 MW_{ac} in 2024, and 12 states installed more than 1 GW_{ac}.



Note: EIA reports values in W_{ac}, which is standard for utilities. The solar industry has traditionally reported in W_{dc}.
Sources: EIA, Electric Power Monthly, forms EIA-023, EIA-826, and EIA-861, April 2025.

U.S. Installation Breakdown Annual: SEIA (GW_{dc})

- SEIA reports that the United States installed 50.0 GW_{dc}* of PV in 2024 (235.6 GW_{dc} cumulative)—an annual increase of 21% y/y.
  - This included 41.4 GW_{dc} of UPV (+33% y/y), 3.9 GW_{dc} of nonresidential (+19% y/y), and 4.7 GW_{dc} of residential (-31% y/y).
- Q4 2024 installations totaled 18.8 GW_{dc}.



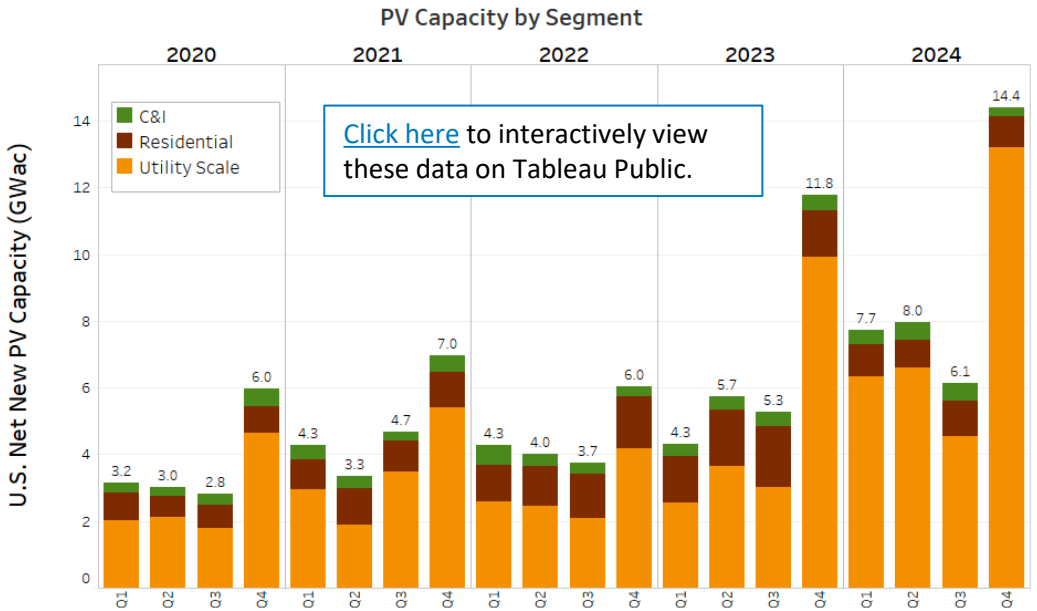
* Wood Mackenzie/SEIA differ from EIA in what is considered an "operational" project.

Sources: Wood Mackenzie/SEIA, U.S. Solar Market Insight: Q4 2024, December 2024

Unlike the previous slide, these values are in GW_{dc}—not GW_{ac}.

- In 2024, 43% of installed capacity occurred in Texas, California, and Florida. However, 41 states and Puerto Rico installed more than 100 MW.
- The reasons for overall 2025 growth varied by market segment:
  - Installations of larger, nonresidential California projects continued to grow in the second half of 2024 from NEM 2.0 due to the longer development cycle. Community solar project growth was also large in New York, Maine, and Illinois.
  - Utility-scale PV installations were aided by high module inventory levels.
  - The residential PV sector decreased overall growth, contracting 31% due to California's transition to NEM 3.0 and sustained high interest rates across the nation.

U.S. Installation Breakdown Quarterly: EIA (GW_{ac})

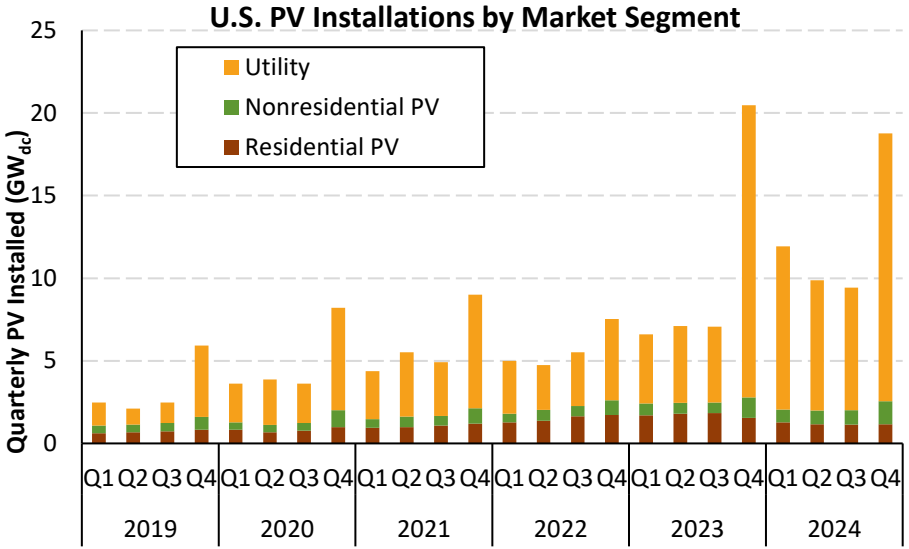


- In Q4 2024, the United Stated installed more than 14 GW_{ac} of solar capacity—up 22% y/y.
- According to EIA data, 40% of 2024 installed U.S. solar capacity occurred in Q4—relatively consistent with previous years, though much greater in absolute terms.
  - Utility-scale PV represented 92% of Q4 2024 solar installations—its highest percentage ever.
- Residential PV installs fell in Q4 2024 q/q (-13%) and y/y (-32%).

Note: EIA reports values in W_{ac}, which is standard for utilities. The solar industry has traditionally reported in W_{dc}. See the next slide for values reported in W_{dc}.
Sources: EIA, Electric Power Monthly, forms EIA-023, EIA-826, and EIA-861, January 2025

U.S. Installation Breakdown Quarterly: SEIA (GW_{dc})

- Wood Mackenzie/SEIA reports 18.8 GW_{dc} of PV installations in Q4 2024—a decrease of 8% y/y.
  - Over this period, utility-scale and residential PV installations decreased 8% and 25%, respectively, while the nonresidential PV sector increased by 13% y/y.

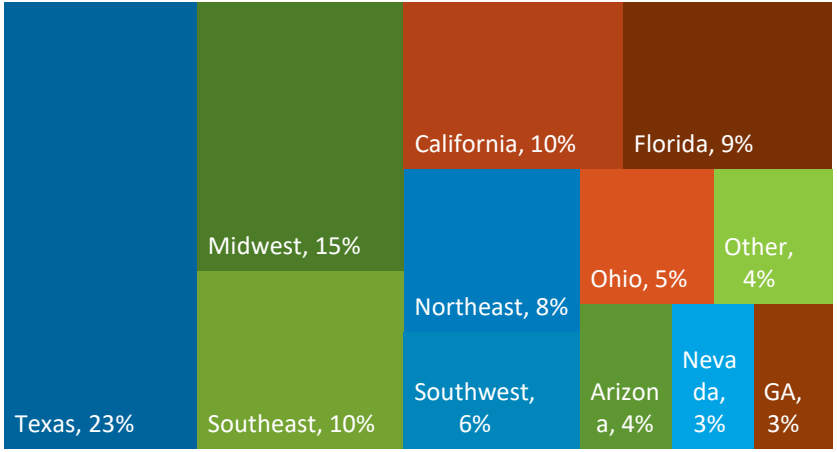


Note: Midwest excludes Ohio; Southeast excludes Florida and Georgia (GA); Southwest excludes Arizona, Texas, and California. **Source:** Wood Mackenzie/SEIA, U.S. Solar Market Insight: Q4 2024, December 2024

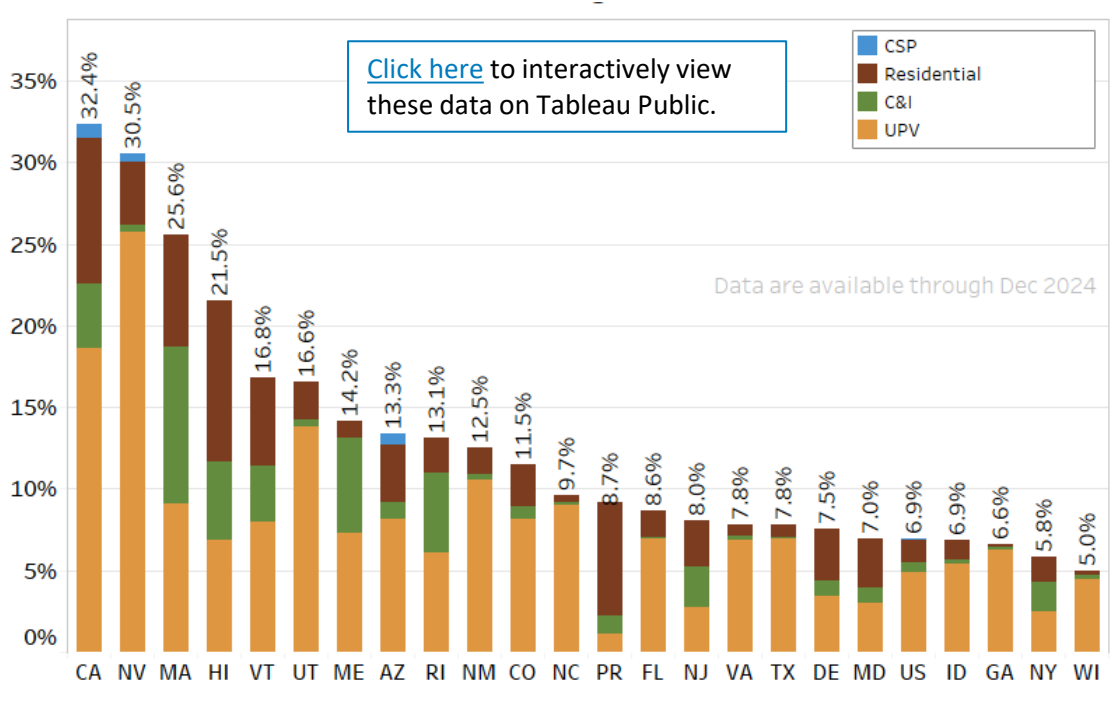
Unlike the previous slide, these values are in GW_{dc}—not GW_{ac}.

- SEIA reports that 79% of 2024 installed capacity occurred in states that installed more than 1 GW_{dc}. For five of those states (Arkansas, Illinois, Indiana, New Mexico, and Ohio), 2024 PV installations represent more than 45% of total PV installs in the state.
- Although 48% of the drop in residential PV installations occurred in California, residential PV in 42 states and territories shrank y/y in 2024.

2024 U.S. PV Installations by Region ($50.0\ GW_{dc}$)



Solar Generation as a Percentage of Total Generation, 2024



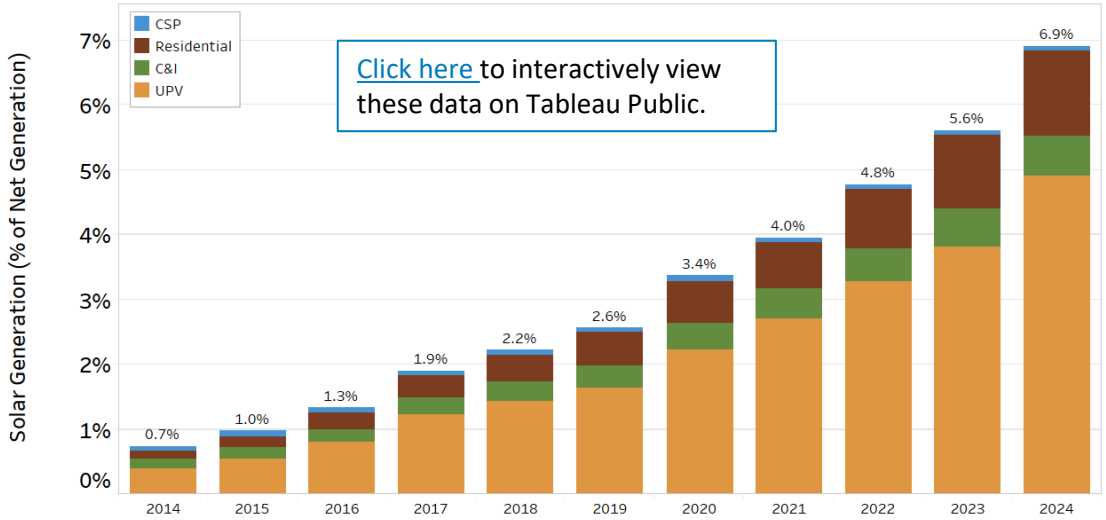
In 2024, 24 states and territories generated more than 5% of their electricity from solar, with California leading the way at 32.4%.

- Six states (California, Nevada, Massachusetts, Hawaii, Vermont, and Utah) generated more than 15% of their electricity using solar.
- Five other states generated more than 10% of their electricity using solar: Maine, Arizona, Rhode Island, New Mexico, and Colorado.

Nationally, 6.9% of electricity was generated from solar in 2024—up from 5.6% in 2023.

The roles of utility-scale and distributed solar vary by state. Southern and western states rely more on utility-scale solar, while northern states and islands rely more on distributed solar.

Solar Generation as a Percentage of Total Generation, 2014–2024

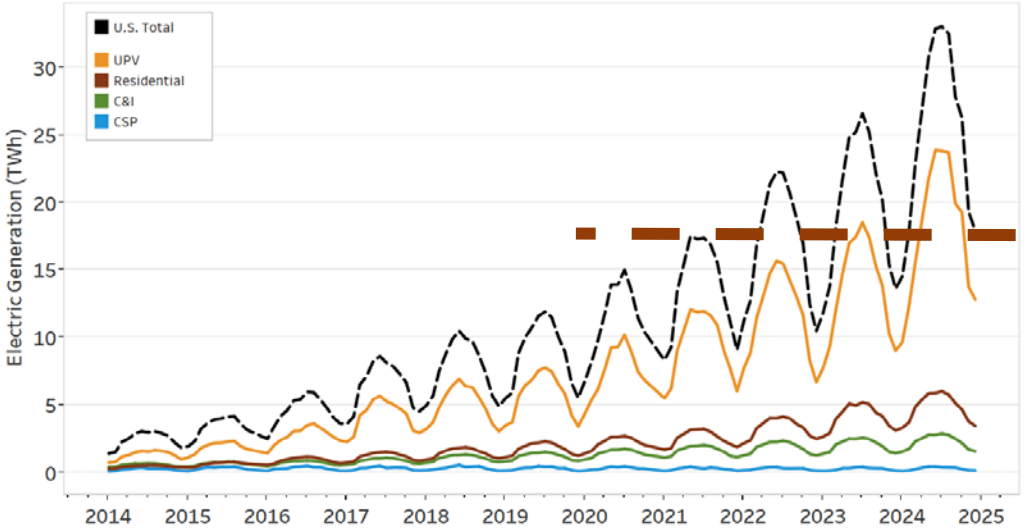


- In 2014, solar produced approximately 0.7% of total U.S. electric generation.
- By 2024, solar grew to about 6.9% of electric generation.
  - 4.9% from utility-scale PV (UPV), a nearly 10-fold increase
  - 1.9% from distributed PV (DPV), a 7-fold increase
  - 0.1% from CSP.

Note: EIA monthly data for 2024 are not final. Additionally, smaller utilities report information to EIA on a yearly basis. Therefore, a certain amount of solar data has not yet been reported.
Source: EIA, Electricity Data Browser, accessed March 12, 2025

Monthly U.S. Solar Generation, 2014–2024

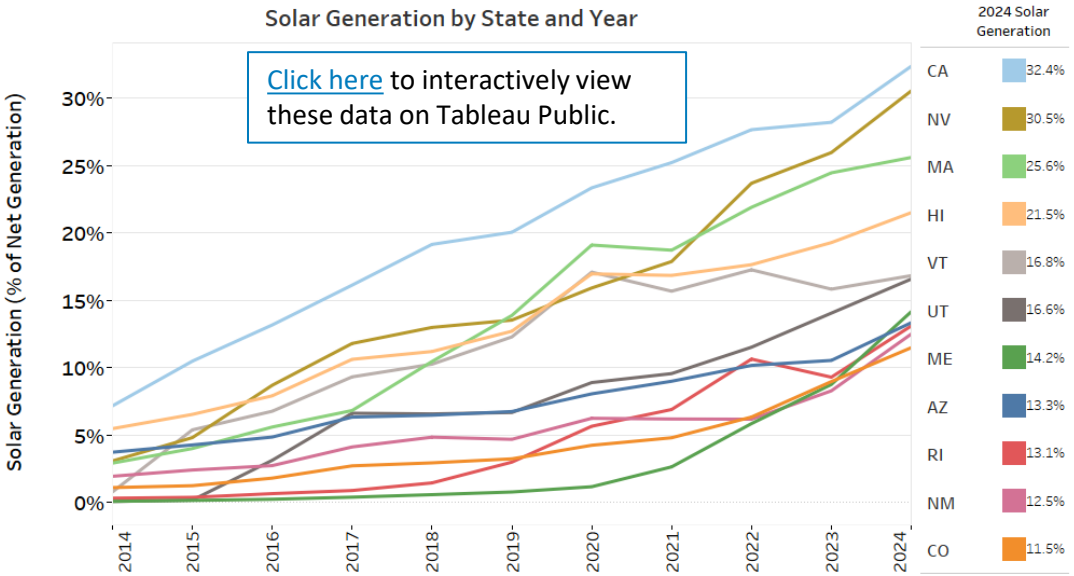
Click here to interactively view these data on Tableau Public.



- Total peak monthly U.S. solar generation increased by a factor of 10 from 2014 to 2024.
  - U.S. electric generation in December 2024 (during the low seasonal period of electric generation) was above the peak level of solar production in 2021 (brown dashed line).
  - In May 2024, solar accounted for 8.7% of all U.S. electricity production, and from March through October 2024, solar accounted for more than 7.5% of all U.S. electricity production.
- Utility-scale solar (including PV and CSP technologies) and C&I PV electricity production dropped by 46% from its summer peak (July 2024) to its winter low (December 2024), and Residential PV systems dropped 43%.
  - The drop in production would likely be greater without continued solar deployment throughout the year.

Note: EIA monthly data for 2023 are not final. Additionally, smaller utilities report information to EIA on a yearly basis. Therefore, a certain amount of solar data have not yet been reported. "U.S. Total" includes DPV generation.
Sources: EIA, Electricity Data Browser, accessed March 12, 2025

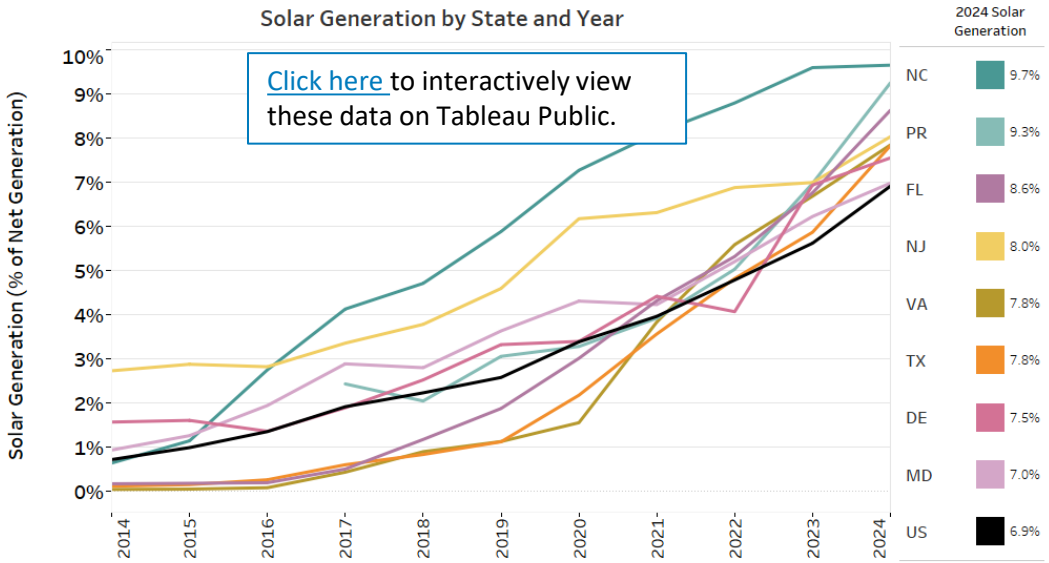
Solar Generation as a Percentage of Total Generation, 2014–2024



- From 2014 to 2024, leading solar deployment states greatly increased solar electricity penetration.
  - California (32%), Nevada (31%), and Massachusetts (26%) led the way in 2024, each generating more than 25% of their electricity generation from solar.
  - An additional eight states generated more than 10% of their electricity generation from solar in 2024.

Note: EIA monthly data for 2024 are not final. Additionally, smaller utilities report information to EIA on a yearly basis, and therefore a certain amount of solar data has not yet been reported. Net generation includes DPV generation. Net generation does not include imports and exports to and from each state. Therefore, the percentage of solar consumed in each state may vary from its percentage of net generation. Some of the increase in some states (e.g., Massachusetts) is due to a reduction in total electricity production in the state.
Source: EIA, Electricity Data Browser, accessed March 12, 2025

Solar Generation as a Percentage of Total Generation, 2014–2024

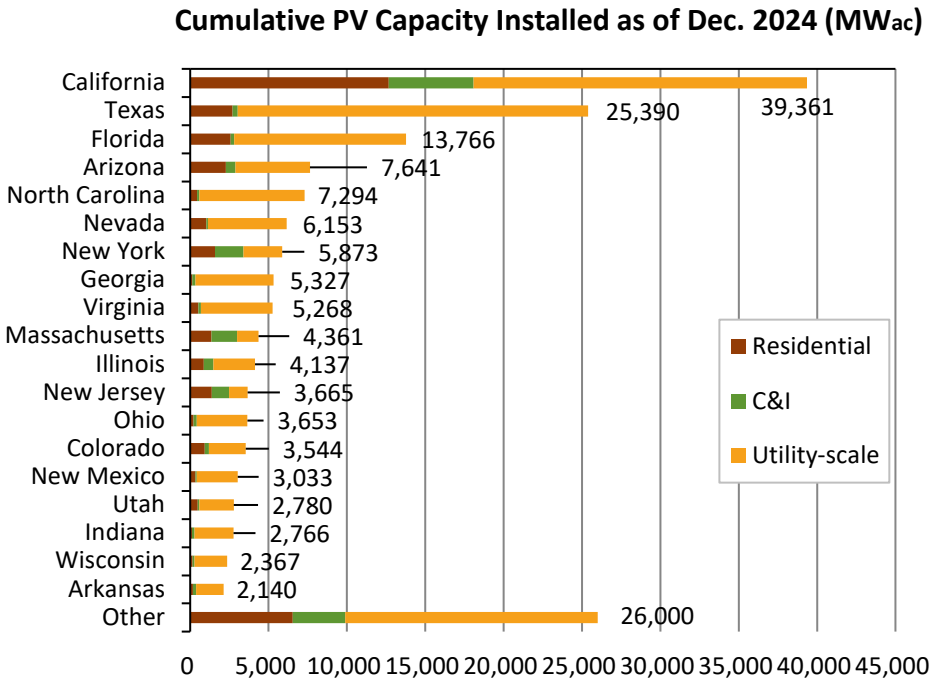


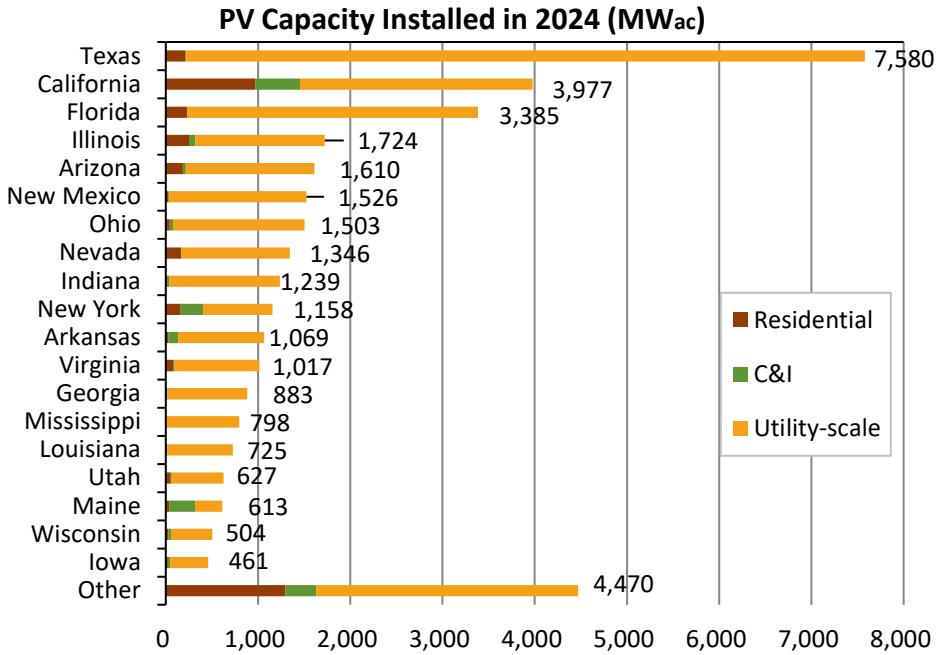
- In addition to the 11 states generating more than 10% of their electricity from solar in 2024, another eight states and territories generated more electricity from solar than the United States as a whole (6.9%).
  - Virginia and Texas have substantially increased solar generation since 2019, going from around 1% of net generation to 8%.

