NREL
NATIONAL RENEWABLE ENERGY LABORATORY

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Solar Industry Update

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Photo by Brendon Shank, 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

U.S. PV Deployment

- EIA projects significant growth for PV in 2024 over the record-breaking year in 2023. Over the next 2 years, virtually all new electric generation capacity will be PV, batteries, and wind.
- The United States installed approximately 14.1 GWh (4.3 GW_{ac}) of energy storage onto the electric grid in Q1/Q2 2024—its largest first half on record.
- Though thin-film PV represented around 3% of global PV deployed from 2015 through 2023, it accounted for more than 17% of U.S. PV deployments during this period (24% of utility-scale deployments).
- In 2023, approximately 45% of battery capacity and 26% of utility-scale PV capacity were hybrid PV/BESS projects—relatively consistent with previous years.
- The third-party ownership share of U.S. residential PV systems increased sharply in 2024, aided by high interest rates and additional incentives from the IRA.

PV System and Component Pricing

- Most data suggest decreases in CAPEX in the first half of 2024, but energy pricing across market segments varied because of other factors.
- In Q3 2024, module prices rose 1% but stayed near record lows, around \$0.10/W_{dc}, as substantial module overcapacity continues to depress prices.
- Global polysilicon spot prices rose 3% from early August (\$5.66/kg) to early October (\$5.86/kg); however, prices are still below production costs for most manufacturers.
- In Q2 2024, the average U.S. module price (\$0.31/W_{dc}) was down 6% q/q and down 16% y/y, and at a 190% premium over the global spot price.
- In Q3 2024, the average imported PV cell price was \$0.12/W_{dc}.

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

Global Manufacturing

- According to Infolink, the top 10 module manufacturers were responsible for 226 GW of shipments (+40% y/y) in H1 2024.
- In H1 2024, the United States produced 4.2 GW of PV modules—an increase of 75%, y/y—roughly evenly split between thin-film and c-Si module technology.
- Since the IRA's passage, more than 95 GW of manufacturing capacity have been added across the solar supply chain (from facilities announced pre- and post-IRA), including nearly 42 GW of new module capacity.
  - U.S. c-Si manufacturers added significant capacity in H1 2024.
  - Analysts estimated that U.S. c-Si cell production and capacity should begin to slowly ramp up in the second half of 2024.
- On October 22, the IRS clarified that domestic solar ingot and wafer producers can receive the 25% 48D investment tax credit.

U.S. PV Imports

- According to U.S. Census data, in Q3 2024, U.S. module imports grew again to nearly 15.4 GW_{dc} or 48.5 GW_{dc} for the first 9 months of 2024.
- On October 1, the Department of Commerce (DOC) issued a preliminary decision to impose countervailing duties (CVD) on c-Si panels and cells produced in Vietnam, Malaysia, Thailand, and Cambodia. Tariffs ranged from 0% to 300%; a preliminary decision on antidumping duties is expected later this fall.
- According to CBP Commodity Status Reports, since the President raised the annual tariff rate quota for cells to 12.5 GW in August, imports have continued to accelerate. As of Oct. 28, 2024, more than 9.4 GW (75% of the TRQ) of cells have been imported.

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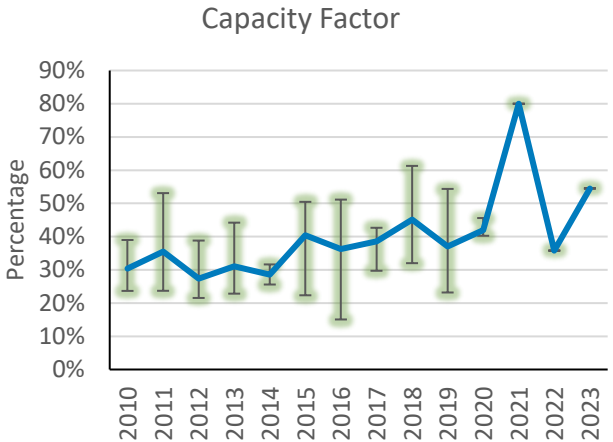
- **IRENA reports that, between 2010 and 2023, the global weighted average levelized cost of energy (LCOE) of concentrating solar power (CSP) fell from $0.39/kWh to under $0.12/kWh—a decline of 70%.**
  - **IRENA reports significant cost declines for all cost drivers within a CSP system, leading total CAPEX for parabolic trough and power tower CSP plants to decline 58% and 68%, respectively, from 2010/2011 to 2023.**
- **Several CSP projects are underway to provide 100-hour+ energy storage.**