Note: EIA monthly data for 2024 are not final. Additionally, smaller utilities report information to EIA on a yearly basis, and therefore a certain amount of solar data has not yet been reported. Net generation includes DPV generation. Net generation does not include imports and exports to and from each state. Therefore, the percentage of solar consumed in each state may vary from its percentage of net generation. Some of the increase in some states (e.g., Massachusetts) is due to a reduction in total electricity production in the state.
Source: EIA, Electricity Data Browser, accessed March 12, 2025

U.S. Installation Breakdown by State

- At the end of 2024, there were 174.5 GW_{ac} of solar PV systems in the United States, of which 121.2 GW_{ac} were utility-scale PV, 36.5 GW_{ac} were residential PV, and 16.9 GW_{ac} were C&I PV.
- In 2024, three states installed >3 GW_{ac} (Texas, California, and Florida), and 12 installed >1 GW_{ac} (+Illinois, Arizona, New Mexico, Ohio, Nevada, Indiana, New York, Arkansas, and Virginia).

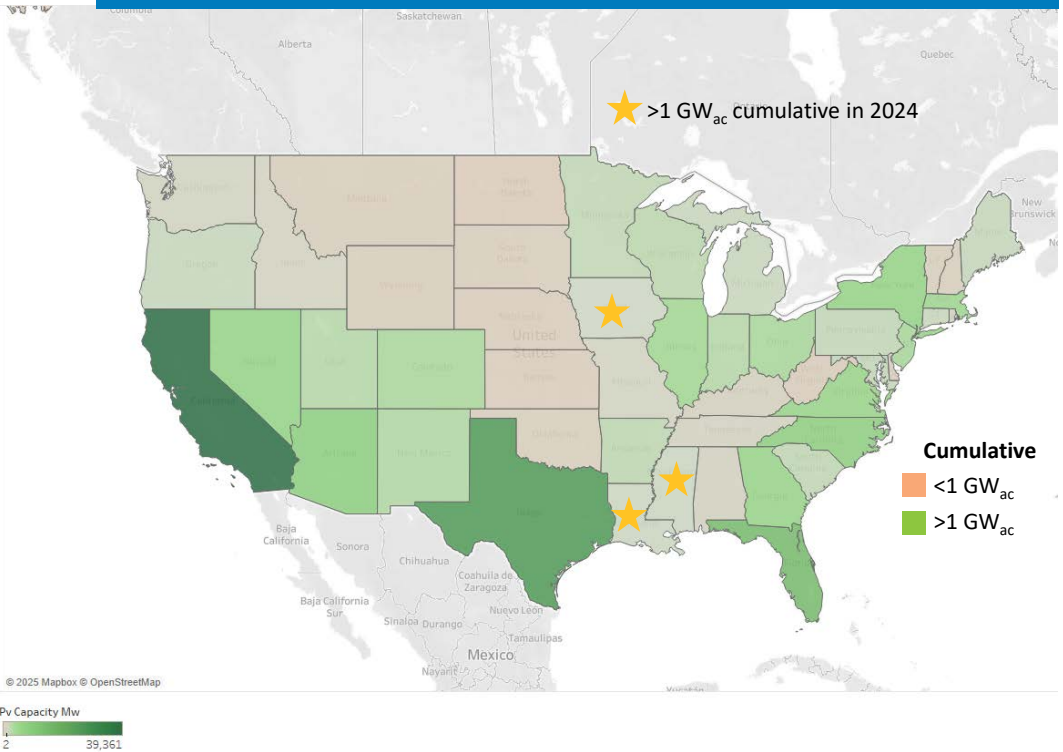




Note: EIA monthly data for 2024 are not final. Additionally, smaller utilities report information to EIA on a yearly basis. Therefore, a certain amount of solar data have not yet been reported. Florida's and Louisiana's C&I installations in 2023 were net negative.

Sources: EIA, Electric Power Monthly, forms EIA-023, EIA-826, and EIA-861, January 2025

Cumulative U.S. Installation Breakdown by State



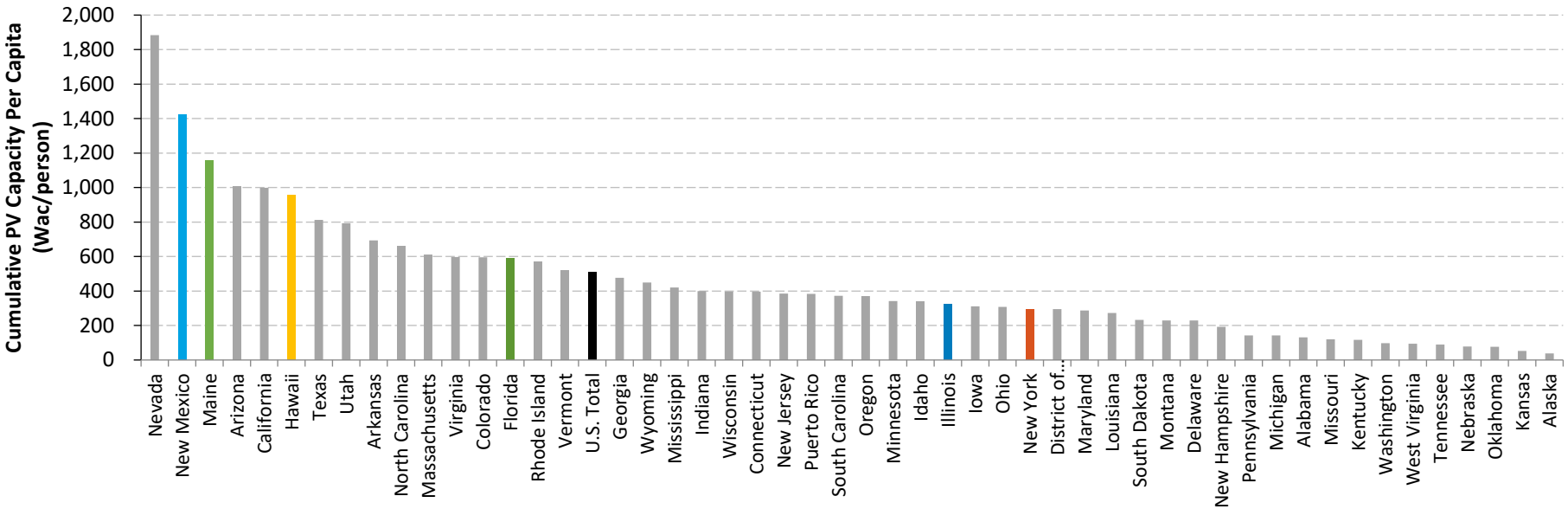
At the end of 2024, 31 states had >1 GW_{ac} of solar installed cumulatively, with Louisiana, Mississippi, and Iowa joining the ranks in 2024.

Note: EIA monthly data for 2024 are not final. Additionally, smaller utilities report information to EIA on a yearly basis. Therefore, a certain amount of solar data have not yet been reported.

Sources: EIA, Electric Power Monthly, February 2025

Cumulative U.S. PV Capacity Per Capita (2024)

- Some large states that ranked high in total cumulative capacity at the end of 2024, such as Florida (#3), New York (#7), and Illinois (#11), are lower in the rankings when looking on a watts per capita basis. Florida drops to #14, New York to #32, and Illinois to #29.
  - Conversely, New Mexico, Maine, and Hawaii, which ranked at #15, #24, and #28 in cumulative PV capacity, are #2, #3, and #6 on a PV watts per capita basis, respectively.

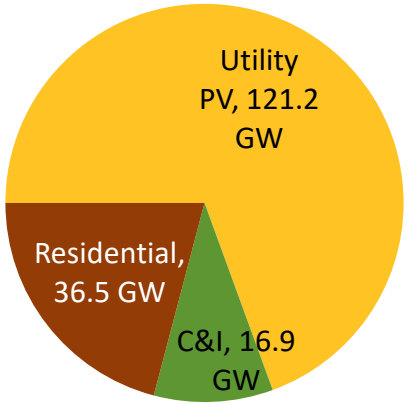


Note: EIA monthly data for 2024 are not final. Additionally, smaller utilities report information to EIA on a yearly basis. Therefore, a certain amount of solar data have not yet been reported. **Sources**: EIA, Electric Power Monthly, forms EIA-023, EIA-826, and EIA-861, February 2025; U.S. Census Bureau, State Population Totals and Components of Change: 2020-2024, December 2024

U.S. PV Installation Breakdown Annual: EIA (GW_{ac})

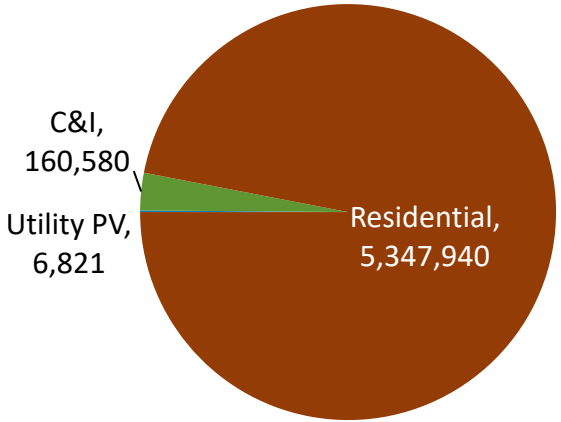
- At the end of 2024, there were 174.5 GW_{ac} of cumulative PV installations.
- EIA reports that at the end of 2024, 69% of U.S. installed PV capacity was from utility-scale PV systems.

Cumulative U.S. PV Installations as of December 2024 (174.5 GW_{ac})



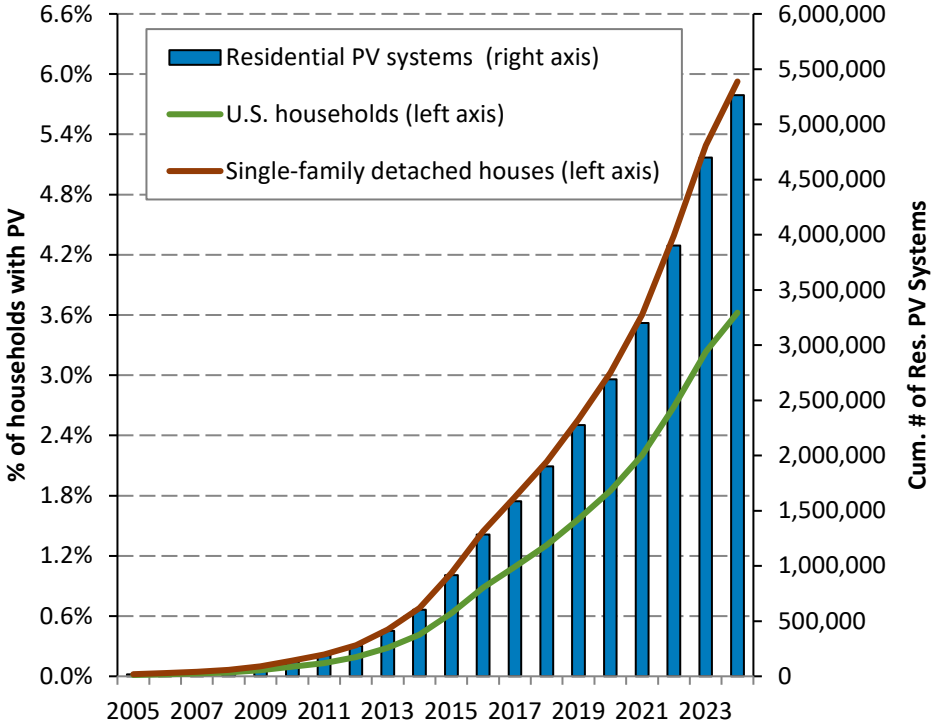
- Despite representing only 21% of installed U.S. PV capacity at the end of 2024, 97% of PV systems—more than 5.3 million systems—were residential applications.
  - In 2024, the United States installed 531,000 PV systems, of which 516,000 were residential (-42% y/y), 14,000 were C&I (+10% y/y), and 505 were utility-scale (+27% y/y).

Cumulative U.S. PV Installations as of December 2024 (5.3 million systems)



Sources: EIA, Electric Power Monthly, forms EIA-860, and EIA-861, April 2025.

U.S. Residential PV Penetration

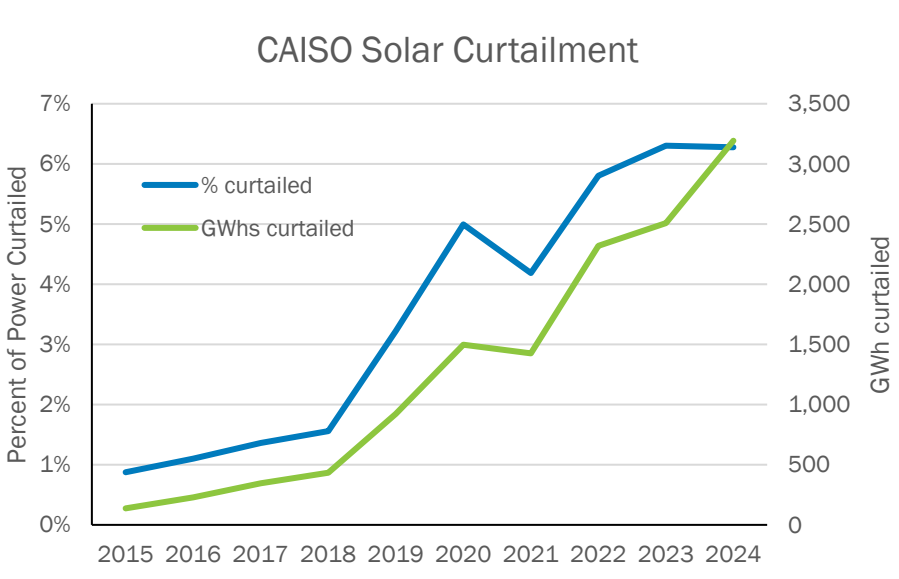


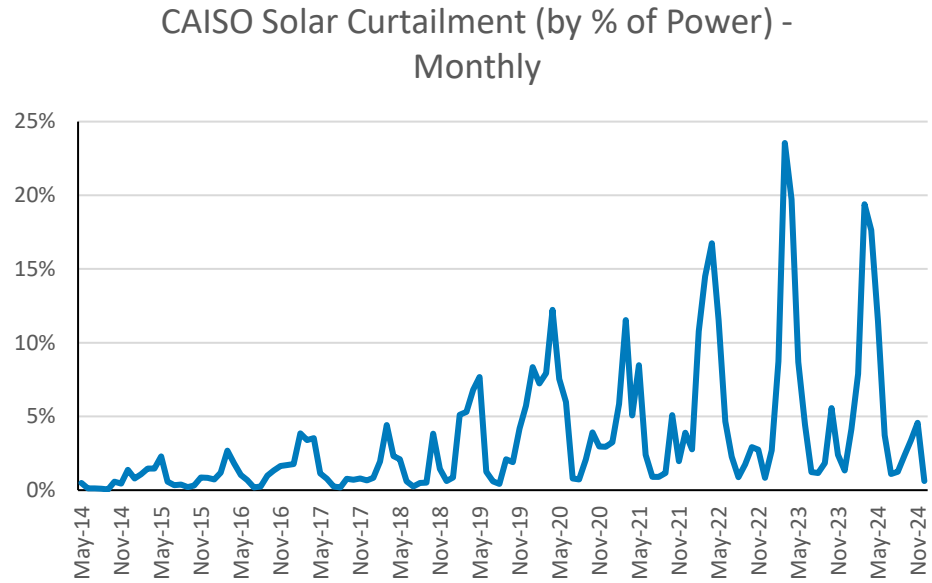
- Since 2005, when Congress passed the investment tax credit, the number of annually installed residential PV systems has grown by approximately 35% per year, or over 280X.
- SEIA estimates that at the end of 2025, there were approximately 5.3 million residential PV systems in the United States.
  - Still, only 3.6% of households own or lease a PV system (or 5.9% of households living in single-family detached structures).
  - However, solar penetration varies by location. Hawaii, California, and Arizona have residential systems on an estimated 37%, 25%, and 15% of households living in single-family detached structures, respectively.

Sources: SEIA/Wood Mackenzie, Solar Market Insight 2024 Year in Review, March 2025; U.S. Census Bureau, U.S. Households, accessed data May 20th, 2025; IREC U.S. Solar Market Trends 2009, July 2010

California Curtailment

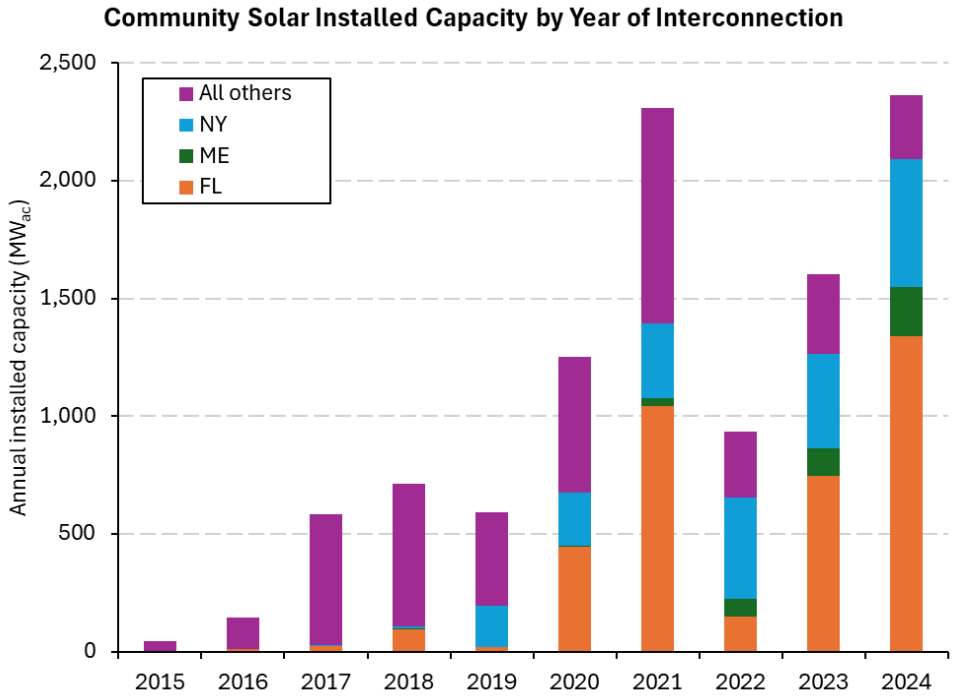
- Curtailment of utility-scale solar increased in CAISO in 2024 but remained flat as a percentage of solar power generated.
- An increase in battery storage might explain the leveling off of storage curtailment as a percent of solar production.
- Though not possible in many cases due to transmission constraints, California has attempted to export its excess solar generation to neighboring states.





Sources: CAISO, Managing the Evolving Grid, 2025; CAISO, Q4 2024 Report on Market Issues and Performance, March 2025

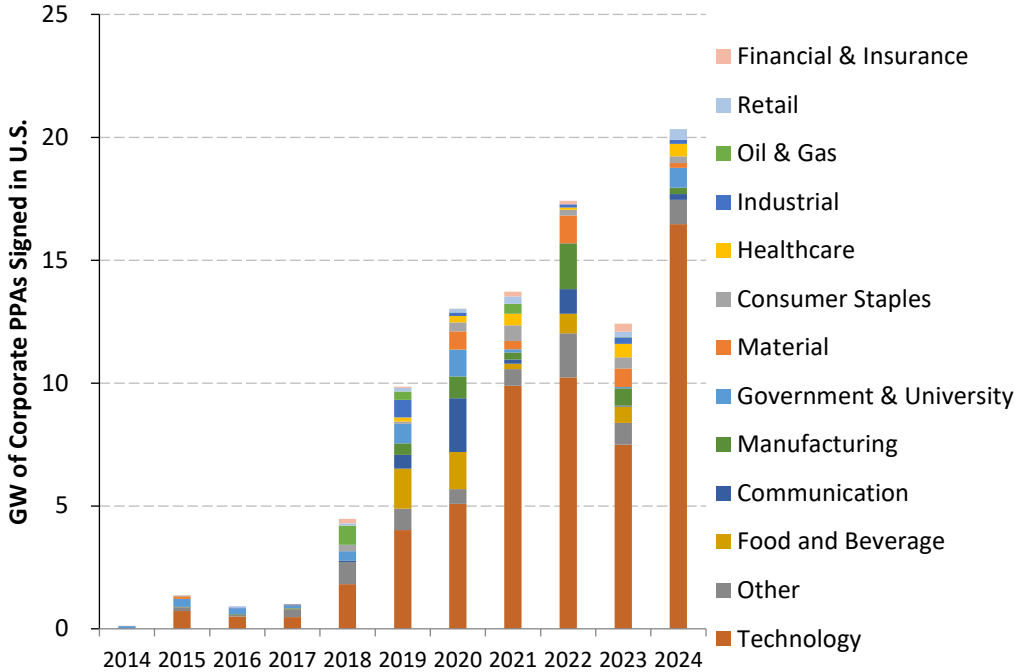
Community Solar



- Cumulative community solar capacity topped 10.6 GW_{ac} in 2024, with 2.4 GW_{ac} interconnected in 2024 alone.
- Most new installations in 2024 were in Florida (1,341 MW_{ac}), New York (545 MW_{ac}), and Maine (206 MW_{ac}).
  - New York's additions increased by 35% from 2023, a potential indication that previous backlogs are being resolved. However, Wood Mackenzie projects that annual installations will decline in 2025.
  - Maine's annual additions increased by almost 80% from 2023, with developers interconnecting most of their expected community solar pipeline before the December 31 net energy billing deadline.
- Wood Mackenzie projects that annual community solar installations will contract beginning in 2025, with a little over 1 GW installed each year for the next 5 years.

Note: Community solar refers to any solar project or purchasing program, within a geographic area, in which the benefits flow to multiple customers, such as individuals, businesses, nonprofits, and other groups. In most cases, customers benefit from energy generated by solar panels at an off-site array.
Source: Wood Mackenzie, Community Solar Outlook H1 2025, February 2025; NREL, Sharing the Sun Project List as of December 2024, accessed April 2025

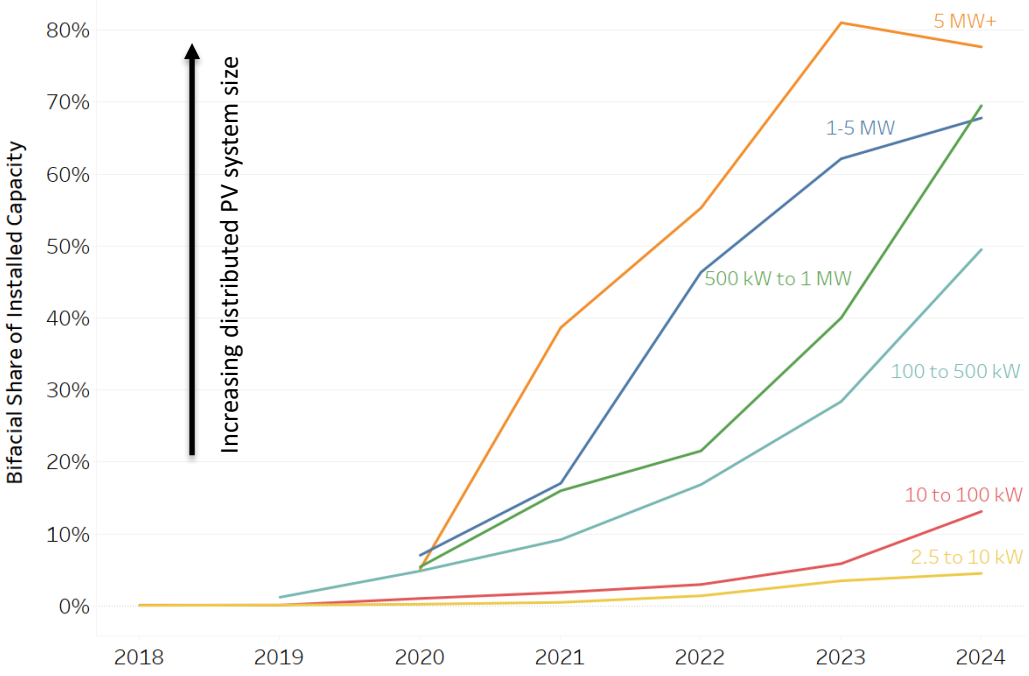
U.S. Off-Site Corporate Solar PPAs



- U.S. corporate solar contracts were up 44% in 2024 y/y. The contracted capacity was 2.4 times larger than it was 5 years ago.
  - The United States represented approximately 52% of the global off-site corporate solar market in 2024, followed by Spain (11%) and India (5%).
  - Most contracts are believed to be “virtual PPAs”; however, there are green tariff programs offered as well.
  - In addition to the 20 GW of U.S. solar PPAs in 2024, companies signed 4 GW of U.S. wind PPAs.
- U.S. off-site corporate PPAs have been dominated by the technology sector, with governments and universities coming in a distant second, followed by the healthcare industry.
  - By the end of 2024, the leading three U.S. off-site corporate solar offtakers were Amazon, Meta, and Microsoft, with a collective 46 GW of PPAs signed.
  - In 2024 alone, Meta signed 4.7 GW, Amazon signed 4.4 GW, and Microsoft signed 2.8 GW of off-site U.S. solar PPAs.