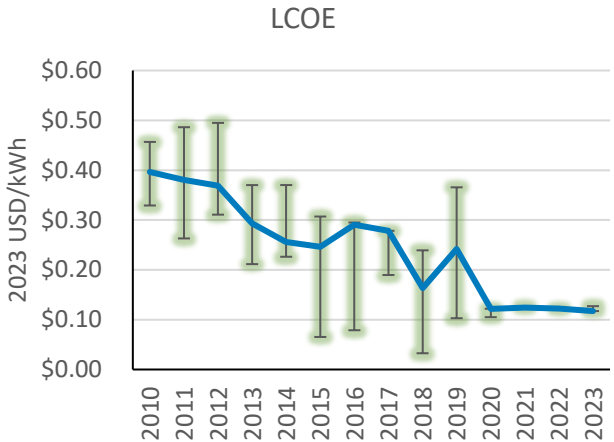
Concentrating Solar Power Update

- NREL is moving to 100-kW demonstration in an ARPA-E-funded 100-hour thermal energy storage project in sand. The technology has a 95% round-trip efficiency, loses 1% of heat a day, and can be used for industrial heat or electricity generation.
- Companies plan to repurpose idle oil wells to act as a thermal energy storage system for solar thermal collectors. The concept eliminates the costs normally required to plug and abandon depleted holes (asset retirement obligations). Additionally, projects are also likely eligible for a 40% tax credit (because the oil well is most likely located in an energy community). A 1,000-hour demo is scheduled to begin construction in California next year.
- This summer, the Chinese company POWERCHINA completed the first sub-Saharan CSP plant, the 100-MW Redstone tower facility. The U.S. company SolarReserve originally developed it in 2014; however, the project was delayed because of South Africa's permitting process and SolarReserve's bankruptcy, which was caused by the Crescent Dunes project.

Global CSP Cost and Performance 2010–2023

- IRENA reports that between 2010 and 2023, the global weighted average LCOE of CSP fell from $0.39/kWh to under $12/kWh—a decline of 70%.
  - IRENA attributes the decrease to a reduction in installed costs (down 37%), higher capacity factor resulting from increased storage (up 82%), and lower O&M costs (down 48%).
- Differences in value between 2022 and 2023 reflect one project installed in each year—one in China in 2022 and one in the United Arab Emirates in 2023 (with 15 hours of storage).
  - From 2022 to 2023, LCOE dropped 4%.

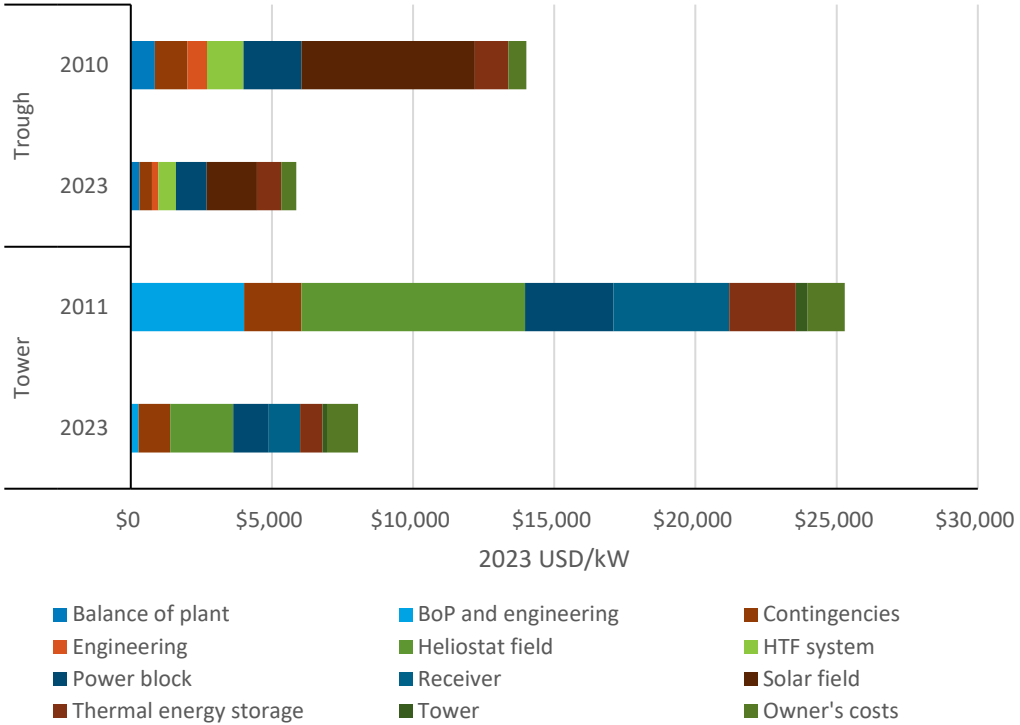




Note: Error bars reflect the 95% and 5% confidence intervals.