Sources: BNEF, Corporate PPA Deal Tracker, accessed April 2025

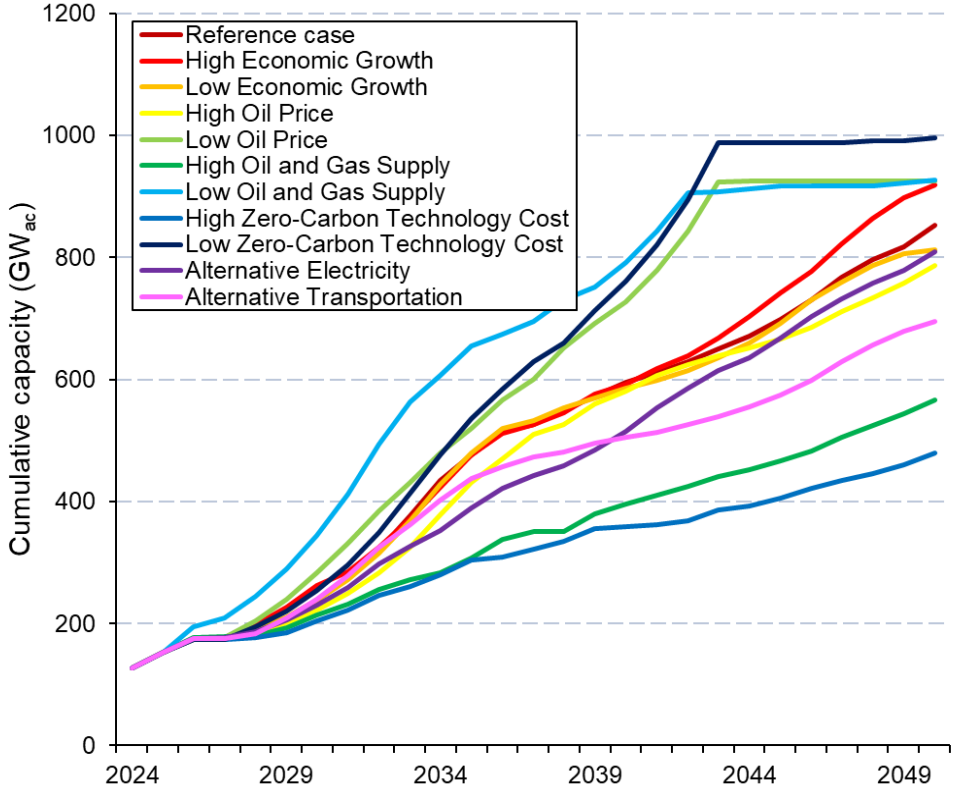
Bifacial Module Surge in Large Distributed PV Systems



- The share of bifacial modules grew in California and New York's distributed PV systems from 2020 to 2024:
  - From 0% of capacity in 2020 to 5% of capacity in 2024 for systems 2.5–10 kW_{dc}
  - From 1% to 13% for systems 10–100 kW_{dc}
  - From 5% to 50% for systems 100–500 kW_{dc}
  - From 5% to 70% for systems 500 kW_{dc} to 1 MW_{dc}
  - From 7% to 68% for systems 1–5 MW_{dc}
  - From 5% to 78% for systems 5+ MW_{dc}.
- Ground-mount and flat-roof nonresidential PV installations can provide bifacial energy gain, but typical sloped residential rooftop installations do not provide bifacial gain.
- Installers may have used bifacial modules to avoid tariff-related module costs. Bifacial modules were exempted from Section 201 tariffs starting in June 2019 and ending in May 2024.
- These distributed PV data do not include utility-scale PV projects, which are the primary application for bifacial modules.

Note: Bifacial modules are defined as having the term "bifacial" in the description field in the California Energy Commission's PV Module List.
Sources: California Distributed Generation Statistics, CA NEM database, January 2025; Data.NY.gov, Solar Electric Programs Reported by NYSERDA: Beginning 2000, January 2025; Solar Power World, Bifacial solar panels are once again exempt from Section 201 tariffs, November 2021; DOE, Solar Futures Study, September 2021

Annual Energy Outlook (AEO) 2025

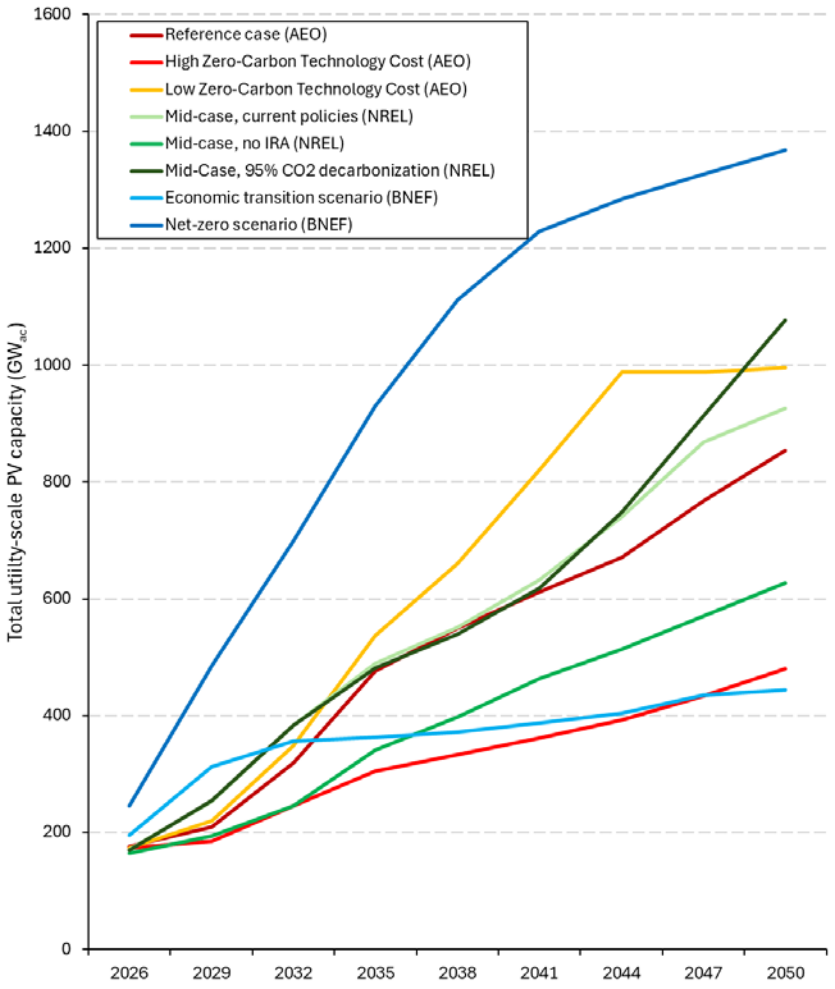


- At the end of 2024, cumulative PV capacity in the United States was approximately 175 GW_{ac}.
- EIA analysts project that, under laws and regulations that were in effect as of December 2024, cumulative utility-scale PV capacity will reach 305–655 GW_{ac} by 2035 and 480–996 GW_{ac} by 2050.
  - The highest deployment projection scenario assumes that the cost of renewable energy will decrease rapidly with increased deployment. Under this scenario, battery storage will reach nearly 320 GW by 2050.
  - The lowest deployment projection scenario assumes that the cost of renewable energy will not continue to decrease with increased deployment. Under this scenario, battery storage will reach 57 GW by 2050.
  - AEO 2025 projections for cumulative PV capacity in 2050 are on average 18% higher than AEO 2023 projections and 4% lower than relevant NREL Standard Scenario projections.
- In addition to the reference case and eight core modeled cases, EIA also ran two alternative policy projection cases this year.
  - The Alternative Electricity case assumes that the EPA will roll back regulations on carbon dioxide emissions from fossil fuel generating units.
  - The Alternative Transportation case assumes that fuel economy standards, tailpipe emission standards, and zero-emission truck sale mandates will not be in place.

Source: EIA, Annual Energy Outlook 2025, April 2025

Long-Term U.S. Projections

- Analysts outside EIA also show wide variation in future projections of cumulative utility-scale PV capacity. Whereas EIA's AEO shows a range of 480–996 GW_{ac} installed by 2050, NREL's Standard Scenarios mid-case shows a range of 627–1077 GW_{ac}, and BNEF projects a range of 444–1369 GW_{ac}.
- For 2050 projections of utility-scale PV capacity, the AEO's reference case is 7.8% lower than NREL's Standard Scenario mid-case and 92.3% higher than BNEF's business-as-usual scenario.
- The NREL Standard Scenarios mid-case assumes median estimates of future technology cost and performance, moderate electricity demand growth (averaging 1.8%/year), and median estimates for future natural gas prices.
    - The mid-case also assumes that all existing state and federal policies as of August 2024 will remain in place. The "no IRA" scenario removes IRA electricity sector tax credits from modeling calculations.
- BNEF's projections use least-cost modeling, and, new this year, they added data centers as a distinct power demand category in their demand forecast models.



Sources: EIA, Annual Energy Outlook 2025, April 2025; NREL, Standard Scenarios, accessed April 2025; BNEF, New Energy Outlook 2025, April 2025
Note: BNEF reports projected cumulative capacity in GW_{dc}. To convert to GW_{ac}, we assumed an inverter loading ratio of 1.2.

U.S. Energy Storage Installations by Market Segment (Energy Storage Association)

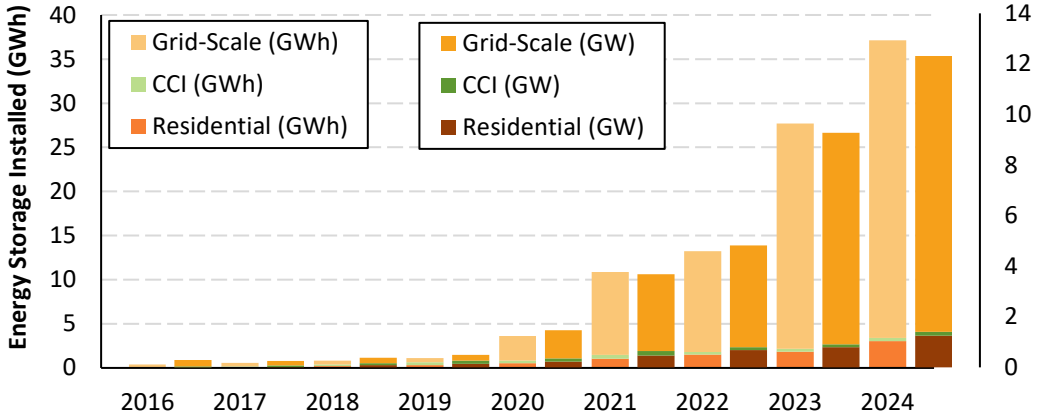
The United States installed approximately 37.1 GWh (12.3 GW_{ac}) of energy storage onto the electric grid in 2024, or +34% (+33%) y/y, with growth in all sectors.

– At the end of 2024, Wood Mackenzie reported 96.0 GWh (33.6 GW_{ac}) of U.S. energy storage.

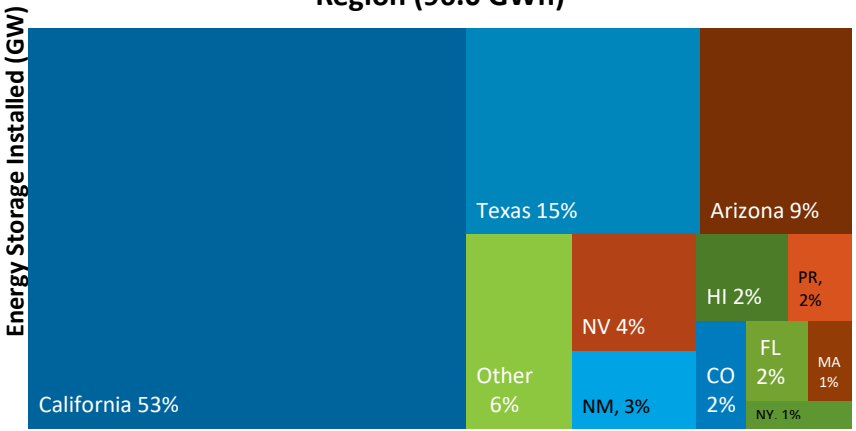
California represented more than half of all installed storage capacity in the United States, followed by Texas, with 15%.

– However, six states installed more than 1 GWh of storage in 2024, and 10 states had cumulatively installed more than 1 GWh by the end of 2024.

U.S. Energy Storage Installations by Market Segment



Cumulative 2024 U.S. Energy Storage Installations by Region (96.0 GWh)



Note: Grid-scale refers to all projects deployed on the utility side of the meter, regardless of size or ownership. CCI refers to community-scale, commercial, and industrial. CO = Colorado; FL = Florida; HI = Hawaii; MA = Massachusetts; NM = New Mexico; NV = Nevada; NY = New York; PR = Puerto Rico

Source: Wood Mackenzie Power and Renewables and Energy Storage Association, U.S. Energy Storage Monitor: Q1 2025

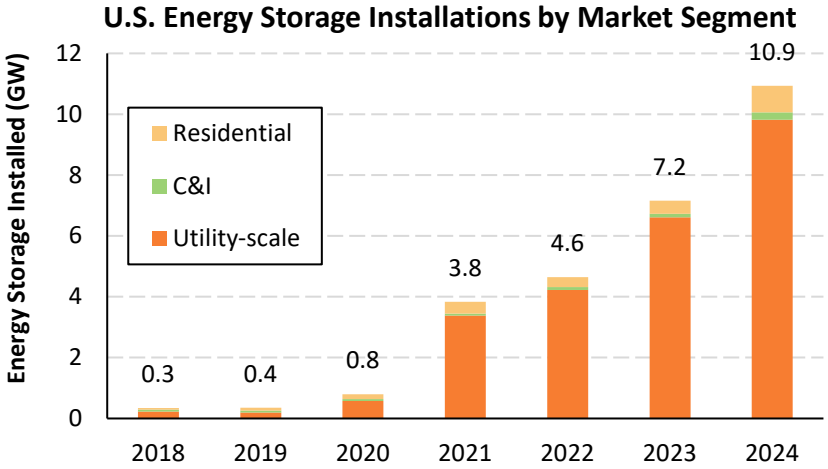
U.S. Energy Storage Installations by Market Segment (EIA)

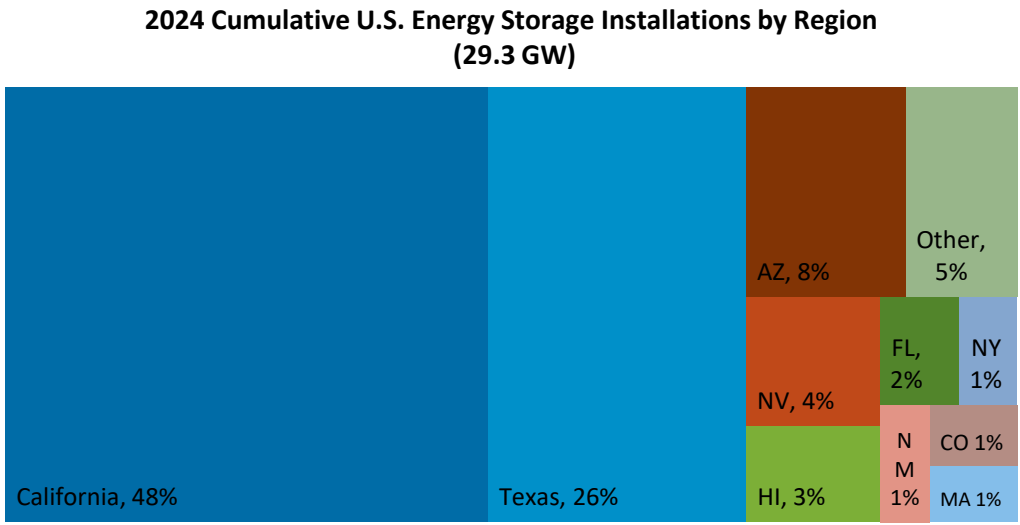
EIA reports that the United States installed approximately 10.9 GW_{ac} of energy storage onto the electric grid in 2024—up 53% y/y as a result of high levels of deployment in all sectors.

– EIA reported a 49% increase in utility-scale, a 99% increase in C&I, and a 102% increase in residential storage installations in 2024 y/y.

At the end of 2024, California represented 48% of cumulative installed battery storage capacity, followed by Texas (26%).

– The top 10 markets represented 95% of installed energy storage capacity.





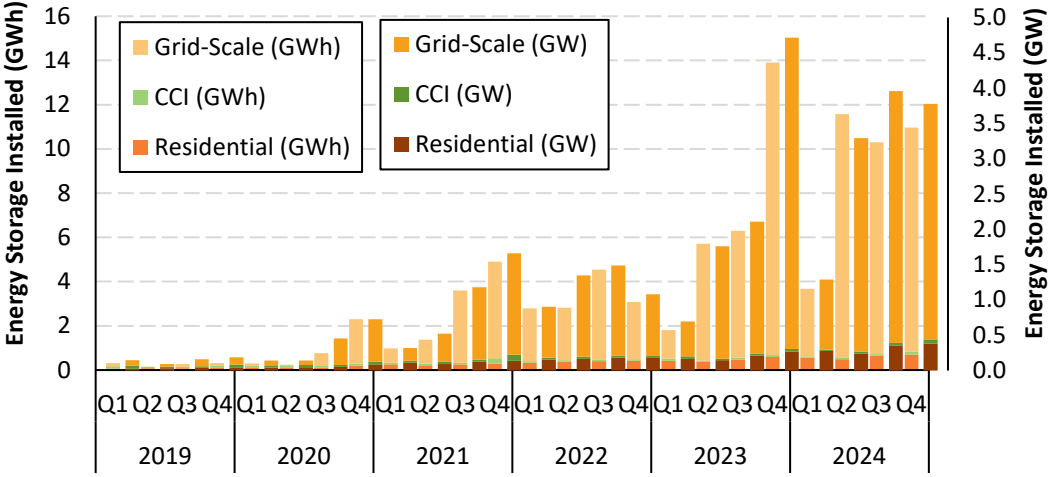
Note: EIA reports no storage from Puerto Rico. AZ = Arizona; CO = Colorado; FL = Florida; HI = Hawaii; MA = Massachusetts; NM = New Mexico; NV = Nevada; NY = New York

Sources: EIA, Form 860M

U.S. Energy Storage Installations by Market Segment (Energy Storage Association)

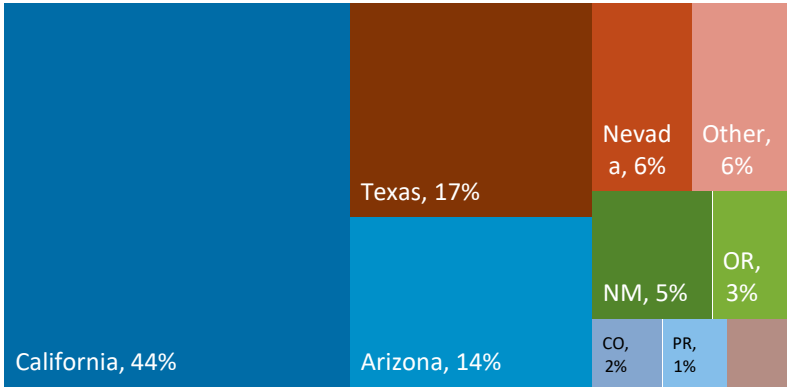
- The United States installed approximately 10.3 GWh (3.8 GW_{ac}) of energy storage onto the electric grid in the fourth quarter of 2024—down 26% y/y.
  - However, U.S. BESS installations in Q2 and Q3 2024 were much larger than in 2023, leading to overall annual growth.

U.S. Energy Storage Installations by Market Segment



- California, Texas, and Arizona represented three-quarters of all 2024 battery installed capacity, with the top nine states representing approximately 92% of the market.
- The U.S. installed a record level of residential BESS in Q4 2024, with California representing 60% of the market. However, the state's residential BESS growth has been tempered by legacy projects, with 23% of residential PV installed in Q4 under NEM 2.0 (which does not incentivize BESS at the same level).

2024 U.S. Energy Storage Installations by Region (37.1 GWh)



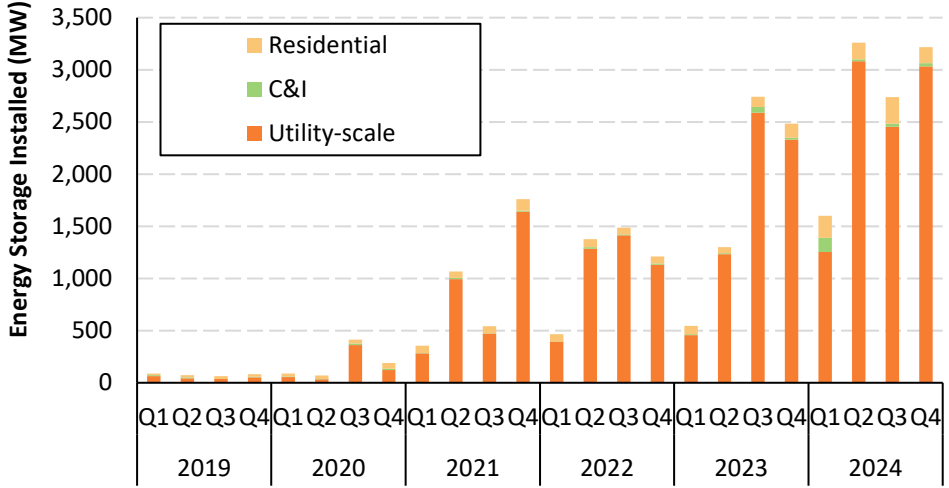
Note: CO = Colorado; NM = New Mexico; OR = Oregon; PR = Puerto Rico. "Grid-scale" refers to all projects deployed on the utility side of the meter, regardless of size or ownership; "CCI" refers to community-scale, commercial, and industrial. **Source:** Wood Mackenzie Power and Renewables and Energy Storage Association, U.S. Energy Storage Monitor: Q1 2025, 2025

U.S. Energy Storage Installations by Market Segment (EIA)

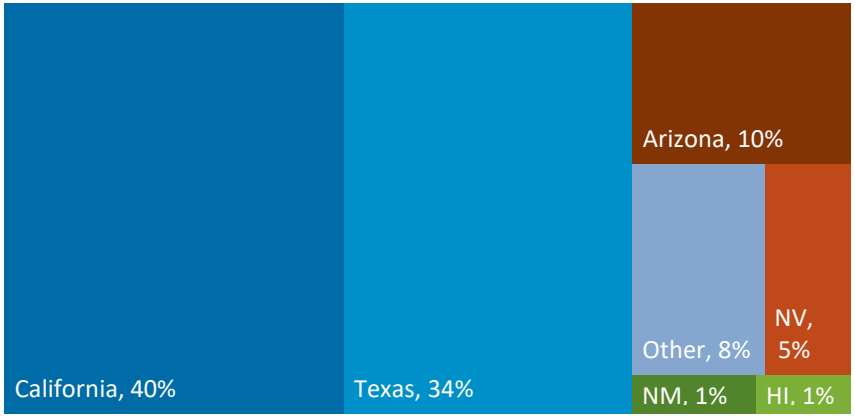
- EIA reports that the United States installed approximately 3.3 GW_{ac} of energy storage onto the electric grid in the fourth quarter of 2024—up 29% y/y.

- California represented 40% of battery installations in 2024, followed by Texas (34%) and Arizona (10%).
- Six states installed more than 100 MW_{ac} of storage in 2024.

U.S. Energy Storage Installations by Market Segment



2024 U.S. Energy Storage Installations by Region (10.9 GW)



Note: HI = Hawaii; NM = New Mexico; NV = Nevada. **Sources:** EIA, Form 860M, May 2025; EIA, Form 861M, May 2025

California Grid-Scale Battery Fire

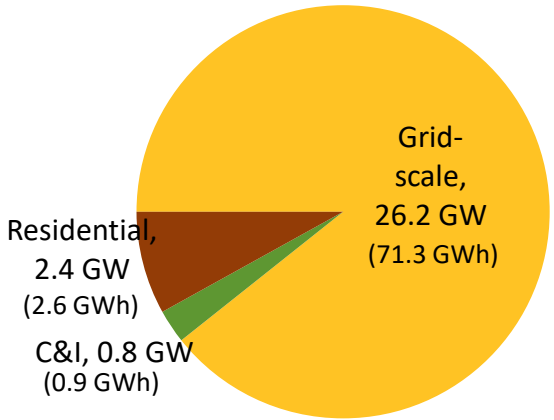
- In January 2025, the 300 MW/1,200 MWh Moss Landing energy storage facility in California caught fire, which lasted a week.
  - Residents close to the site reported feeling ill afterward, and there was concern of soil contamination.
- Since the fire, California state and local regulators have proposed regulations to increase battery safety, and several counties have issued moratoriums on large-scale BESS development.
- The Moss Landing BESS facility was built in 2020, indoors, using NMC batteries, which are more prone to thermal runaway than LFP batteries which are more commonly used in stationary storage today. Since 2020, several national energy storage safety standards (e.g., UL 9540/A, NFP 855) have been established.
  - Utility Dive also cited progress in battery management system technology, which does a better job of monitoring and controlling BESS at the cell level, where a thermal runaway might start.

Sources: Wood Mackenzie Power and Renewables and Energy Storage Association, U.S. Energy Storage Monitor: Q1 2025, 2025; Utility Dive, After Moss Landing, what's next for battery storage?, February 2025

U.S. BESS Installation Breakdown Annual: EIA (GW_{ac})

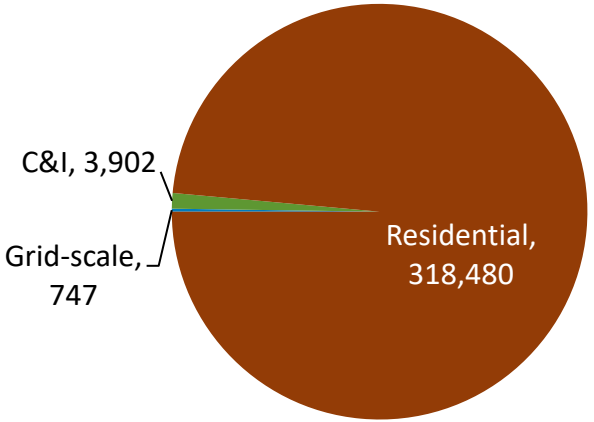
- EIA reports that at the end of 2024, there were 29.3 GW_{ac} (74.7 GWh) of cumulative U.S. battery energy storage installations.
- EIA reports that at the end of 2024, 89% of U.S. installed battery energy storage capacity was from grid-scale PV systems.

Cumulative U.S. BESS Installations as of December 2024 (29.3 GW_{ac}/74.7 GWh)



- Despite representing only 8% of installed U.S. battery energy storage capacity at the end of 2023, 99% of battery systems—more than 318,000 systems—were residential applications.
  - Virtually all distributed BESSs and most utility-scale BESSs are colocated with PV.
  - EIA reports that in 2024, the United States installed 104,800 BESSs, of which 104,100 were residential, 500 were C&I, and 200 were grid-scale.

Cumulative U.S. BESS Installations as of December 2024 (333,000 systems)



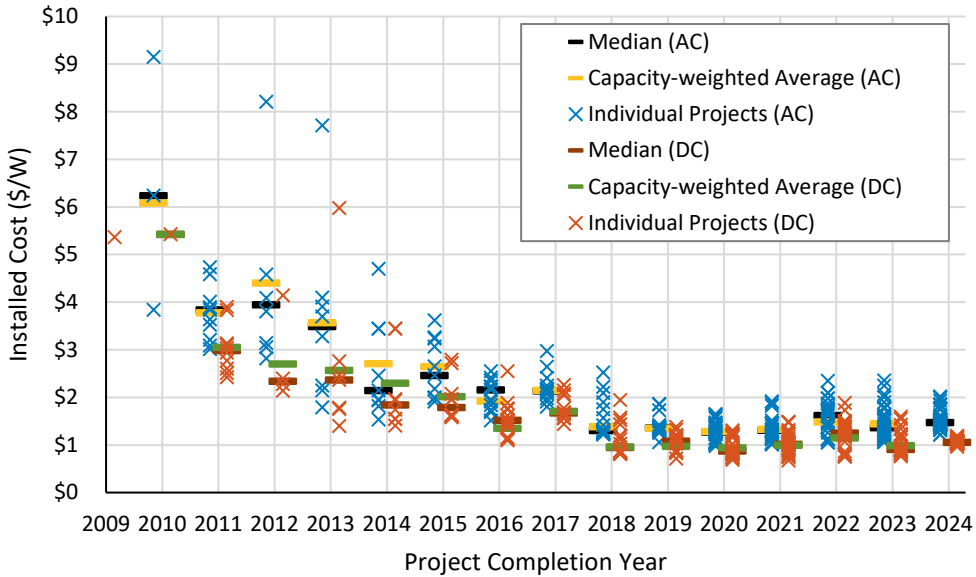
Sources: EIA, Electric Power Monthly, forms EIA-860, and EIA-861, April 2025.

Agenda

1. Global Solar Deployment
2. U.S. PV Deployment
3. **PV System Pricing**
4. Global Manufacturing
5. Component Pricing
6. Market and Policy
7. U.S. PV Imports

- **The median system price of large-scale, utility-owned PV systems in 2024 was \$1.51/W_{ac}—increasing about \$0.1/W since 2018.**
- **EnergySage reported that the median gross cost of stand-alone PV was \$2.65/W_{dc} in the second half of 2024.**
- **In 2024, residential PV-plus-storage systems in California had a median system price of \$3,074/kWh of battery, \$5,670/kW_{ac} of battery, and \$5,236/kW_{dc} of PV.**
- **LevelTen reports that in Q4 2024, the U.S. utility-scale photovoltaic PPA prices remained flat q/q, though they were up 10% y/y.**

Utility-Owned PV Pricing (>5 MW)



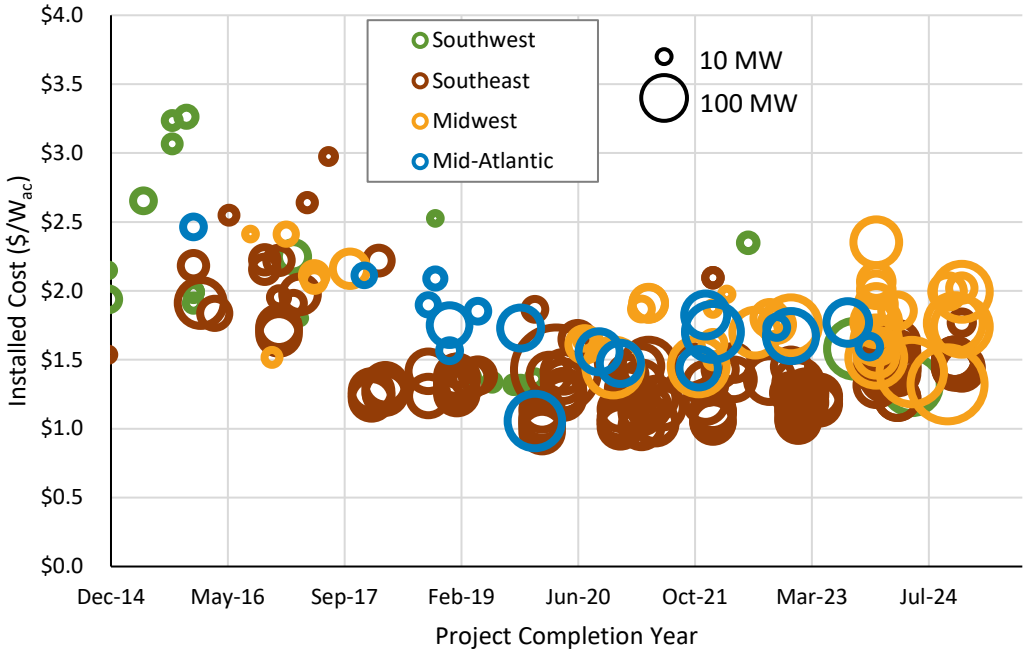
The median system price of large-scale, utility-owned PV systems in 2024 was \$1.51/W_{ac}—increasing about \$0.1/W since 2018.

- The lowest and highest reported prices in 2024 were \$1.22/W_{ac} and \$2.92/W_{ac}, respectively.
- A little over half the systems also reported capacity in W_{dc}, with a median cost of \$1.06/W_{dc}.

Note: Values represent a select dataset of utility-scale PV systems owned by 37 regulated utilities for 287 projects totaling 15.7 GW_{ac} installed from 2010 to 2024.

Sources: FERC Form 1 filings from the following utilities: Alabama Power, Allete, Ameren, Arizona Public Service, Dominion, DTE, Duke Energy (Carolinas, Florida, Indiana, and Progressive), El Paso Electric, Entergy (Arkansas, Mississippi, and New Orleans), Florida Power and Light, Georgia Power, Indiana Michigan Power, Kentucky Utilities, Madison Gas and Electric, MidAmerican, Nevada Power, Northern States Power Co, Pacific Gas and Electric, Public Service of New Mexico, Southern California Edison, Sierra Pacific, Southern Indiana Gas and Electric, Tampa Electric, Tucson Electric, United Illuminating, Union Electric, UNS Electric, Virginia Electric, Wisconsin Electric Power Company, and Wisconsin Public Service

Utility-Owned PV Pricing (>5 MW)



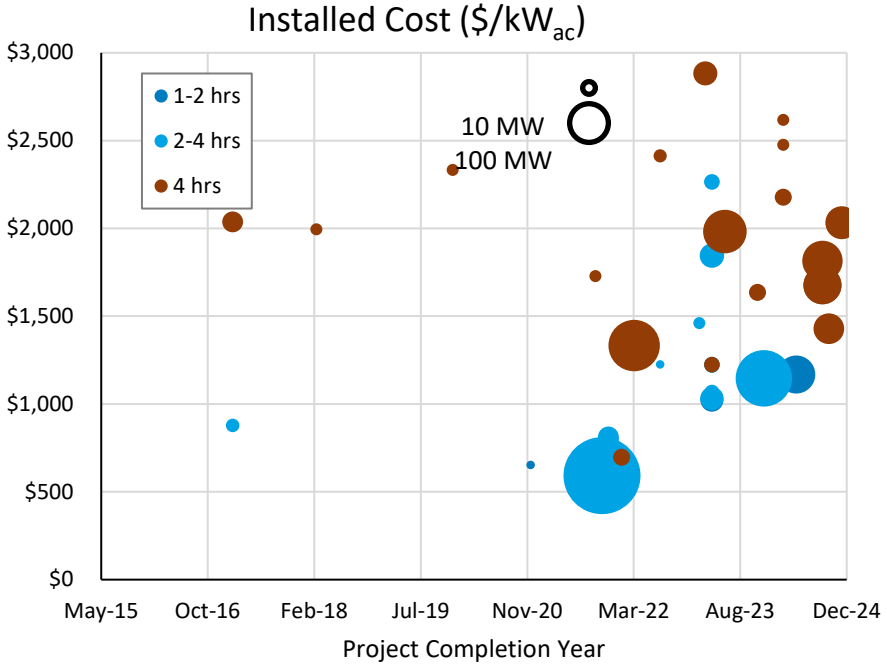
- Project prices in the Southeast were, on average, lower than the rest of the country, with a capacity-weighted average of $\$1.5/W_{ac}$ in 2024, compared to $\$1.6/W_{ac}$ in the Midwest and Mid-Atlantic.

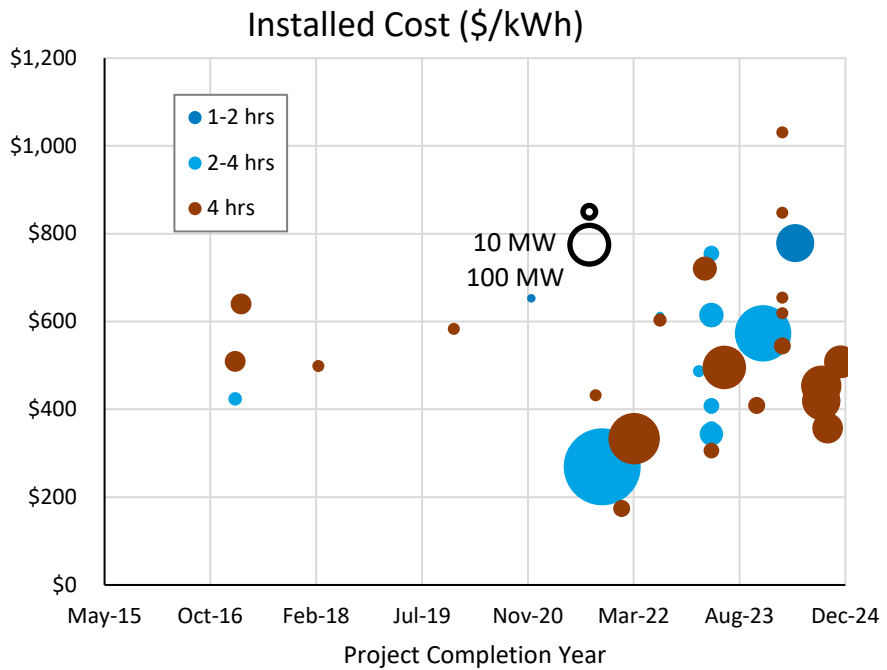
Note: Values represent a select dataset of utility-scale PV systems owned by 37 regulated utilities for 287 projects totaling 15.7 GW_{ac} installed from 2010 to 2024.

Sources: FERC Form 1 filings from the following utilities: Alabama Power, Allete, Ameren, Arizona Public Service, Dominion, DTE, Duke Energy (Carolinas, Florida, Indiana, and Progressive), El Paso Electric, Entergy (Arkansas, Mississippi, and New Orleans), Florida Power and Light, Georgia Power, Indiana Michigan Power, Kentucky Utilities, Madison Gas and Electric, MidAmerican, Nevada Power, Northern States Power Co, Pacific Gas and Electric, Public Service of New Mexico, Southern California Edison, Sierra Pacific, Southern Indiana Gas and Electric, Tampa Electric, Tucson Electric, United Illuminating, Union Electric, UNS Electric, Virginia Electric, Wisconsin Electric Power Company, and Wisconsin Public Service

Utility-Owned BESS Pricing (>5 MW)

- There is a wide variety of reported pricing for utility-owned battery storage systems, even accounting for differences in the hours of storage.
- In general, the price of a 4-hour battery system was around $500/kWh (though some smaller BESS microgrid systems reported higher prices).

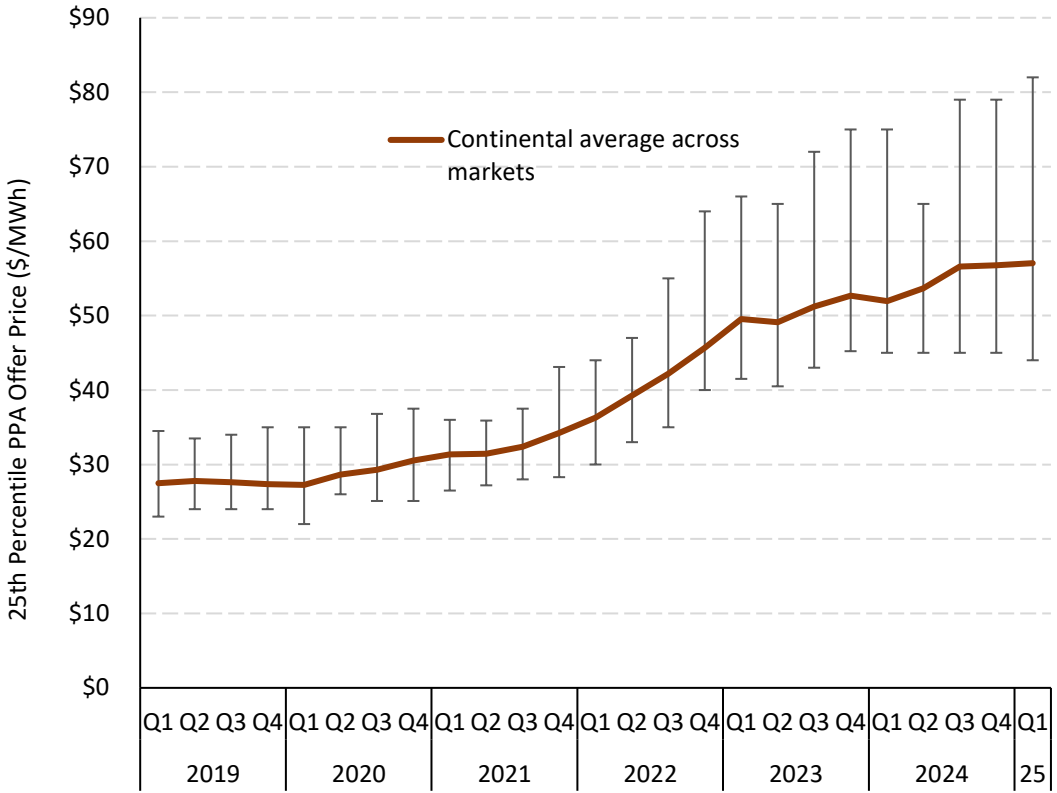




Note: Values represent a select dataset of utility-scale PV systems owned by eight regulated utilities for 21 projects totaling 1.2 GW$_{ac}$ installed from 2010 to 2023.

Sources: FERC Form 1 filings from the from the following utilities: Arizona Public Service, Duke Energy-Indiana, Florida Power and Light, Georgia Power, Nevada Power, Pacific Gas and Electric, Portland Electric, San Diego Gas and Electric, Southern California Edison, Sierra Pacific, Tampa Electric, Virginia Electric, and Wisconsin Public Service

U.S. Solar PPA Pricing (LevelTen)

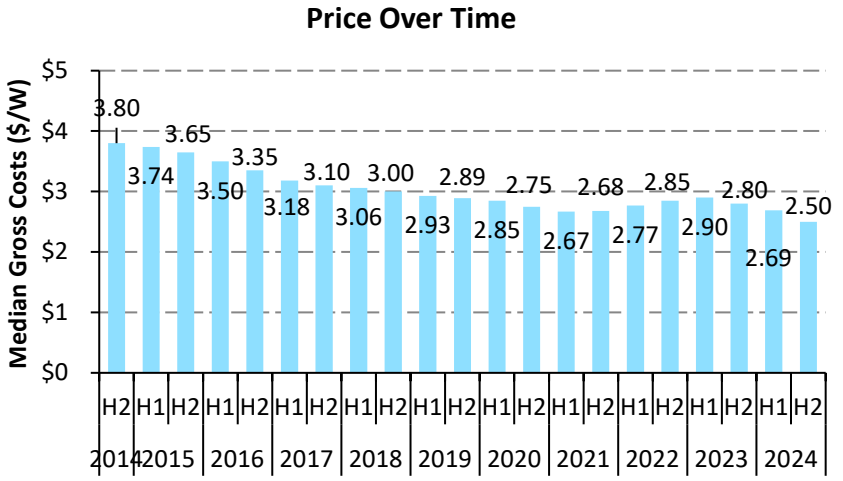


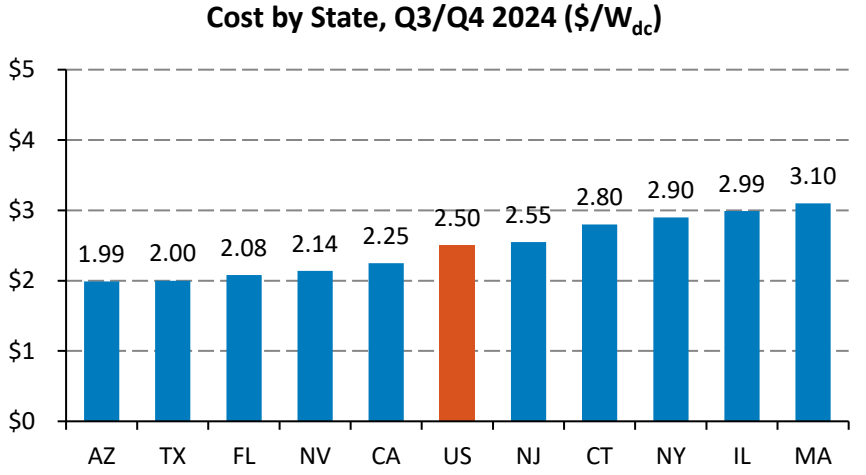
- LevelTen reports that, in Q1 2025, U.S. utility-scale photovoltaic PPA prices remained relatively flat for the second quarter in a row, though they were still up 10% y/y.
- LevelTen reports that the steady pricing reflects a relatively robust supply chain that can manage potential changes in trade policies.
- LevelTen reported that ERCOT was the lowest-price market in Q1 2025, while NYISO was the highest. LevelTen also reported increased pricing in CAISO due to a lack of hub-settled PPA deals, as well as a new interconnection queue process that includes an expression of interest requirement for early-stage projects.

Note: In addition to U.S. wholesale markets (CAISO, ERCOT, Southwest Power Pool [SPP], Midcontinent Independent System Operator [MISO], PJM, NYISO; ISO New England), LevelTen also tracks pricing in Alberta, Canada (Alberta Electric System Operator [AESO]). **Source:** LevelTen, Q1 2025 PPA Price Index Executive Summary North America, May 2025

Residential System Price Reported by EnergySage

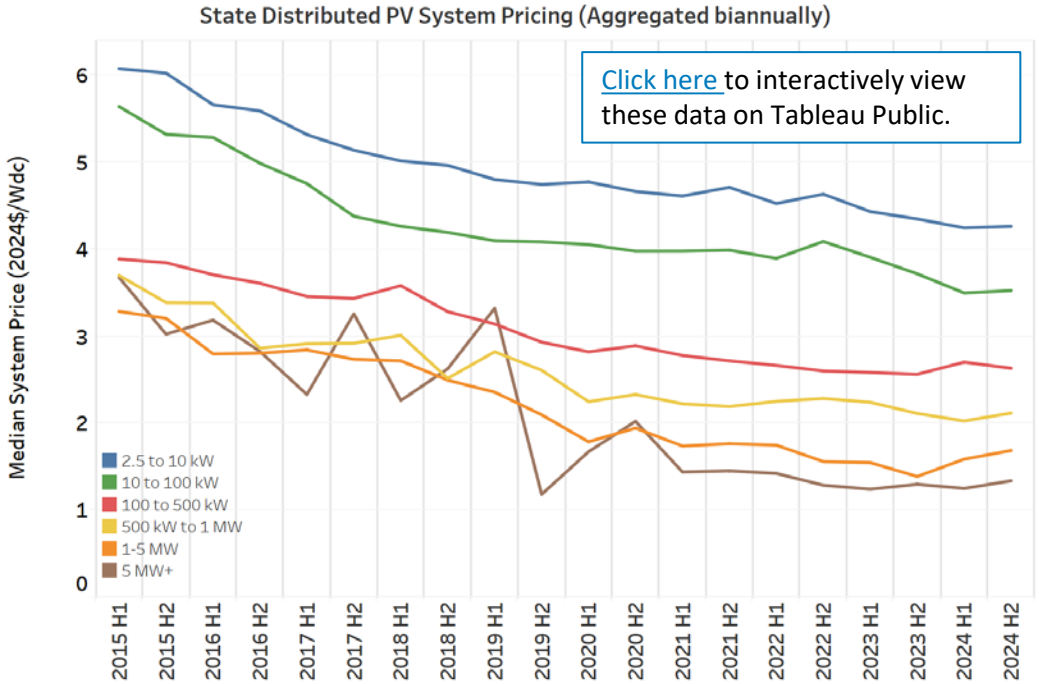
- The median price for residential PV systems reported by EnergySage fell 11% y/y.
  - Some of the price decrease may be explained by having the largest average system size on record—11.5 kW_{dc}—allowing projects to benefit from economies of scale.
  - EnergySage also includes in its data PV systems bought with BESS, where the inverter is located in the BESS. The median gross cost of stand-alone PV was \$2.65/W_{dc} in Q3/Q4 2024 (and \$2.80/W_{dc} in Q1/Q2 2024).
- Residential system price varied by state. In Q3/Q4 2024, the median price of a residential system in Massachusetts was 36% higher than the median price of a residential system in Arizona.
  - Part of the price disparity between states may be due to differences in average system size (13.6 kW in Arizona versus 10.5 kW in Massachusetts), though other factors also play a role—high PV-priced states tended to have higher-priced electricity and/or incentives for solar.