Source: IRENA, Renewable Power Generation Costs in 2023.

Global CSP Cost and Performance 2010–2023



- IRENA reports significant cost declines for all cost drivers within a CSP system, leading total cost for parabolic trough and power tower CSP plants to decline 58% and 68%, respectively, from 2010/2011 to 2023.
- The largest drivers of cost declines for towers were the heliostat field, balance of plant and engineering, and the receiver.
- The largest driver of cost declines for parabolic trough plants was the solar field.

Source: IRENA, Renewable Power Generation Costs in 2023.

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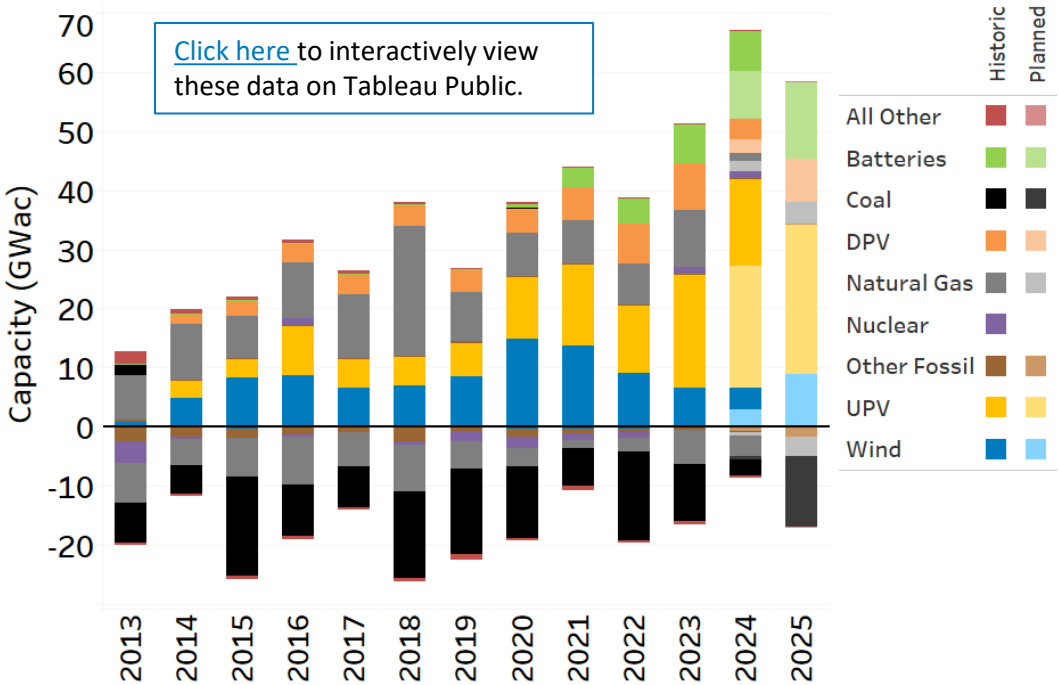
- **EIA projects significant growth for PV in 2024 over the record-breaking year in 2023. Over the next 2 years virtually all new electric generation capacity will be PV, batteries, and wind.**
- **The United States installed approximately 14.1 GWh (4.3 GW_{ac}) of energy storage onto the electric grid in Q1/Q2 2024—its largest first half on record.**
- **Though thin-film PV represented around 3% of global PV deployed from 2015 through 2023, it accounted for more than 17% of U.S. PV deployments during this period (24% of utility-scale deployments).**
- **In 2023, approximately 45% of battery capacity and 26% of utility-scale PV capacity were hybrid PV/BESS projects—relatively consistent with previous years.**
- **The third-party ownership share of U.S. residential PV systems increased sharply in 2024, aided by high interest rates and additional incentives from the IRA.**

U.S. Generation Capacity Additions and Retirements by Source: 2013–2023 and Planned 2024–2025



- EIA projects significant growth for PV in 2024 over the record-breaking year of 2023.
- Over the next 2 years, virtually all new electric generation capacity will be PV, batteries, and wind.
- EIA's current projections are lower than projections made earlier in the year; however, there are currently more projects in their pipeline.
- By the end of 2025, EIA projects more than 220 GW_{ac} of PV capacity in the United States.
  - This figure is second only to natural gas for most U.S. installed capacity.

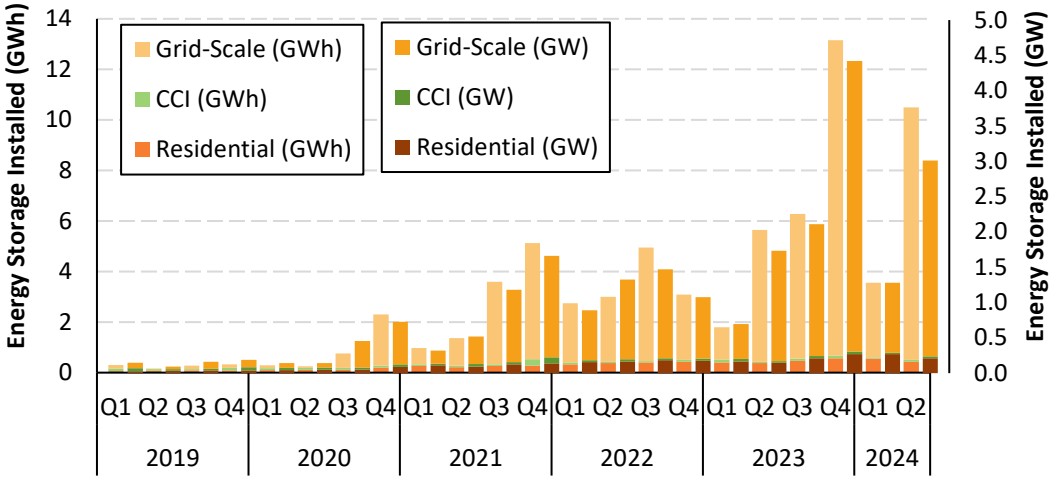
Sources: EIA Form 860M/Preliminary Monthly Electric Generator Inventory ("Planned" and "Operating") and EIA Short-Term Energy Outlook, Table 7e, downloaded October 2024.

U.S. Energy Storage Installations by Market Segment

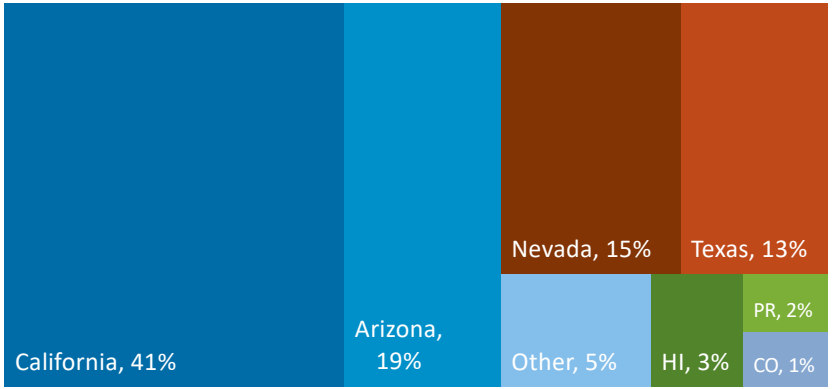
- The United States installed approximately 14.1 GWh (4.3 GW_{ac}) of energy storage onto the electric grid in Q1/Q2 2024—its largest first half on record.

- The majority of grid-scale installations were in four states: California, Nevada, Arizona, and Texas.
- Residential storage was driven in California by changes to net metering, causing a 70% attachment rate, from 8% a year ago.

U.S. Energy Storage Installations by Market Segment

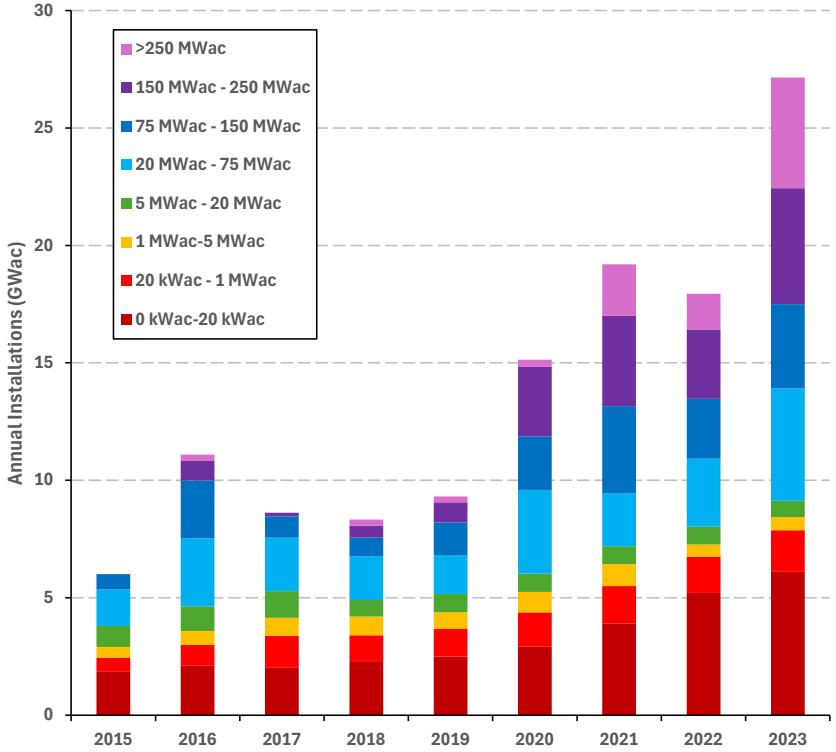


Q1/Q2 2024 U.S. Energy Storage Installations by Region (14.1 GWh)