Note: Price based on winning quoted price.
Source: EnergySage, Solar and Storage Marketplace Report, Spring 2025

Distributed PV System Pricing From Select States



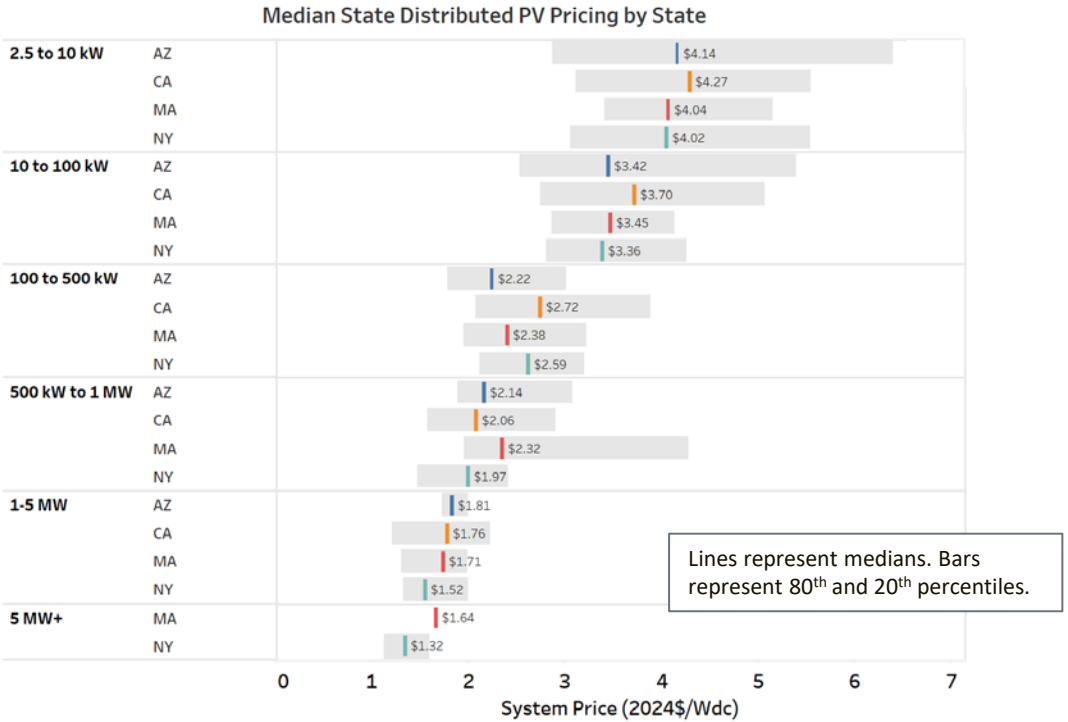
- From the second half (H2) of 2023 to the second half of 2024, the median reported stand-alone (no energy storage) distributed PV system price—**in 2024 (inflation-adjusted) dollars**—changed across Arizona, California, Massachusetts, and New York.
- Adjusting for inflation reveals the generally decreasing distributed PV system price trends in real dollars over the past several years of economic volatility.

System Size	Price H2 2024 ($/$W_{dc}$)	Change 2023–2024
2.5–10 kW_{dc}	$4.27	–2%
10–100 kW_{dc}	$3.53	–5%
100–500 kW_{dc}	$2.63	+3%
0.5–1 MW_{dc}	$2.12	0%
1–5 MW_{dc}	$1.69	+22%
5 MW_{dc}+	$1.34	+3%

2024 MW data: Arizona (183), California (767), Massachusetts (39), New York (888).
Note: System prices above $10/W and below $0.75/W were removed from the dataset. The volatility in median system price among the largest systems is because of the relatively small number of systems deployed each year.
Sources: Arizona Goes Solar, Utility Programs, May 2025; California Distributed Generation Statistics, Distributed Generation Interconnection Program Data, Interconnected Project Sites Data Set, January 2025; Mass.gov, Massachusetts Lists of Qualified Generation Units, February 2025; Data.NY.gov, Solar Electric Programs Reported by NYSERDA, April 2025

Distributed PV System Pricing From Select States, 2024

Click here to interactively view these data on Tableau Public.

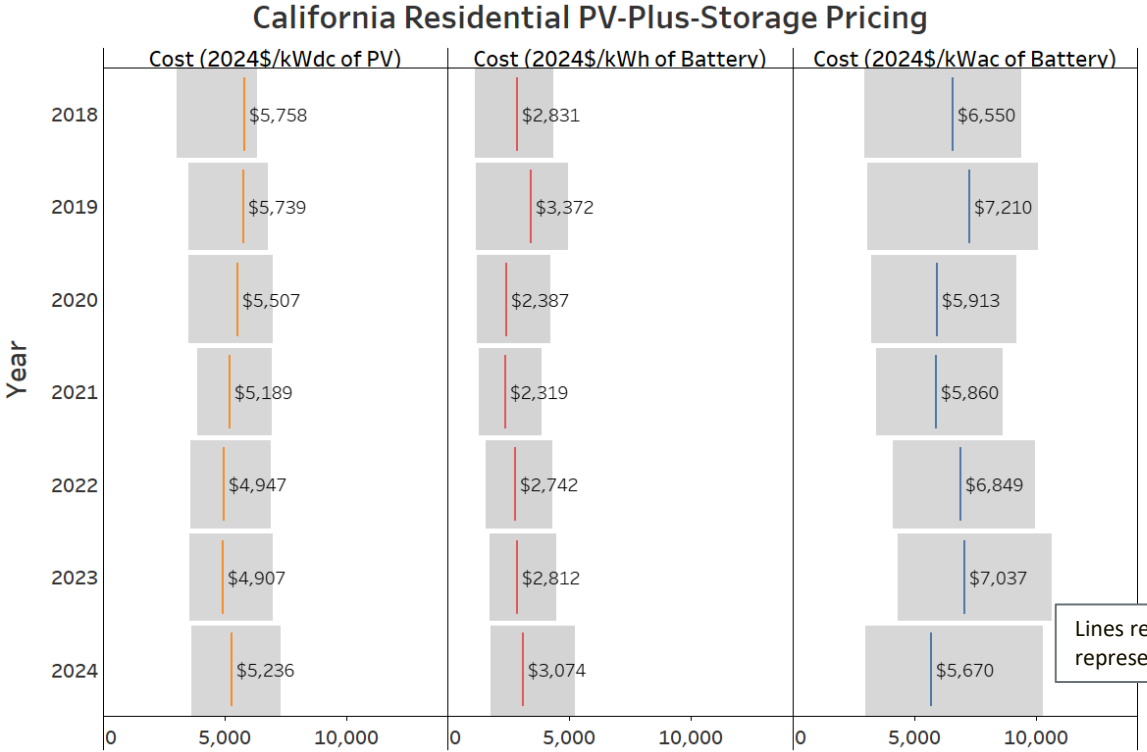


- In addition to price differences based on system size, there is variation in the price of stand-alone (no energy storage) distributed PV systems between states and within individual markets.
- Dollar-per-watt prices generally decrease as system size increases.
- For systems 2.5–10 kW, median price changes varied between 2023 and 2024:
  - –8% in Arizona, –2% in California, –1% in Massachusetts, and –9% in New York.

2024 MW data: Arizona (183), California (767), Massachusetts (39), New York (888).
Note: System prices above $10/W and below $0.75/W were removed from the dataset.
Sources: Arizona Goes Solar, Utility Programs, May 2025; California Distributed Generation Statistics, Distributed Generation Interconnection Program Data, Interconnected Project Sites Data Set, January 2025; Mass.gov, Massachusetts Lists of Qualified Generation Units, February 2025; Data.NY.gov, Solar Electric Programs Reported by NYSERDA, April 2025

Residential PV-Plus-Storage Pricing in California

Click here to interactively view these data on Tableau Public.

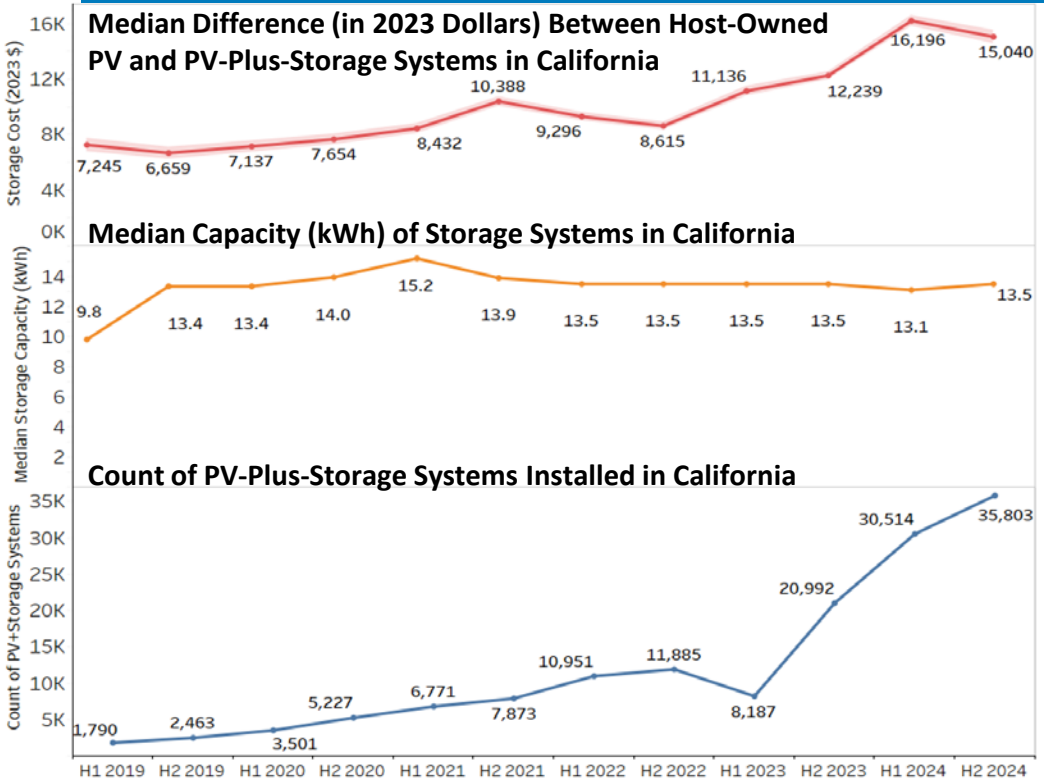


Lines represent medians. Bars represent 80th to 20th percentiles.

- In 2024, residential PV-plus-storage systems in California had a median system price of \$3,074/kWh of battery, \$5,670/kW_{ac} of battery, and \$5,236/kW_{dc} of PV.
  - The cost per kW_{ac} of battery fell 19% between 2023 and 2024, while the cost per kWh of battery rose 9% and the cost per kW_{dc} of PV rose 7%.
  - Most of these systems offer 2–3 hours of storage.

The data are filtered to residential rooftop PV systems between 3 kW_{dc} and 30 kW_{dc} with a cost between \$0.75/kW_{dc} and \$20/kW_{dc} (2024 dollars).
Source: California Distributed Generation Statistics, Distributed Generation Interconnection Program Data, Interconnected Project Sites Data Set, January 2025

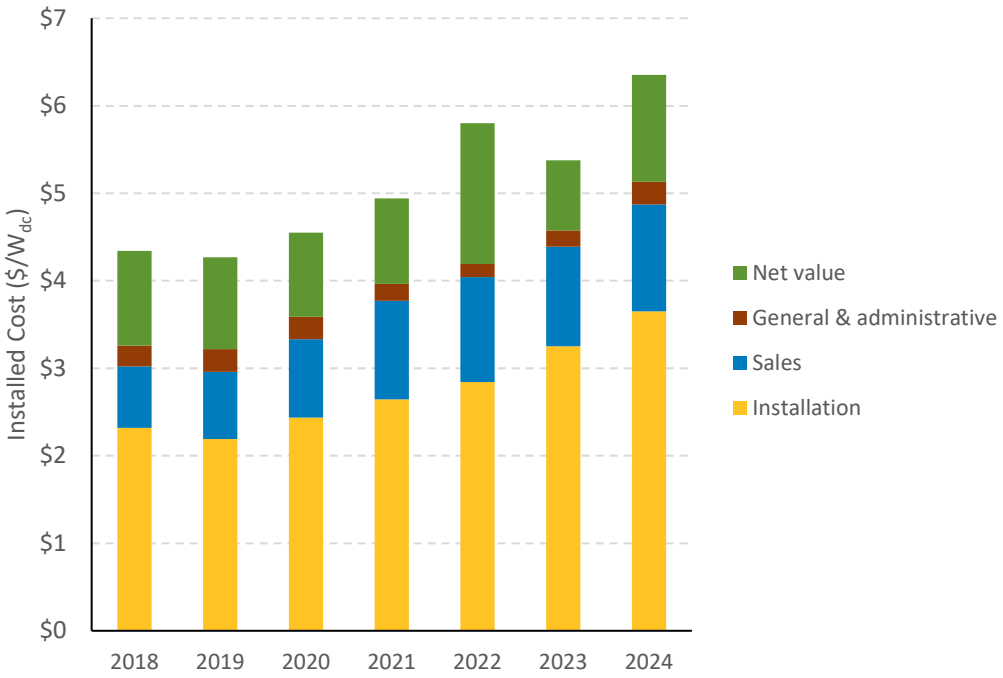
Rising Residential Storage Costs in California



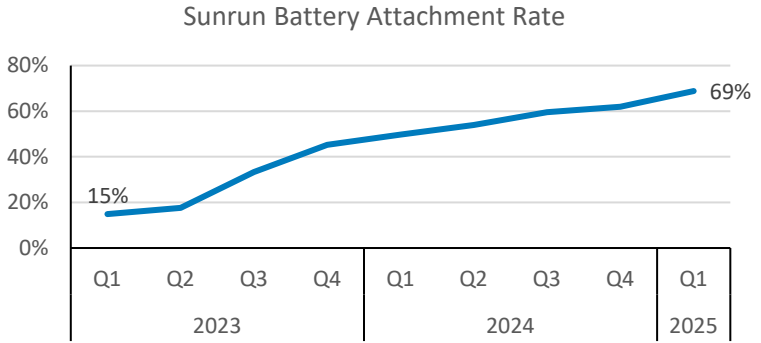
- Over 5 years, the cost associated with storage in California's host-owned, residential PV-plus-storage systems increased from about $7,000 to $15,000 per system, including a rapid rise between 2022 and 2024.
- Median storage capacity remained relatively constant, suggesting the increase did not result from systems using larger batteries.
  - The potential effect of other technological changes on costs will be analyzed in future work.
- The cost increase may be due in part to increased PV-plus-storage demand after California's net billing policy (NEM 3.0) became effective in April 2023.
  - Annual PV-plus-storage system installations tripled between 2022 and 2024.
  - Including storage enables system owners to optimize economics under NEM 3.0, which reduced compensation for PV energy exported to the grid.
  - Lawrence Berkeley National Laboratory found that PV-plus-storage system price increases post NEM 3.0 were likely due to rising demand and corresponding equipment and/or labor shortages.

Storage costs were derived from a linear regression of system prices against system size and binary variables for the presence of storage and module-level power electronics, with consideration of county-level fixed effects. Host-owned, rooftop residential systems installed after 2019 in Pacific Gas & Electric and Southern California Edison territories were analyzed. The red shaded area around the cost line is the 95% confidence interval. **Sources:** LBNL, One Year In: Tracking the Impacts of NEM 3.0 on California's Residential Solar Market, May 2024; California Distributed Generation Statistics, Distributed Generation Interconnection Program Data, Interconnected Project Sites Data Set, January 2025

Sunrun and SunPower Cost and Value, 2018–2024



- National integrator Sunrun's cost of installing residential systems has generally risen each year since 2019.
- Recent increases in installation costs are due in part to increasing battery attachment, which grew from 15% in Q1 2023 to 69% in Q1 2025.

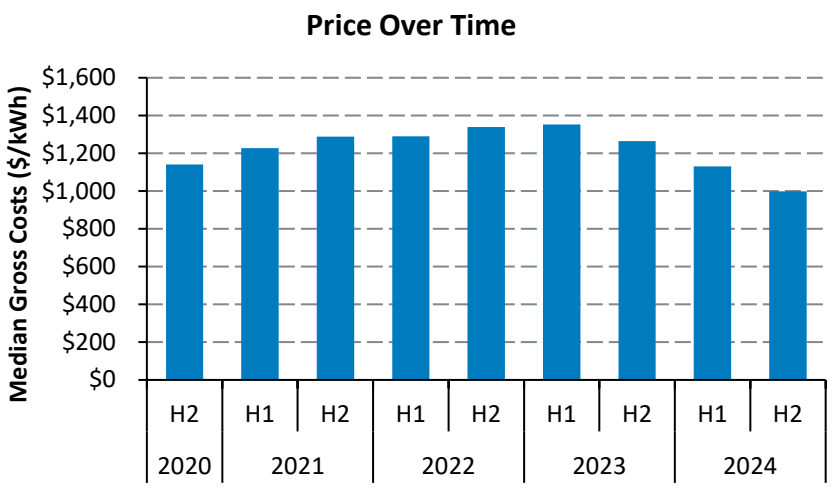


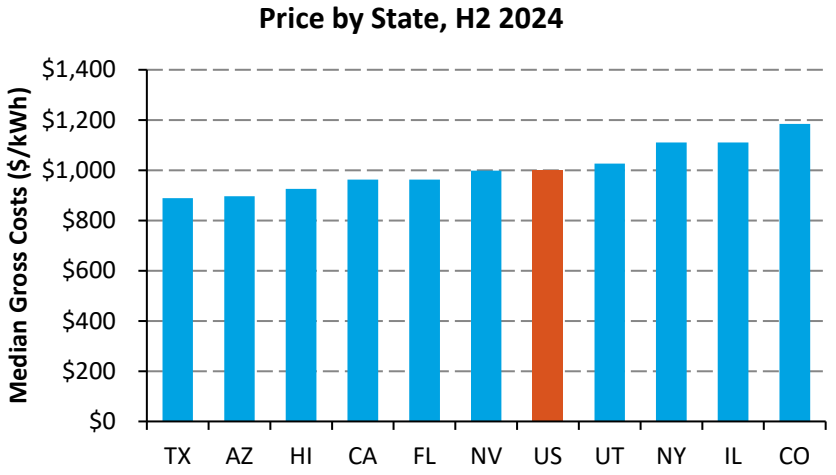
- Increases in sales costs also contributed to higher prices.
- While installation and sales costs have generally increased, general and administrative costs have remained relatively flat.

Sources: Corporate filings

Residential Storage Price Reported by EnergySage

- The median price for residential energy storage reported by EnergySage fell 21% y/y.
  - EnergySage attributed the drop in price to the underlying drop in battery pack prices from 2023 to 2024.
  - EnergySage also noted that 90% of the U.S. battery industry relied on China; therefore, tariffs are expected to impact BESS price trends in 2025.
- Residential storage system price varied by state. In H2 2024, the median price of a residential storage system in Texas was 25% less than the median price of a residential storage system in Colorado.





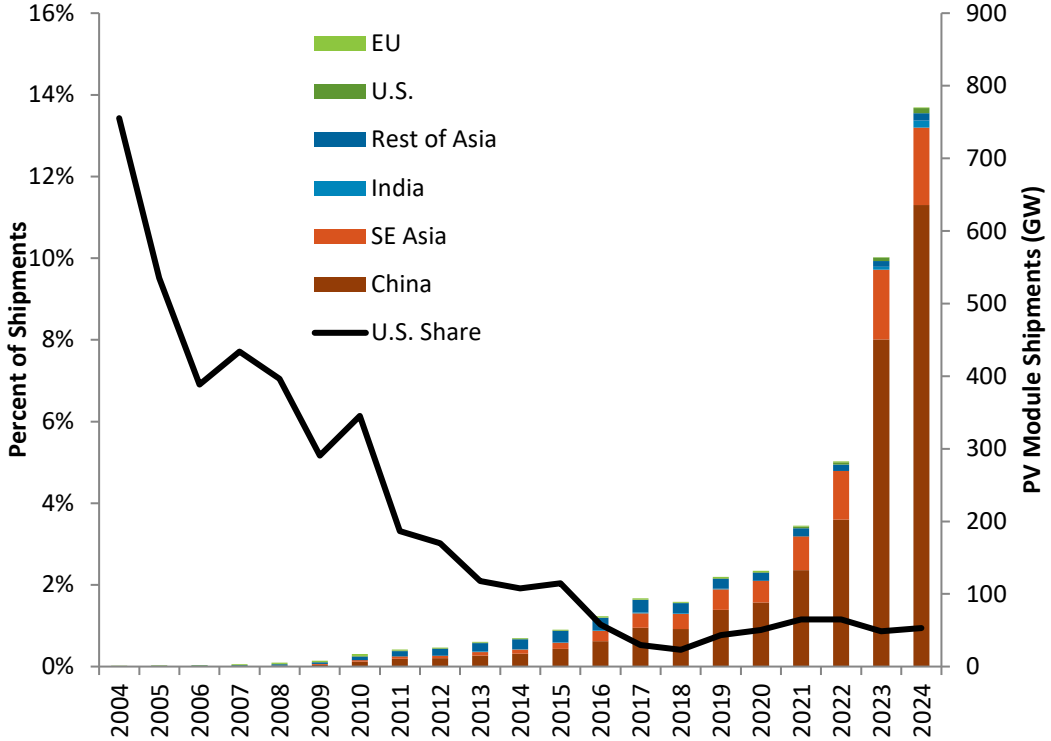
Note: Price based on winning quoted price.
Source: EnergySage, Solar and Storage Marketplace Report, Spring 2025

Agenda

1. Global Solar Deployment
2. U.S. PV Deployment
3. PV System Pricing
4. **Global Manufacturing**
5. Component Pricing
6. Market and Policy
7. U.S. PV Imports

- **SPV Market Research reported that 2024 global PV shipments were approximately 770 GW—an increase of 37% from 2023, with 90% of the increase coming from China.**
  - **98% of PV shipments were mono c-Si technology, with 58% TOPCon.**
- **Margins for the leading PV wafer, cell, and module manufacturers continued to decline through Q1 2025, due to record-low pricing.**
- **The United States manufactured approximately 12.0 GW_{dc} of PV panels in 2024 (+114% y/y)**

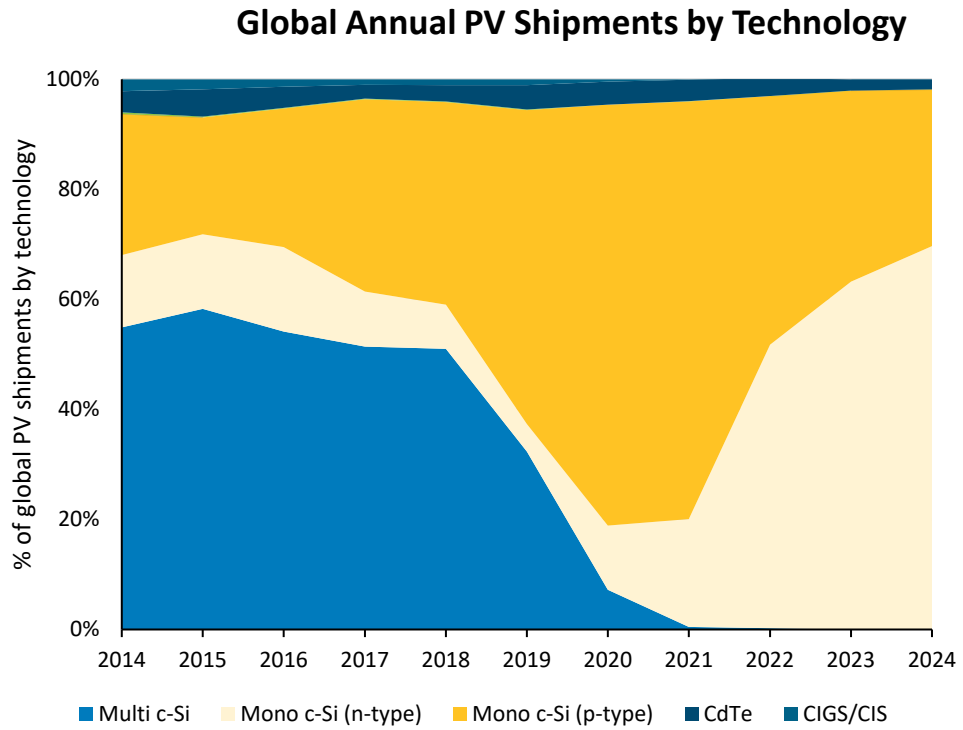
Global Annual PV Shipments by Region*



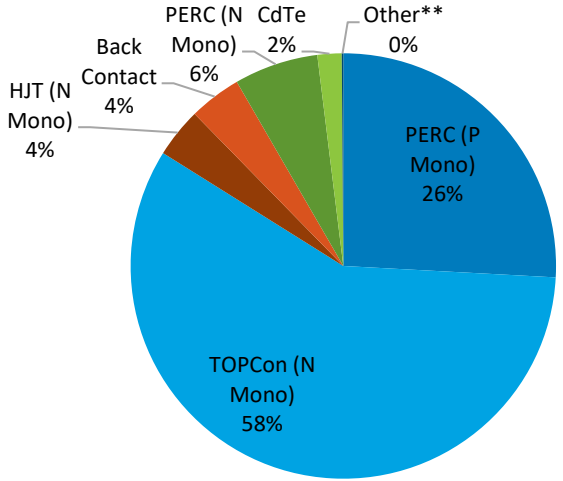
- SPV Market Research reported that 2024 global PV shipments were approximately 770 GW—an increase of 37% from 2023.
  - 90% of the increase came from China, with the remainder mostly coming from Laos, Thailand, and India.
- From 2004 to 2024:
  - The U.S.-manufactured percentage of global PV shipments declined from about 13% to 0.9%.
  - The Chinese-manufactured share of global PV shipments grew from 1% to 83%.
  - Together, the Malaysian-, Vietnamese-, and South Thai-manufactured percentage of global PV shipments went from 0% to 23% in 2022; however, it dipped to 12% in 2024, with non-Chinese PV manufacturing expanding elsewhere.