Note: CO= Colorado; HI=Hawaii; 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 & Renewables and Energy Storage Association, U.S. Energy Storage Monitor: Q3 2024.

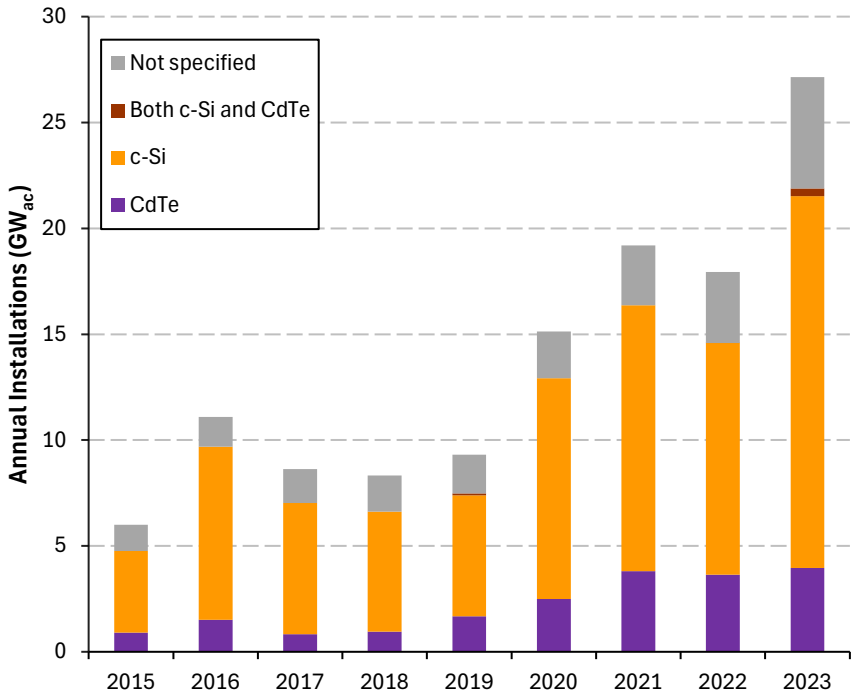
U.S. PV System Size Distribution by Year



- Since 2015, the growth in annual U.S. PV deployment has come mostly from both systems less than 20 kW_{ac} and greater than 20 MW_{ac}, with the largest growth coming from those greater than 150 MW_{ac}.
- 0% of all U.S. PV systems installed in 2015 were above 150 MW_{ac}, compared to more than 35% of 2023 installations.

Sources: U.S. EIA, Form EIA-860 2023; U.S. EIA, Form EIA-861M; Tracking the Sun, LBNL, August 2024.