*** Note:** Excludes inventory sales and outsourcing.
Source: SPV Market Research, Photovoltaic Manufacturer Capacity, Shipments, Price & Revenues 2024/2025, April 2025

Global Annual PV Shipments by Technology*



- In 2024, 98% of PV shipments were mono c-Si technology, compared to 35% in 2015.
  - N-type mono c-Si grew to 70%—up from 63% in 2023 (and 5% in 2019).
- TOPCon was the leading cell type in 2024, followed by mono P PERC, mono N PERC, and HJT.
  - Perovskite shipments began in 2024, shipping 68 MW from China and Europe (Si tandem).



***Note:** Excludes inventory sales and outsourcing.
Source: SPV Market Research, Photovoltaic Manufacturer Capacity, Shipments, Price & Revenues 2024/2025, April 2025

** Includes a-Si, CIS/CIGS, multi PERC, perovskite, and TOPCon (P mono).

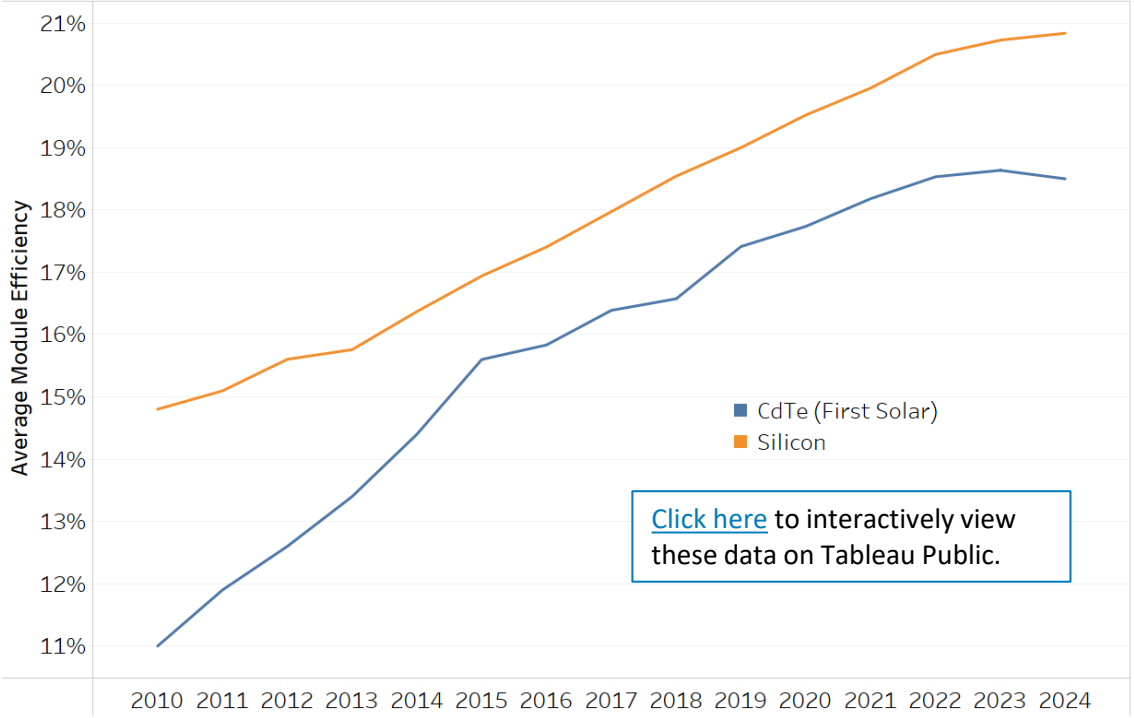
Global Leading PV Manufacturers by Shipments

Ranking	2019	GWdc	2023	GWdc	2024	GWdc
1	Tongwei	12.8	Tongwei	65.5	Jinko Solar	78.9
2	LONGi	11.0	Jinko Solar	60.2	JA Solar	66.5
3	Jinko Solar	9.7	LONGi	58.4	Trina Solar	63.3
4	Canadian Solar	8.6	Trina Solar	55.9	Tongwei	59.6
5	Aiko Solar	7.6	JA Solar	51.2	LONGi	59.3
6	JA Solar	7.6	Aiko Solar	36.8	Aiko Solar	53.9
7	Trina Solar	6.0	Canadian Solar	30.7	Runergy	50.9
8	First Solar	5.4	Astroenergy	19.5	SolarSpace	37.0
9	Hanwha Q-Cells	5.2	Risen	18.5	Astronergy	32.8
10	UREC	4.2	Runergy	17.0	Canadian Solar	31.1
Total Above		**78.0**		**413.7**		**533.2**
Total Shipped		**123.5**		**564.0**		**770.0**

- From 2019 to 2024, shipments from the top 10 PV manufacturers grew from 78 GW to 533 GW, with some companies shipping more than 75 GW annually.
- Approximately half of 2024 shipments came from the top six companies.

***Note:** Excludes inventory sales and outsourcing.
Source: SPV Market Research, Photovoltaic Manufacturer Capacity, Shipments, Price & Revenues 2024/2025, April 2025

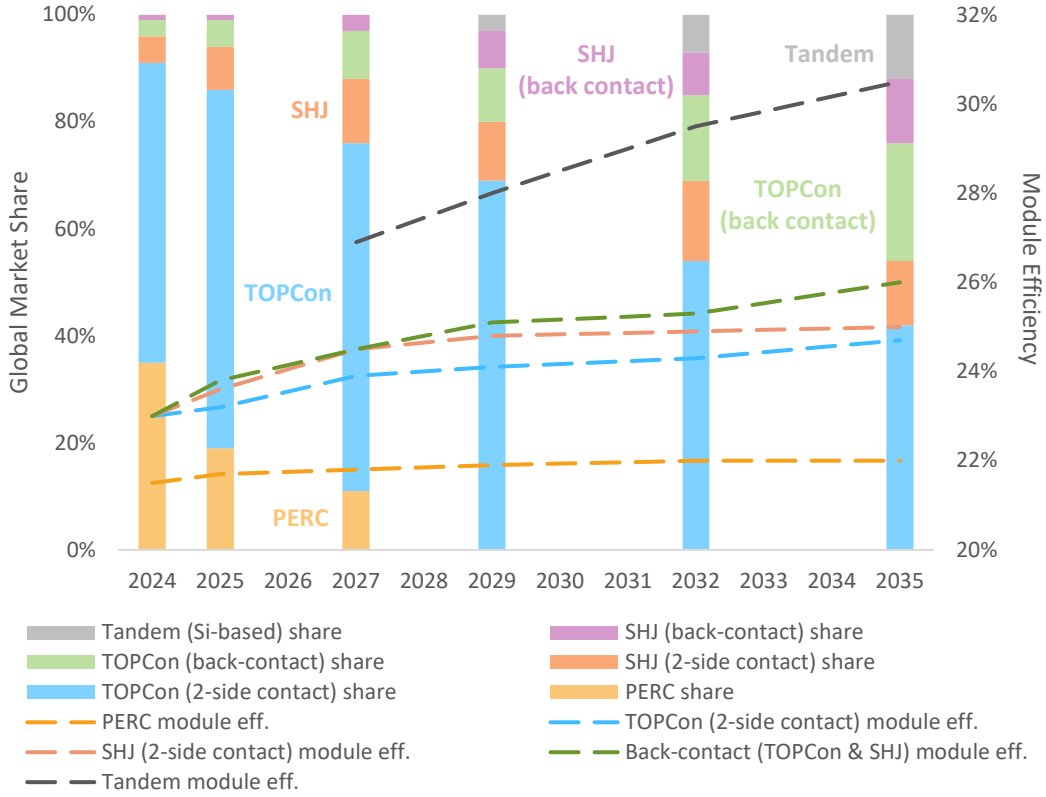
PV Module Efficiency Improvements



- From 2010 to 2024, the weighted average efficiency of installed modules increased:
  - From 14.8% to 20.8% for c-Si technologies (in California and New York distributed PV systems).
  - From 11.0% to 18.5% for CdTe (in U.S. utility-scale PV systems).
- Efficiency changes occur through incremental improvements in given technologies as well as changes in technology market share (e.g., PERC to TOPCon).
- First Solar reported lower average power output in 2024 for both its CdTe products compared to 2023.
  - The company did not provide an explanation; however, this could relate to the scale-up of several manufacturing lines in 2024, or manufacturing issues reported in Q3 2024.

Sources: CdTe: First Solar Investor Relations, average module efficiency produced; California Distributed Generation Statistics, c-Si: Distributed Generation Interconnection Program Data, Interconnected Project Sites Data Set, January 2025; Data.NY.gov, Solar Electric Programs Reported by NYSERDA, January 2025

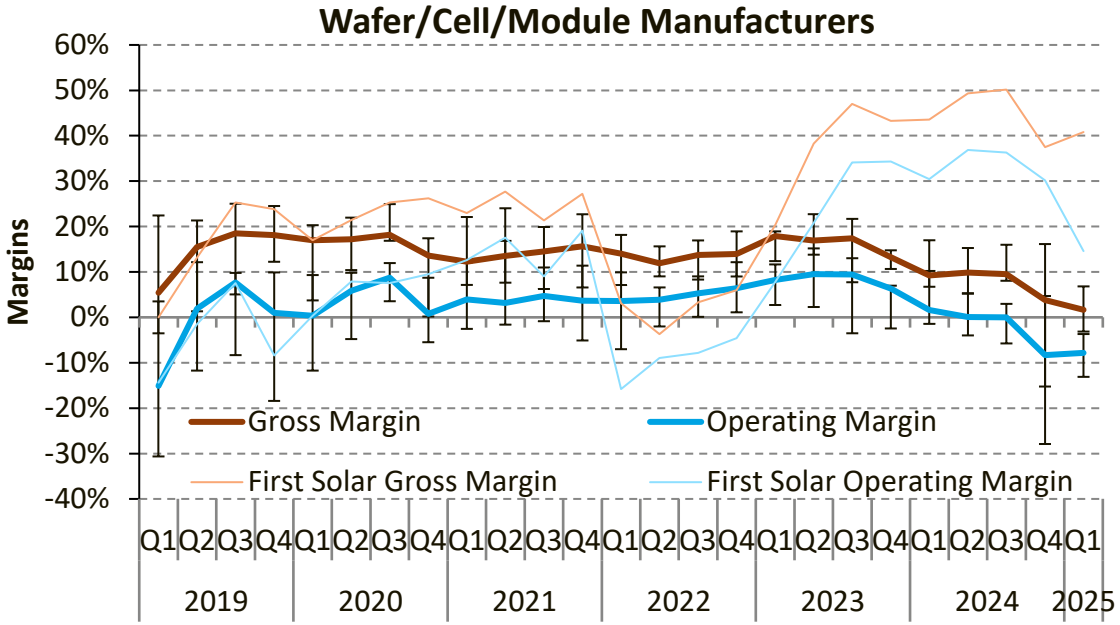
Silicon Module Market Share and Efficiency Projections



- The 2025 International Technology Roadmap for Photovoltaics (ITRPV) projects an accelerated global transition away from PERC technology—which dominated until recently—toward higher-efficiency technologies. Compared with last year's ITRPV projections:
  - PERC disappears more rapidly (by 2029 vs. 2034)
  - The TOPCon market share grows more quickly and peaks higher (69% vs. 62%).
  - The market share of back-contact technologies grows more quickly (e.g., to 24% in 2032 in this year's edition vs. only 16% in 2034 in last year's edition).
  - The market share of non-back-contact SHJ shrinks (e.g., to 12% in 2035 in this year's edition vs. 21% in 2034 last year).
- Module efficiencies are generally projected to continue rising in 2035, reaching:
  - 30.5% for tandems
  - 26.0% for back-contact technologies
  - 25.0% for SHJ (two-side contact)
  - 24.7% for TOPCon (two-side contact)
  - 22.0% for PERC.

Source: VDMA, International Technology Roadmap for Photovoltaics (ITRPV), 16th Edition, Key Findings and Selected Report Presentation, March 2025

PV Wafer/Cell/Module Manufacturers' Margins



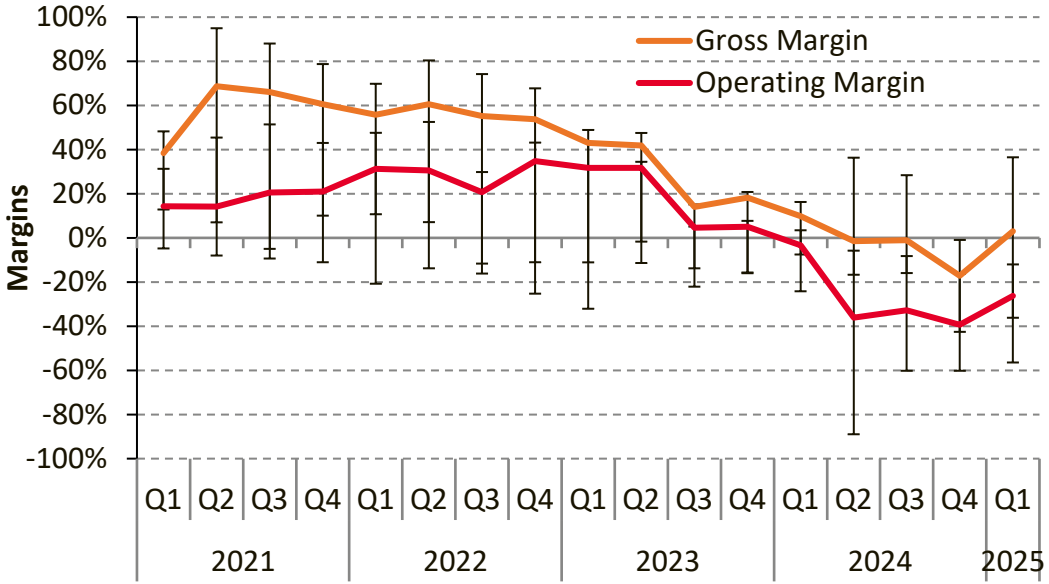
- Margins for the leading PV wafer, cell, and module manufacturers continued to decline through Q1 2025, due to record-low pricing.
  - Some manufacturers sold products below the cost to make them.
  - Jinko Solar, LONGi, JA Solar, and Trina Solar collectively shipped 65 GW in Q1 2025, yet earned 30% less in revenues.
- Conversely, First Solar maintained higher gross margins (41%) due to its positioning in the U.S. marketplace.
  - Its dip in Q1 operating margins was due to seasonally expected lower sales volume.

Lines represent the median, with error bars representing the 80th and 20th percentiles for the following companies in Q1 2025: First Solar, GCL, JA Solar, Jinko Solar, LONGi, Risen, Shanghai Aiko, Shanghai Aerospace, Tongwei, and Trina Solar. Q3 2024 data are not available for the following companies; however, the chart incorporates previous financial performance: Canadian Solar, Maxeon, Motech Industries, Renesola, and United Renewable Energy.

Note: Gross margin = revenue minus cost of goods sold (i.e., the money a company retains after incurring the direct costs associated with producing the goods or services it sells); operating margin = gross margin minus overhead and operating expenses (i.e., the money a company retains before taxes and financing expenses).

Sources: Company figures based on public filings and finance.yahoo.com

PV Polysilicon Manufacturers' Margins



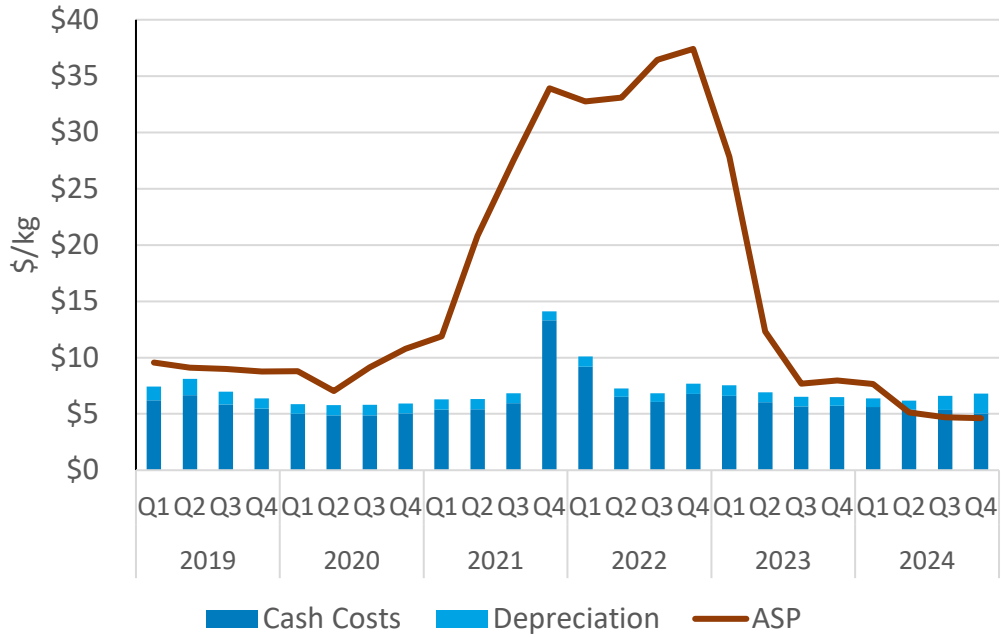
- Polysilicon manufacturers are also suffering from low pricing within the marketplace, with most manufacturers selling below cost in Q4 2024.
- Wacker reported higher margins than its competitors; however, it still had no operating profit in Q1 2025.
  - While its semiconductor-grade sales increased, its solar-grade polysilicon volumes declined, which Wacker attributed to overcapacity in China, high inventories, and uncertainty in tariffs.

Lines represent the median, with error bars representing the 80th and 20th percentiles for the following companies in Q1 2025: Daqo, GCL Poly, REC Silicon, TCL Zhonghuan, Wacker, and Xinte.

Note: Gross margin = revenue minus cost of goods sold (i.e., the money a company retains after incurring the direct costs associated with producing the goods or services it sells); operating margin = gross margin minus overhead and operating expenses (i.e., the money a company retains before taxes and financing expenses).

Sources: Company figures based on public filings and finance.yahoo.com

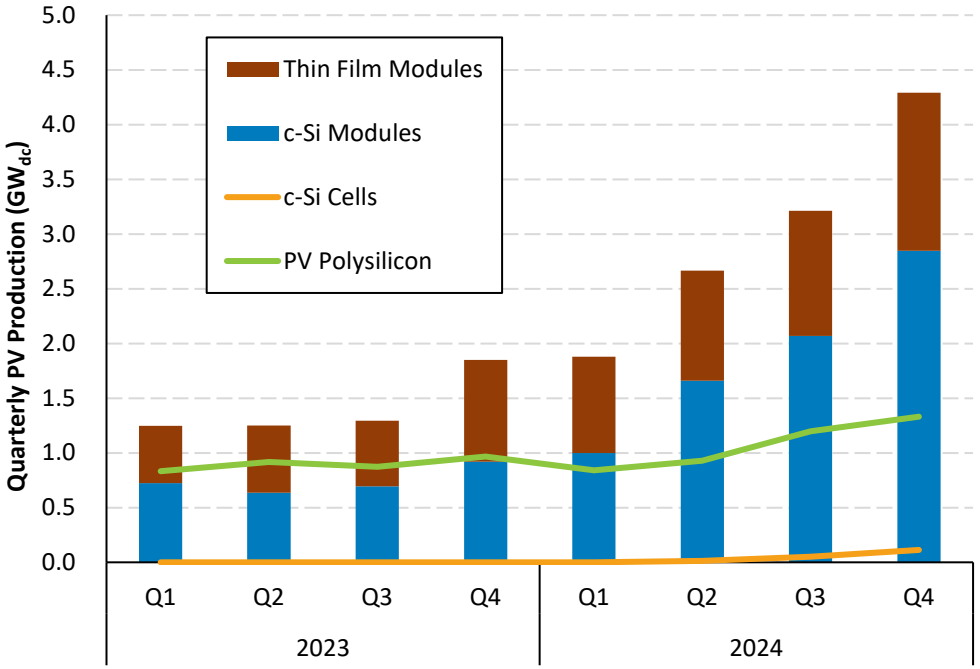
Polysilicon Costs vs. Pricing



- Daqo reported that polysilicon prices rose dramatically in 2021, due to manufacturing capacity shortages; however, they fell precipitously in 2023, as increased polysilicon manufacturing capacity came online.
- Daqo reported that the average selling price of polysilicon was below cash costs from Q2–Q4 2024.

Sources: Daqo, Q4 and Fiscal Year 2024 Results Presentation, February 2025

U.S. PV Manufacturing

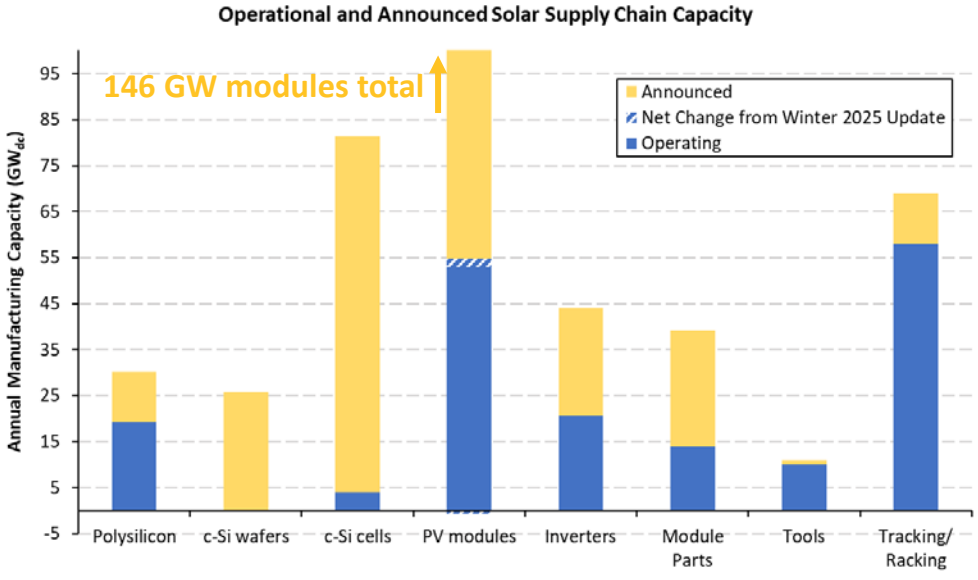


- The United States manufactured approximately 12.0 GW_{dc} of PV panels in 2024 (+114% y/y), of which 4.3 GW_{dc} were produced in Q4 2024 (+34% q/q, 132% y/y).
  - c-Si module production experienced the highest growth levels, as its ~33 GW_{dc} of capacity started to ramp.
- Polysilicon production in 2024 for PV also increased 20% y/y, and domestic c-Si production began again for the first time this decade in 2024, with an end-of-year production capacity of approximately 2.5 GW_{dc}.

Sources: Values represent the average of: PVTech, PV Manufacturing & Technology Quarterly Report—Release 36, March 2025; and Wood Mackenzie/SEIA, U.S. Solar Market Insight: Q4 2024, December 2024

Domestic Manufacturing Growth

In Q1 2025, domestic manufacturing capacity remained flat, with approximately 19 GW of operational nameplate polysilicon capacity, 4 GW of c-Si cell capacity, more than 50 GW of module manufacturing capacity, more than 20 GW of inverter capacity, and more.

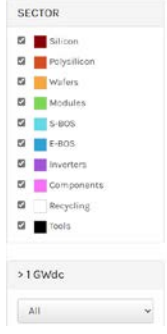


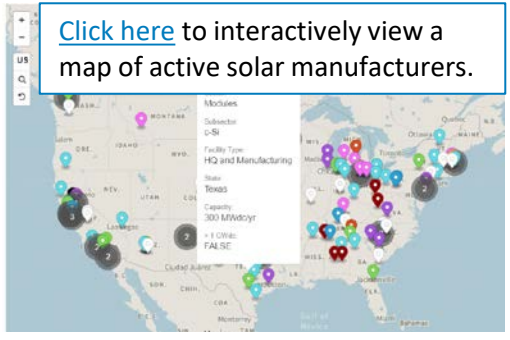
Sources: U.S. Census Bureau USA Trade Online, and internal DOE tracking of public announcements as of April 10, 2025. *Not all announcements include facility locations, jobs, operating capacities, or investment numbers.

Several facilities have hit milestones in the last several months:

- **Origami Solar/Priefert Steel** announced that they commissioned a new steel frame production line in Arkansas. They have inked several supply agreements with domestic module manufacturers.
- **Boviet Solar** opened their 2-GW module facility in North Carolina in late April.
- **ES Foundry** announced that they will supply 300 MW of solar cells to **Bila Solar** for use in their domestic modules.
- **Corning, Suniva, and Heliene** have announced a partnership to create a U.S.-made solar module supply chain. Corning will supply polysilicon and wafers, Suniva will make the cells, and Heliene will make the modules.

Notably, however, **SPI/Solar4America** closed their 700-MW module production facility in California.