U.S. PV Technology Distribution by Year

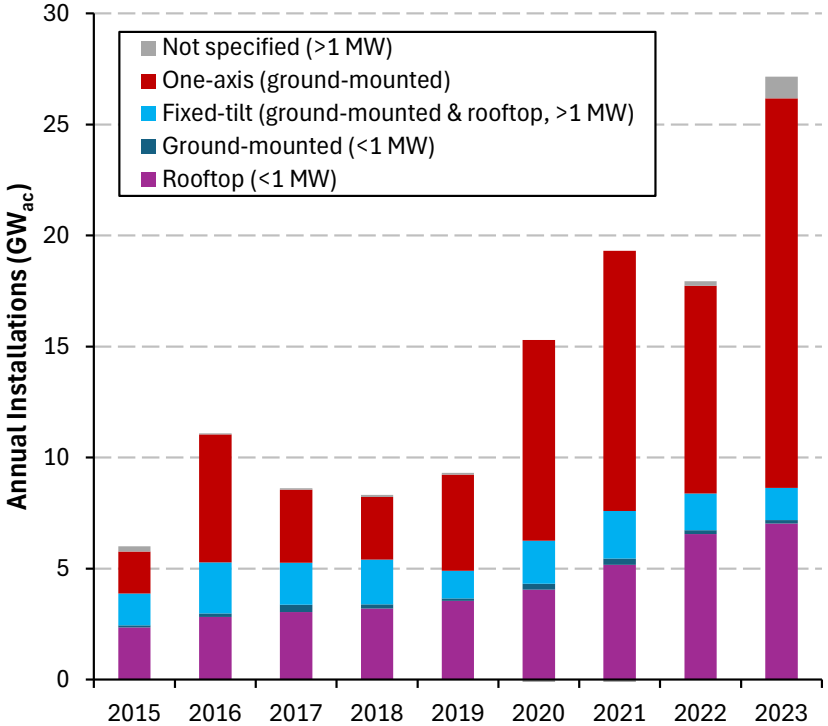


- Though thin-film PV represented around 3% of global PV deployed from 2015 through 2023, it accounted for more than 17% of U.S. PV deployments during this period (24% of utility-scale deployments).
  - 16.5% of all U.S. PV systems built in 2023 used at least some CdTe panels.

Note: "Not specified" also includes a small number of CIGS and a-Si modules.

Sources: U.S. EIA, Form EIA-860 2023; Paula Mints, "Photovoltaic Manufacturer Capacity, Shipments, Price & Revenues 2023/2024." SPV Market Research. Report SPV-Supply12. April 2024.

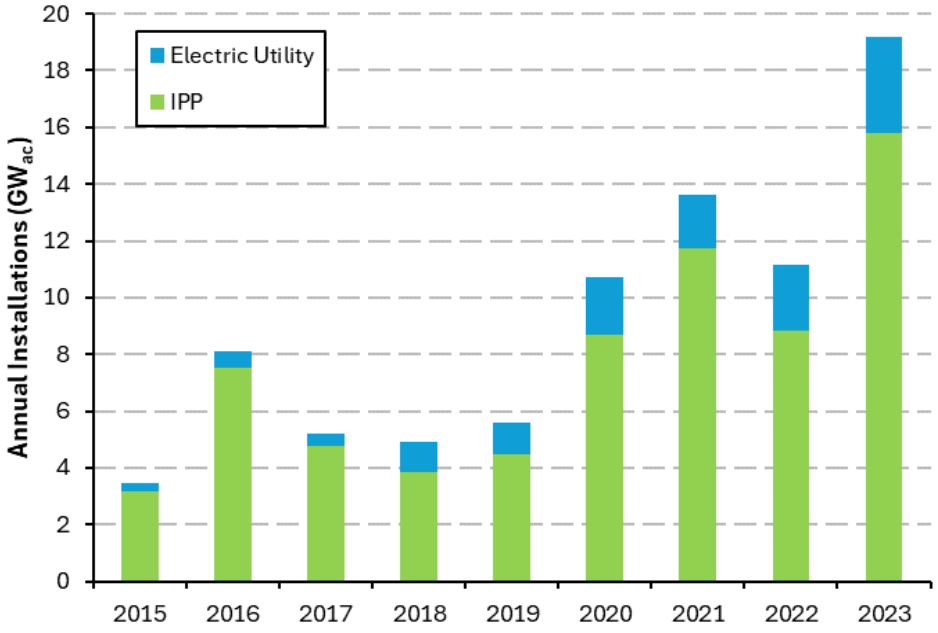
U.S. PV Mounting Type by Year



- The use of single-axis/one-axis tracking in the U.S. utility PV market has grown significantly since 2015.
  - In 2023, 65% of all PV systems installed used single-axis tracking; 92% of ground-mounted PV systems installed in 2023 used single-axis tracking.
  - This growth can be attributed to the reduced cost and increased reliability of trackers, making them the economic choice in a broader distribution of PV systems (e.g., less irradiant climates).

Note: "Not specified" may also include a small number of two-axis tracking systems.
Sources: U.S. EIA, Form EIA-860 2023; U.S. EIA, Form EIA-861M; Tracking the Sun, LBNL, August 2024.

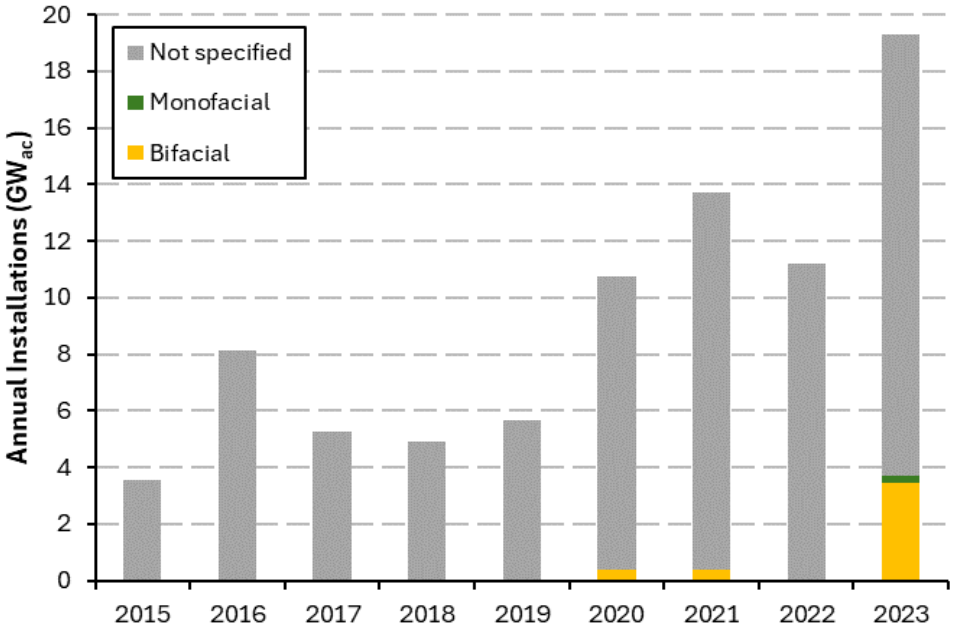
>1 MW_{ac} U.S. PV Asset Ownership by Year



- Most U.S. utility-scale PV systems—82% of installations in 2023, 84% cumulative—are owned by independent power producers, which sell their electricity under long-term contracts.
- From 2015 to 2023, 13.1 GW_{ac} of PV installed were owned by electric utilities—3.4 GW_{ac} were installed in 2023 alone.

Source: U.S. EIA, Form EIA-860 2023.

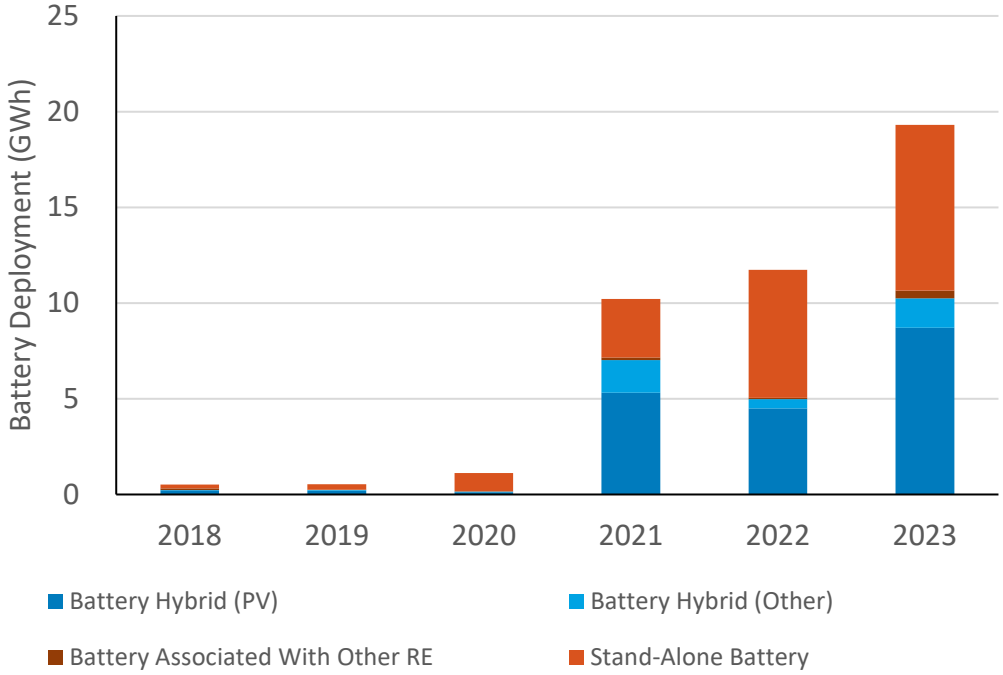
>1 MW_{ac} U.S. PV BIFACIAL



- EIA recently began collecting information on whether panels deployed in installations >1 MW_{ac} were bifacial.
- As this data collection is relatively new, it is not expected to be perfect nor entirely representative of the current U.S. market.
- In 2023, around 18% of utility-scale PV installations were reported as bifacial, whereas 1.4% were reported as monofacial, and another more than 80% of installations did not specify their bifaciality.
- Cumulatively, around 4.2 GW_{ac} (4.6%) of utility-scale PV installations have been reported as bifacial.

Source: U.S. EIA, Form EIA-860 2023.