Domestic Manufacturing Announcements

For more detailed information on domestic solar manufacturing announcements, including supply chain segment, date of announcement, and whether the facility is operational, check out our map on Tableau Public!

Click here to interactively view a map of manufacturing announcements.

Sources: Internal DOE tracking of public announcements

*Not all announcements include facility locations, jobs, operating capacities, or investment numbers.

Despite headwinds noted by companies—including political uncertainty and cost declines—recent announcements span the supply chain, including:

- **Corning** announced that they will be expanding their wafer manufacturing facility in Michigan.
- **Mission Solar/OCI** announced that they will be building a 2-GW cell facility near their module facility in Texas.
- **Waaree Energies** announced that they will be expanding their Brookshire, Texas, facility by an additional 1.6 GW, bringing their total capacity to 3.2 GW.
- **APA Solar** announced that they will be building a new racking manufacturing facility in northwest Ohio.
- **Opsun Corporation** announced that they will be building a new mounting structures manufacturing facility in High Point, North Carolina.
- **Vitro Glass** announced that they will be expanding their Texas facility to produce patterned solar glass. They received a $67.6 million investment tax credit allocation (48C) for this project.

Agenda

1. Global Solar Deployment
2. U.S. PV Deployment
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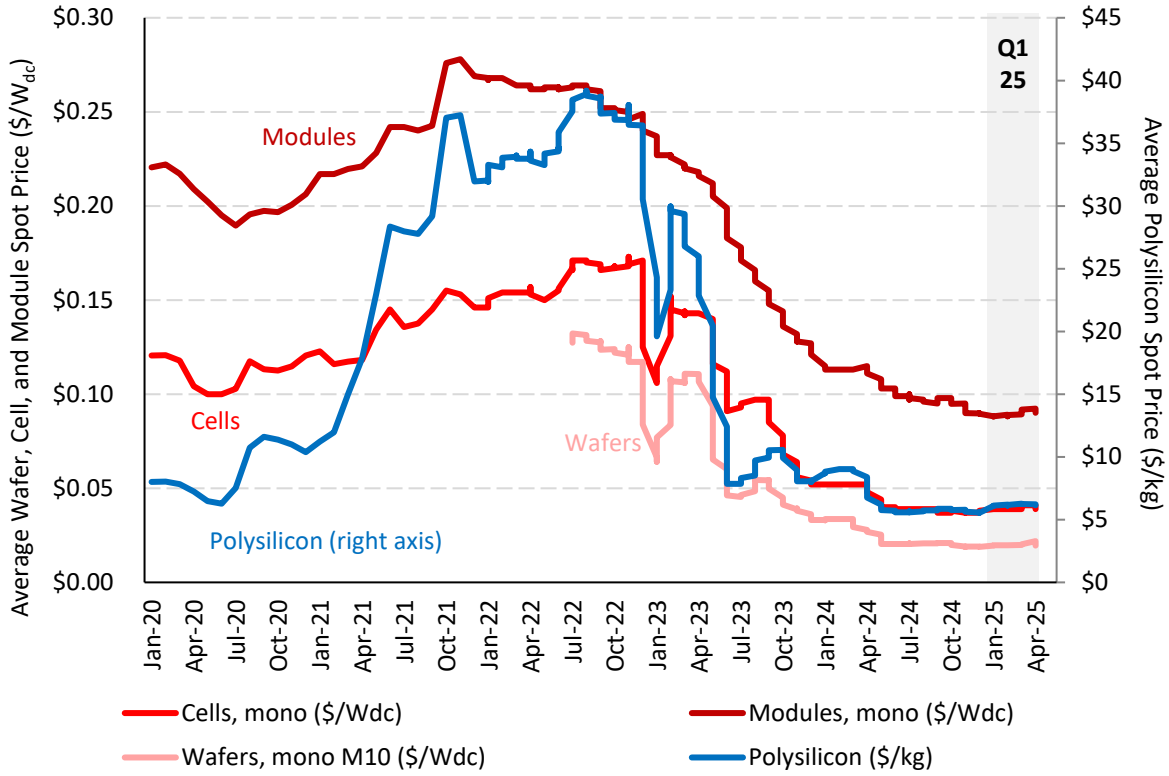
7. U.S. PV Imports

- **Module spot prices rose 2% in Q1 2025 and remained around $0.09/$W_{dc}$.**
  - **The impact of China's PV development surge on module prices was muted by the persistence of oversupply conditions and poor economics for module manufacturers.**
- **Global polysilicon spot prices rose 12% in Q1 2025, from $5.54/kg to $6.24/kg.**
  - **The increase was supported by higher demand from PV developers seeking to build before China's solar policy changed in May.**
- **In Q4 2024, the average U.S. module price ($0.28/$W_{dc}$) was down 3% q/q and about three times higher than the global spot price.**
  - **Analysts report price premiums in the United States for domestically manufactured modules, with a particular premium for those using domestically produced PV cells.**
- **In Q1 2025, the average imported PV cell price was $0.11/$W_{dc}$.**

PV Value Chain Global Spot Pricing



Global polysilicon spot prices rose 12% in Q1 2025, from $5.54/kg to $6.24/kg.

- The increase was supported by higher demand from PV developers seeking to build before China's solar policy changed in May.
- Polysilicon manufacturers operated at half capacity (vs. the same period in 2024)—about equivalent to wafer demand—which also helped keep prices up.
- The end of the pre-May building surge and the persistent large inventory of polysilicon led to a resumption of price declines in April.

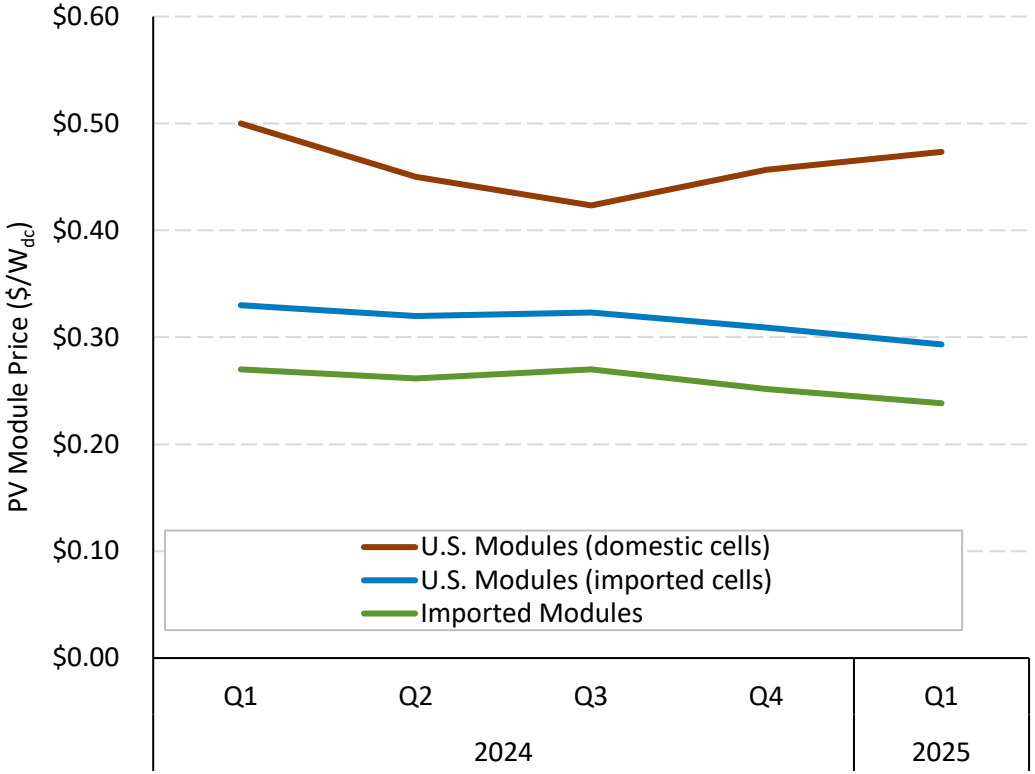
In Q1 2025, global spot prices rose 7% for wafers and 8% for cells.

Module spot prices rose 2% in Q1 2025 and remained around $0.09/$W_{dc}$.

- The impact of China's PV development surge on module prices was muted by the persistence of oversupply conditions and poor economics for module manufacturers.
- BNEF expects further module price reductions and new record lows in 2025.

Sources: BNEF, Solar Supply Chain Data, April 2025; BNEF, Solar Supply Chain Index, April 2025

U.S. Distributed Module Prices by Origin



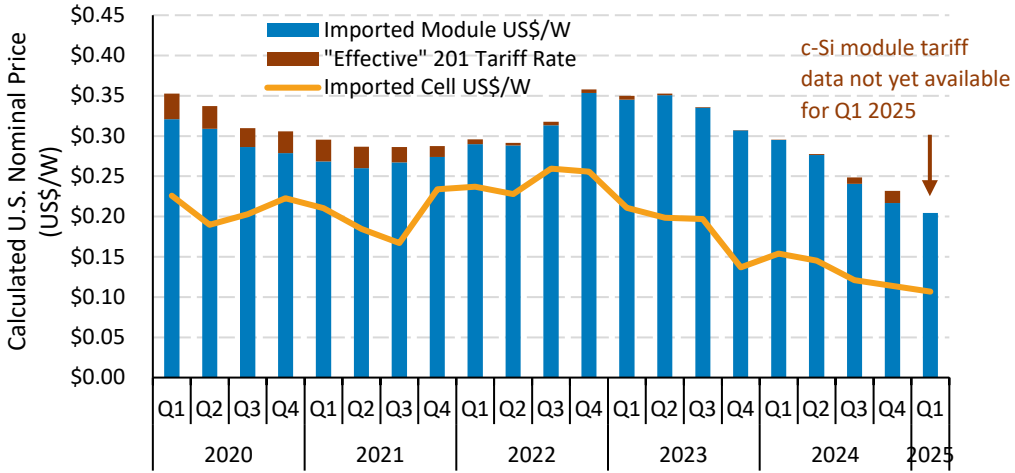
- Analysts report price premiums in the United States for domestically manufactured modules, with a particular premium for those using domestically produced PV cells.
- Analysts also noted a premium of approximately $\$0.03/W_{dc}$ for TOPCon over mono PERC.

Sources: Anza, U.S. Distributed Generation Q2 2025 Solar Module Pricing Insights Report; Wood Mackenzie/SEIA, US Solar Market Insight: Q4 2024, March 2025

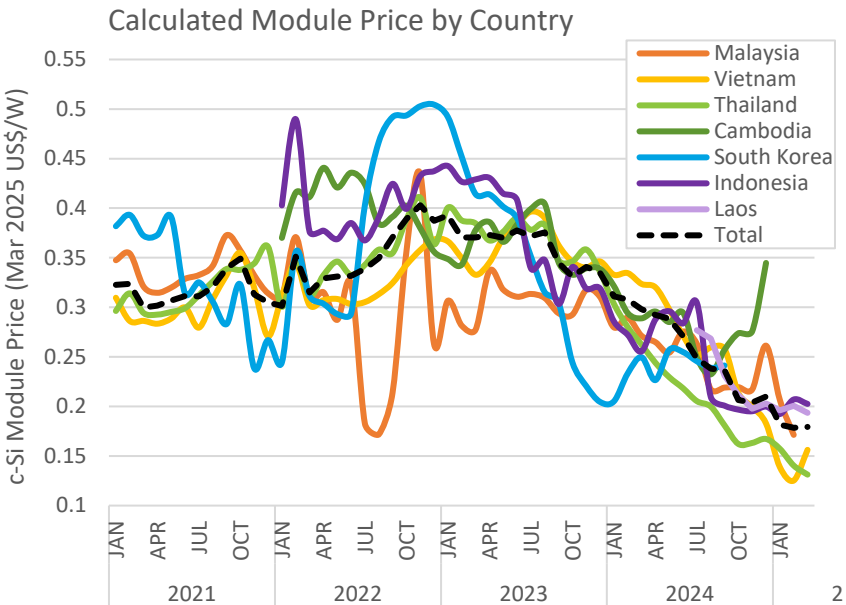
Calculated U.S. Module and Cell Import Pricing

Based on the reported value and capacity of imported PV modules and cells, in Q4 2024, the average price of a U.S. module fell further, to just under $\$0.22/W_{dc}$, while cell prices declined to $\$0.11/W_{dc}$.

- In Q4, approximately 49% of modules reported paying a tariff, up from 23% in Q3 and 3% in Q2.



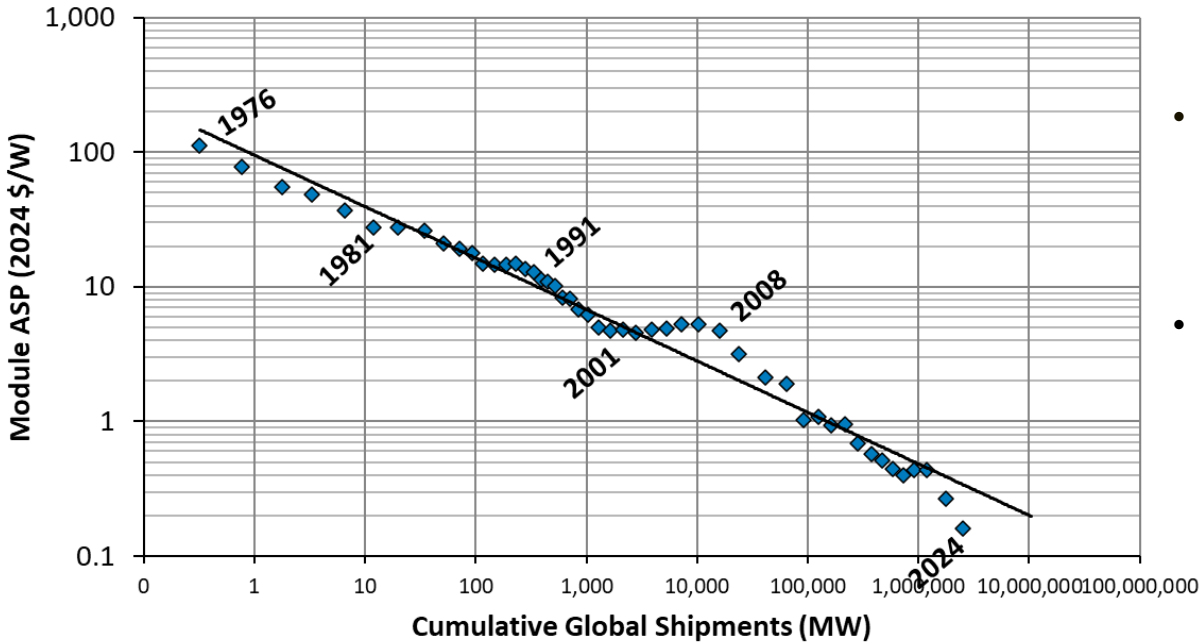
These module price declines were observed across all countries of import. However, prices have declined most steeply over the past several months for modules from Thailand, Vietnam, and Malaysia. Current prices continue to hit all-time domestic lows, when adjusted for inflation.



Note: The tariff rate was adjusted by the capacity subject to the tariffs. Manual corrections were made to three values because of suspected data entry errors for harmonized tariff schedule (HTS) code 8541430010: Cambodia (February 2022), Malaysia (June 2020), and Vietnam (July 2019). Several gigawatts of imports from India entered under the HTS code for thin-film modules in 2022–2024 but are believed to be c-Si based on news reports. Module price by country data plotted for import volumes over 10 MW/month.

Sources: Imports by HTS code: 8541406015 (2018–2021)/8541430010 (2022–), 8541406035 (2018–2021)/8541430080 (2022–), and 8541406025 (2018–2021)/8541420010 (2022–). Second quantity (watts) from the U.S. Census Bureau USA Trade Online tool and corrections page as of May 6, 2025

PV Experience Curve



- This solar PV experience curve, known as Swanson's Law, displays the relationship, in logarithmic form, between the average selling price of a PV module and the cumulative global shipments of PV modules.
- For every doubling of cumulative PV shipments from 1976 to 2024, there has been, on average, a ~23% reduction in PV module price.
- Historically, due in large part to undersupply and oversupply conditions, pricing has deviated from the experience curve.

Source: SPV Market Research, Photovoltaic Manufacturer Capacity, Shipments, Price & Revenues 2024/2025, April 2025

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- **Connecticut's Public Utilities Regulatory Authority adopted changes to the nonresidential interconnection process, allowing for a group study process that will simultaneously study the impacts of several interconnection applications within an area.**
- **New Jersey passed a law streamlining the interconnection process for solar and energy storage projects >5 MW to use the level 3 interconnection procedure instead of the more intensive level 4 procedure.**
- **The Invesco Solar ETF (TAN) fell 12% in Q1 2025, compared with a 4% decline for the S&P 500 and a 10% decline for the Russell 2000.**

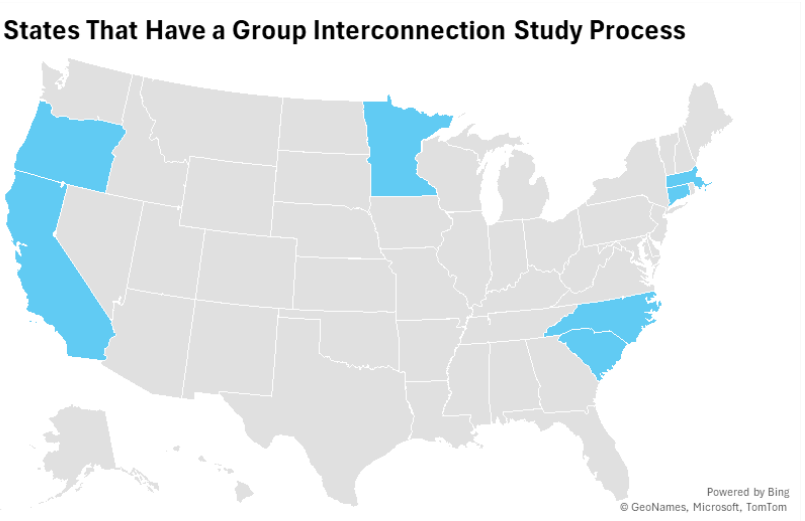
States: Q1 2025 Updates

New Jersey passed a law streamlining the interconnection process for solar and energy storage projects >5 MW to use the level 3 interconnection procedure instead of the more intensive level 4 procedure.

Maryland passed the Renewable Energy Certainty Act, which streamlines the approval process for solar and storage projects by standardizing permitting regulations across the state and prohibiting local jurisdictions from adopting zoning laws that restrict construction or operation of solar and energy storage projects that meet the state's permitting requirements.

Illinois completed a study to assess compensation structures for distributed energy resources. The study recommends maintaining the existing rebate floor. It also recommends that dispatchable resources like energy storage should be compensated based on actual performance and ability to align with grid needs.

Connecticut's Public Utilities Regulatory Authority adopted changes to the nonresidential interconnection process, allowing for a group study process that will simultaneously study the impacts of several interconnection applications within an area.



Mississippi's Public Service Commission approved Entergy Mississippi's proposal to revise compensation rates for excess net metering credits, reducing the value of the credits.

Sources: NC Clean Energy Technology Center, 50 States of Solar: Q1 2025 Quarterly Report, April 2025; PV Tech, Maryland passes act standardising 'onerous' solar zoning laws, April 2025; IREC, Thinking Outside the Lines: Group Studies in the Distribution Interconnection Process, October 2023

Section 232 Tariffs and the Solar Supply Chain

- Section 232 tariffs were originally imposed in 2018 on raw steel (25%) and aluminum (10%) imports from nearly all countries for national security reasons. However, a process was put in place to request exclusions on certain countries and/or products.
- In February 2025, President Trump introduced a flat 25% tariff on all steel and aluminum imports to the United States with **no exemptions** for countries or specific products. The tariffs were set to begin effective March 12.
    - **Prior agreements had suspended Section 232 tariffs for many countries, including several top steel exporters to the United States (e.g., Canada, Brazil, Mexico, South Korea, and the EU).**
- The U.S. solar industry uses steel for solar tracker systems and racking. Aluminum is primarily used for solar module frames, though certain companies (like Origami Solar) make module frames out of steel.
- Since the tariffs were announced, U.S. steel producers' stock prices have risen, while foreign steel producers' stock prices have fallen.

	Current Cost of Racking	Cost of Racking +25%	Current Cost of Frames	Cost of Frames +25%
Residential PV	$0.11/$W_{dc}$	$0.14/$W_{dc}$	$0.03/$W_{dc}$	$0.04/$W_{dc}$

Sources: PV Tech, Trump announces 25% tariffs on steel and aluminium, February 2025; CNN, Trump imposes 25% tariffs on steel and aluminum, February 2025; Sandler, Travis, and Rosenberg, P.A., Section 232 Tariffs on Steel & Aluminum, accessed February 2025; DOE, Solar Photovoltaic System Cost Benchmarks, accessed February 2025

Sweeping Tariffs Hit the Solar Supply Chain

Country (% of 2025 YTD cell + module imports)	New (paused at 10%) country-wide tariff	Most recent AD/CVD rates (majority and range)
Malaysia (26%)	24%	30.8% (15-250%)
Vietnam (17%)	46%	230% (126-396%)
Indonesia (13%)	32%	N/A
South Korea (12%)	25%	N/A
Thailand (11%)	36%	375% (375-1,000%)
Laos (9%)	48%	N/A
India (8%)	27%	N/A
Cambodia (7%)	49%	2,000% (660-3,529%)

"Liberation Day" tariffs:

- On April 2, President Trump announced new, sweeping tariffs on all countries.
- Key countries in the solar supply chain were hit with higher tariffs than the baseline 10%.
- Notably, solar-grade polysilicon and wafers, as well as solar manufacturing equipment are exempt.
- Some analysts believe short-term impacts on installations will be limited due to a stockpile of mainly residential modules.
- Most analysts project that these tariffs will stifle both solar deployment and manufacturing as tariffs will raise prices for importers and domestic manufacturers (beyond the current Section 201 and AD/CVD duties).
- Stock prices are down for U.S. solar manufacturers and major Chinese solar manufacturers.

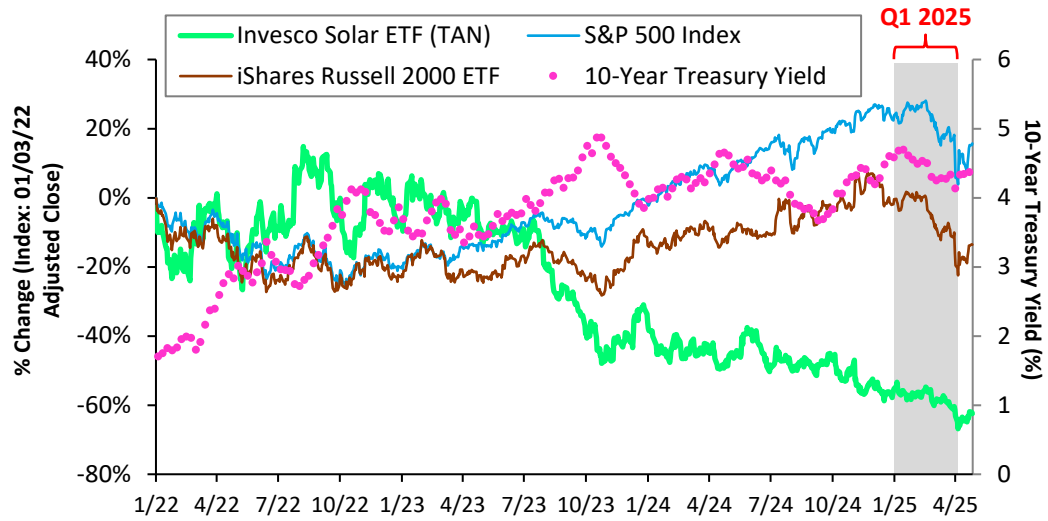
Final AD/CVD determinations for southeast Asia:

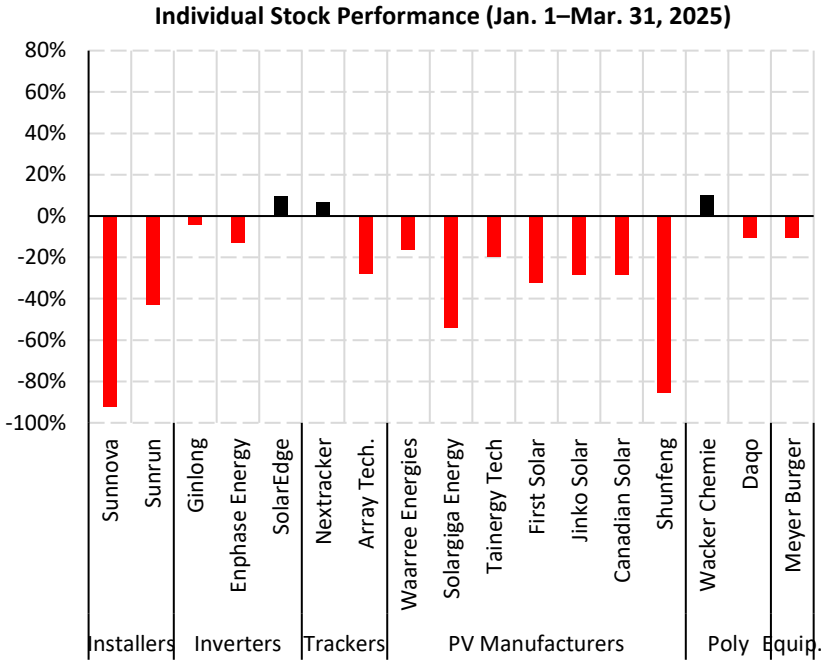
- On April 21, the Department of Commerce released final AD/CVD duties on silicon cells and modules from Malaysia, Vietnam, Thailand, and Cambodia.
- Duty values went up for every manufacturer investigated except for Hanwha, which was a petitioner on the investigation.
- On average, tariff values gained an additional 25% in Malaysia, 170% in Vietnam, 460% in Thailand, and nearly 2,000% in Cambodia between the preliminary and final determinations.
- These tariffs are significantly higher than the country-wide tariffs announced at the beginning of April

Sources: PV Tech, Trump tariffs hit Southeast Asian solar supply, 4/3/2025; PV Tech, PV Magazine, Trump tariffs deal damage to U.S., 4/7/2025; Politico, Trump's tariffs could choke US solar boom , 4/4/2025; Time, The Biggest Clean Energy Impacts from Trump's Tariffs, 4/8/2025; Trump tariffs to have limited effect on US solar imports from Asia, 4/7/2025; PV Tech, US tariffs hit Chinese solar stocks hard, 4/7/2025, Bloomberg, US Solar's Hoarding Habit Will Help Blunt Sting From Trump Tariffs, 4/5/2025; InfoLink Consulting, Impact of US trade barriers on solar PV supply chain: challenges and outlook-Industry, 4/10/2025; BBB, Trump tariffs list: See all the tariffs by country, 4/10/2025; Mint, From smartphones to laptops — US exempts THESE 20 items from Trump tariffs amid trade war | Check full list | Today News, 4/12/2025; Final Affirmative Determinations in the Antidumping and Countervailing Duty Investigations of Crystalline Photovoltaic Cells Whether or Not Assembled into Modules from Cambodia, Malaysia, Thailand, and the Socialist Republic of Vietnam, 4/21/2025.

Stock Market Activity

The Invesco Solar ETF (TAN) fell 12% in Q1 2025, compared with a 4% decline for the S&P 500 and a 10% decline for the Russell 2000. For all three indicators, performance was stronger in early 2025 before declining due to investor caution over the prospect of increased tariffs. Ten-year U.S. Treasury yields were relatively constant in Q1 as the Federal Reserve maintained benchmark policy rates of 4.25%–4.5% while evaluating the economic impacts of new federal policies. Solar projects—with their high upfront costs—are sensitive to interest rates.



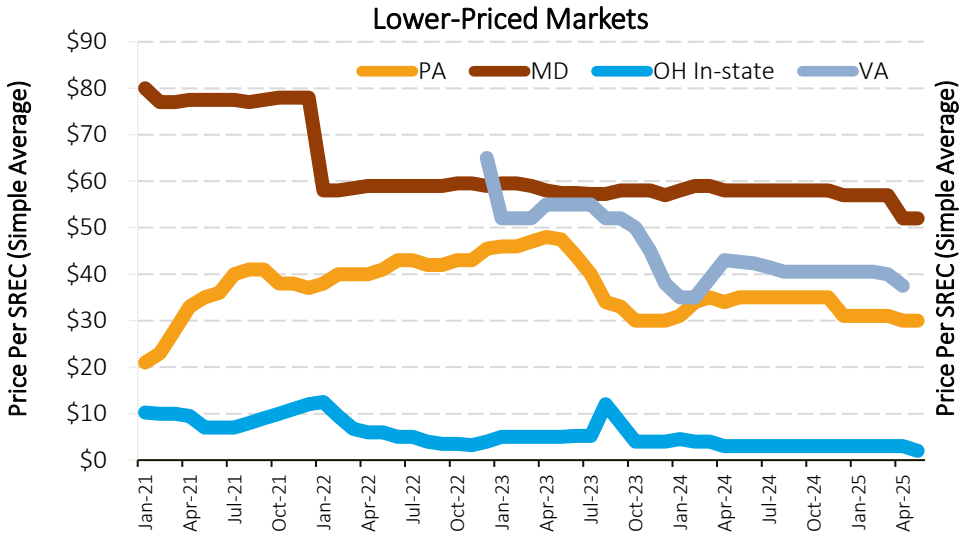


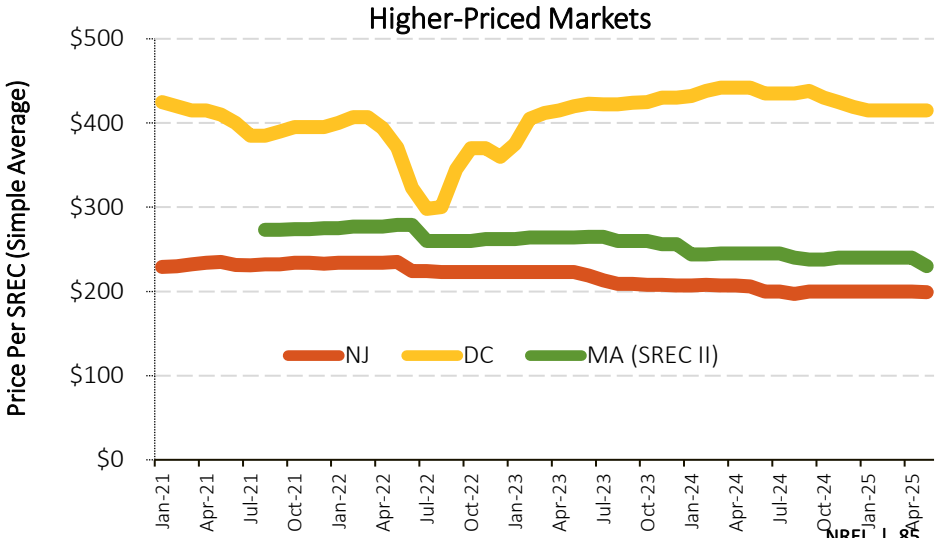
Note: The TAN index is weighted toward particular countries and sectors. As of April 29, 2025, 52% of its funds were in U.S. companies, and 19% were in Chinese companies. Its top 10 holdings, representing 60% of its value, were First Solar, NEXTracker, Enphase, GCL, Sunrun, Xinyi, HA Sustainable Infrastructure, Clearway Energy, Enlight Renewable Energy, and Solaria Energia y Medio Ambiente.

Sources: Federal Reserve Bank of St. Louis, Market Yield on U.S. Treasury Securities at 10-Year Constant Maturity, accessed April 2025; Invesco, Invesco Solar ETF, April 2025; Morningstar, Q1 2025 in Review and Q2 2025 Market Outlook, April 2025; Reuters, Weaker jobs signal, stronger prices highlight potential Fed dilemma, April 2025; Yahoo Finance, Invesco Solar ETF, iShares Russell 2000 ETF, and S&P 500, accessed April 2025

SREC Pricing

- Solar renewable energy certificate (SREC) pricing was relatively stable in the Q1 2025, though some markets dropped near the end of states' energy years in May and December.
- Prices vary depending on whether SRECs are sold in the spot market or for a forward contract. For example, RECmint estimates 10%–43% and 24%–47% discounts over spot prices for 3- and 5-year contracts, respectively.





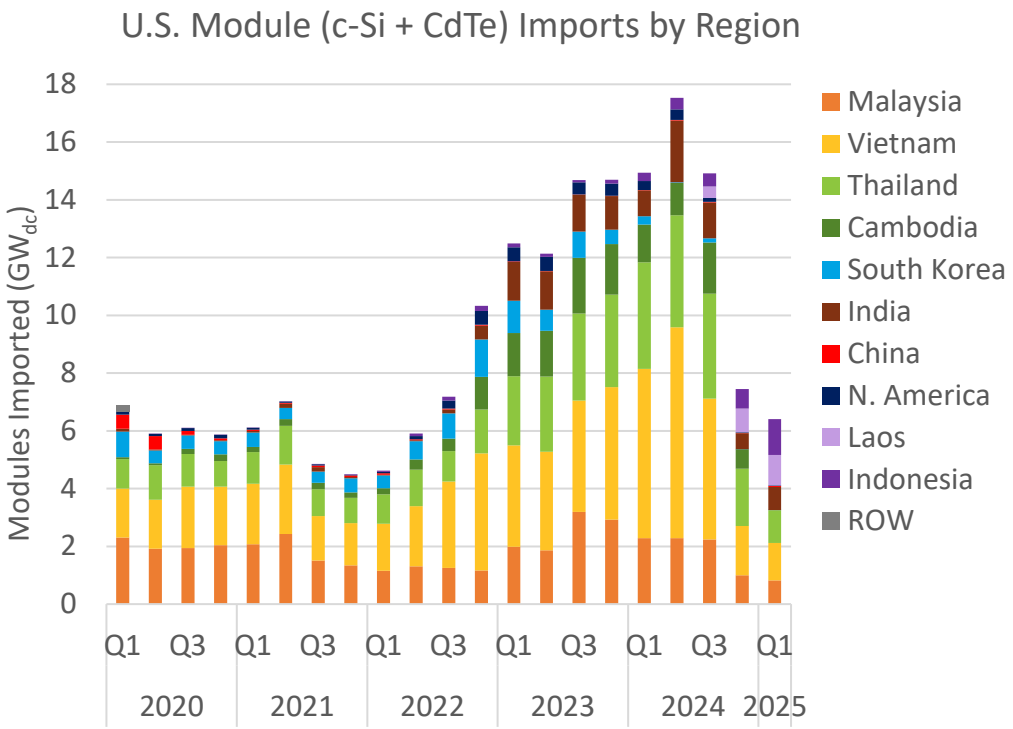
Sources: SRECTrade, accessed May 2025; RECmint, SREC market pricing for Virginia, accessed May 2025

Agenda

1. Global Solar Deployment
2. U.S. PV Deployment
3. PV System Pricing
4. Global Manufacturing
5. Component Pricing
6. Market and Policy
7. **U.S. PV Imports**

- **According to U.S. Census data, Q1 2025 module imports fell 14% q/q, hitting only 6.6 GW_{dc}—a level not seen since the first half of 2022.**
- **According to U.S. Census data, the United States imported 4.4 GW_{dc} of PV cells in Q1 2025, leveling off the meteoric growth from the last 18 months.**
- **By April 29, the United States had already imported 5 GW_{dc} of cells. If imports were to continue at the current rate, the TRQ would be exceeded by mid-August, halfway through the tariff-year.**

U.S. Module Imports Q1 2025 by Region

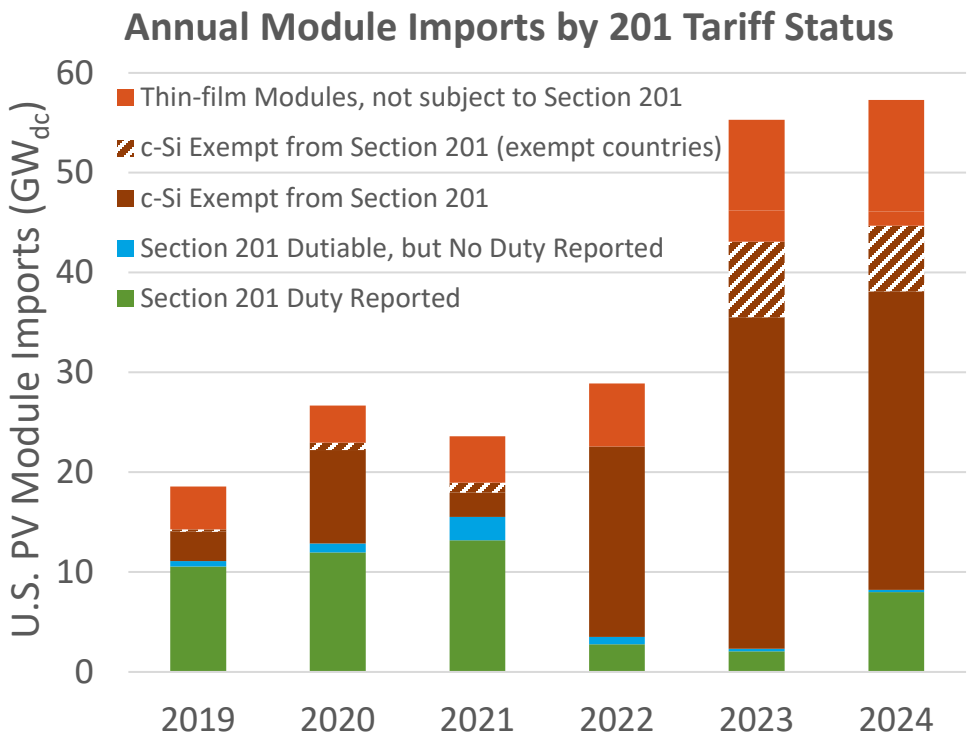


According to U.S. Census data, Q1 2025 module imports fell 14% q/q, hitting only 6.6 GW_{dc}.

- As imports from Thailand, Cambodia, Vietnam, and Malaysia continued to fall, Laos (16% of Q1 2025) and Indonesia (19% of Q1 2025) have begun to make up larger fractions of imports.
- This is likely in response to a combination of factors, including the end of the Chinese AD/CVD circumvention bridge over the summer, the positive Southeast Asia AD/CVD determinations in the fall, and the start of significant domestic production.
- Imports from North America have also fallen to nearly zero over the last several quarters, presumably because of the ongoing detention of Maxeon's shipments from Mexico and Canadian manufacturers prioritizing their domestic manufacturing endeavors.

Note: Several gigawatts of imports from India entered under the HTS code for thin-film modules in 2022–2024, but classifications may be erroneous, as the volumes exceed known manufacturing capacities for thin-film panels in India. **Sources:** Imports by HTS code: 8541460015 (2018–2021)/8541430010 (2022–) and 8541460035 (2018–2021)/8541430080 (2022-); second quantity (watts) from the U.S. Census Bureau USA Trade Online tool and corrections page as of May 6, 2025; Maxeon, Maxeon Provides Strategic Business Update, April 2025

U.S. Module Imports by Tariff Over Time



According to U.S. Census data, in 2019–2021, a much higher fraction of imported modules (40%–60%) reported paying a tariff than in 2022–2024.

Starting in 2022, that percentage began to fall off dramatically, hitting a record low of 4% in 2023. Modules can be exempt from Section 201 tariffs for a variety of reasons:

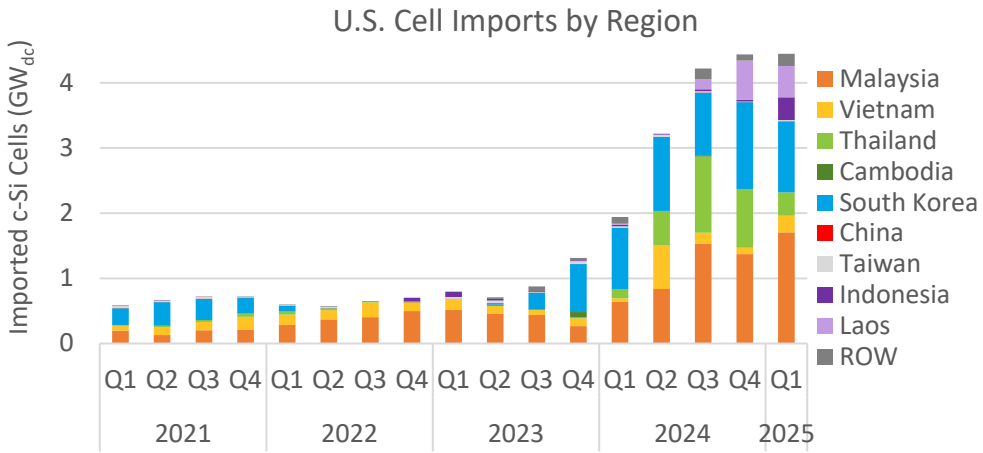
- If they are thin-film modules (including CdTe)[a]
- If they were imported from certain exempt countries (most notably Canada and Cambodia)
- If they are bifacial modules when the bifacial exemption was active (October 2020–May 2024) or interdigitated back-contact modules.
  - Although country of import and thin-film modules can be differentiated in CBP data, other reasons for exemption cannot.

Sources: Imports by HTS code: 8541460015(2018–2021)/8541430010(2022–) and 8541460035(2018–2021)/8541430080(2022–); second quantity (watts) from the U.S. Census Bureau USA Trade Online tool and corrections page as of February 5, 2024. [a] Several GW of imports from India entered under the HTS code for thin-film modules in 2022–2024, but classifications may be erroneous, as the volumes exceed known manufacturing capacities for thin-film panels in India.

c-Si PV Cell Import Data Q4 2024

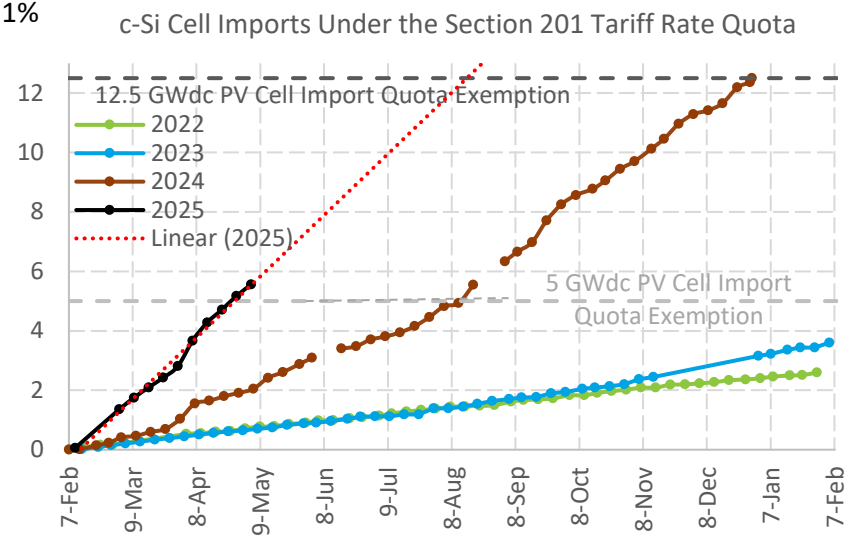
According to U.S. Census data, the United States imported 4.4 GW_{dc} of PV cells in Q1 2025, leveling off the meteoric growth from last 18 months.

– Although the majority of imports still come from Malaysia (38%) and South Korea (25%), over the last several quarters, imports from Laos have grown substantially (0% to 4% to 14% to 11%), as have imports from Indonesia (1% to 8%), as imports from Thailand have fallen.

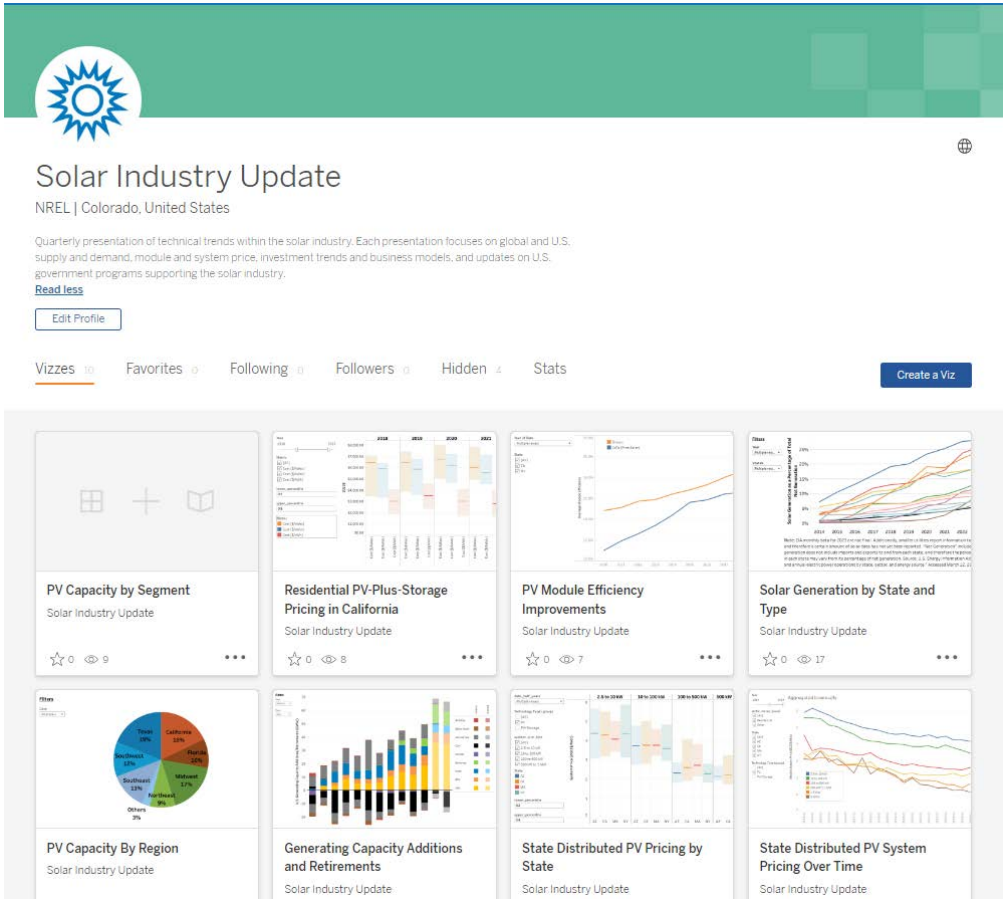


According to CBP Commodity Status Reports, since the annual TRQ for cells was raised to 12.5 GW_{dc} in August, imports have continued to accelerate.

On February 7, 2025, the TRQ reset, but began to refill quickly. By April 29, the United States had already imported 5 GW_{dc} of cells. If imports were to continue at the current rate, the TRQ would be exceeded by mid-August, halfway through the tariff-year.



Sources: Imports by HTS code: 8541460025(2018–2021)/8541420010(2022–); second quantity (watts) from U.S. Census Bureau USA Trade Online tool and corrections page as of May 5, 2025; U.S. Customs and Border Protection Commodity Status Reports February 2019–May 2025



Interested in checking out more of our data in Tableau? Click here.

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List of Acronyms and Abbreviations

a-Si: amorphous silicon
ac: alternating current
AD/CVD: antidumping and countervailing duties
AD: antidumping
ADD: antidumping duty
AEO: Annual Energy Outlook
AI: artificial intelligence
ALMM: Approved List of Models and Manufacturers
ASP: average selling price
BESS: battery energy storage system
BNEF: BloombergNEF
C&I: commercial and industrial
c-Si: crystalline silicon
CAISO: California Independent System Operator
CBP: U.S. Customs and Border Protection
CCI: Community, commercial, and industrial
CdTe: cadmium telluride
CIS/CIGS: copper indium gallium selenide
CPUC: California Public Utilities Commission
CSP: concentrating solar power
CSTA: Chinese Solar Thermal Alliance
CVD: countervailing duty
dc: direct current
DOE: U.S. Department of Energy
DPV: distributed photovoltaic
EIA: U.S. Energy Information Administration
EPA: United States Environmental Projection Agency
ERCOT: Electric Reliability Council of Texas
ETF: exchange traded fund
EU: European Union
FERC: Federal Energy Regulatory Commission
FPV: floating photovoltaic
GW: gigawatt
GWh: gigawatt-hour
H1: first half of year
H2: second half of year
HJT: heterojunction
HTS: harmonized tariff schedule
IEA: International Energy Agency
IOU: investor-owned utility
IRA: Inflation Reduction Act
IREC: Interstate Renewable Energy Council
ITC: investment tax credit
ITRPV: International Technology Roadmap for Photovoltaics
kW: kilowatt
kWh: kilowatt-hour
LBNL: Lawrence Berkeley National Laboratory
LFP: lithium iron phosphate
LPO: U.S. Department of Energy Loan Program Office
MLPE: module-level power electronics
MW: megawatt
MWh: megawatt-hour
MWth: megawatt thermal
NEA: National Energy Administration
NEM: net energy metering
NMC: nickel manganese cobalt
NREL: National Renewable Energy Laboratory
NYSERDA: New York State Energy Research & Development Authority
NYISO: New York Independent System Operator
PERC: passivated emitter and rear contact
PG&E: Pacific Gas & Electric
PPA: power purchase agreement
PV: photovoltaics
Q: quarter
q/q: quarter over quarter
RE: renewable energy
ROW: rest of world
RPS: renewable portfolio standard
SCE: Southern California Edison
SE: southeast
SEGS: Solar Energy Generating Systems
SEIA: Solar Energy Industries Association
SETO: Solar Energy Technology Office
SHIP: solar heat in industrial processes
SHJ: silicon heterojunction
Si: silicon
SREC: solar renewable energy certificate
T&D: transmission and distribution
TAN: Invesco Solar ETF
TOPCon: tunnel oxide passivated contact
TPO: third-party owner
TRQ: tariff rate quota
TW: terawatt
UAE: United Arab Emirates
UPV: utility-scale PV
USD: U.S. dollars
W: watt
Wt avg: weighted average
y/y: year over year
YTD: year to date
ZEV: zero-emission vehicle
ZTC: zero-carbon technology cost