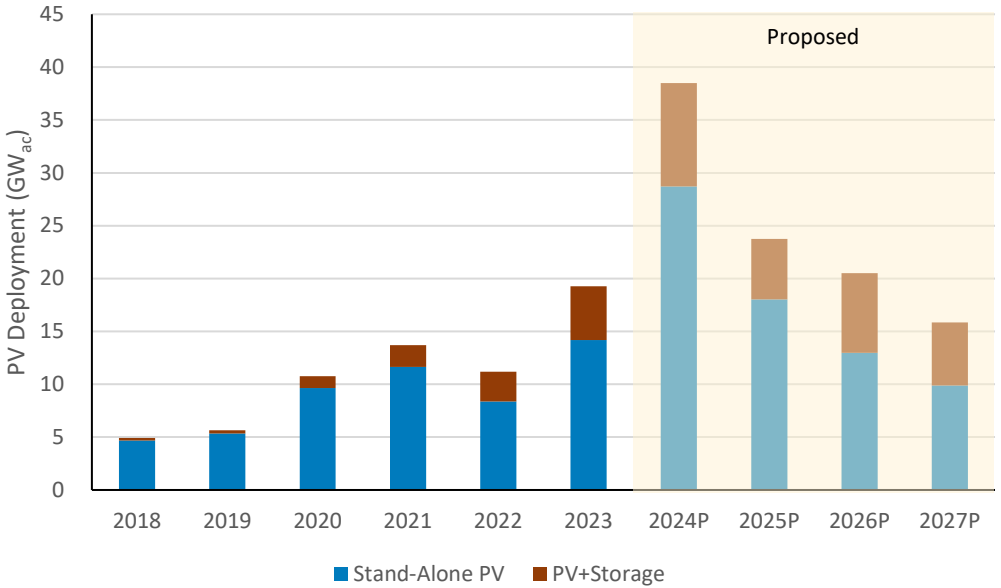
U.S. Utility-Scale PV and Batteries



- In 2023, approximately 45% of battery capacity was collocated with a PV system—relatively consistent with previous years.
- The other half of battery capacity has not been directly tied to PV or other renewable energy generation capacity.
  - Though likely spurred from renewable energy deployment, a significant amount of capacity has been built as separate projects.

Note: Hybrid plants report the same plant code as energy generation technologies. Battery plants associated with other wind and solar have no listed associated plant but have been designated as handling excess wind and solar capacity or "co-located renewable firming."
Source: U.S. EIA, Form EIA-860 2023.

U.S. Utility-Scale PV and Batteries

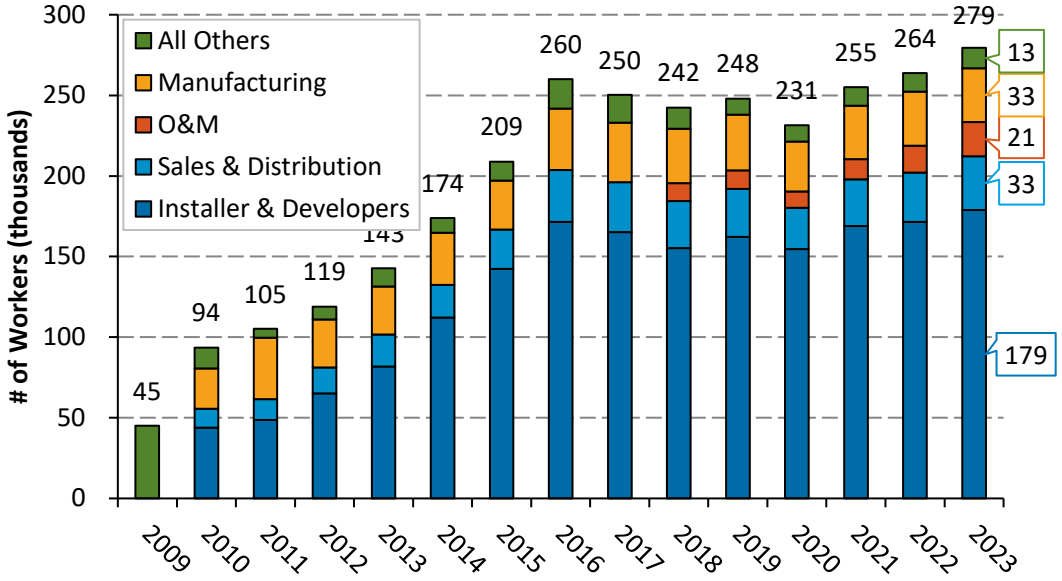


- In 2023, approximately 26% of PV capacity was co-located with a BESS.
- EIA projects significant growth of PV and batteries between 2023 and 2024, with approximately the same attachment rate.
- The attachment rate for 2026–2027 projects in the queue grows to ~38%.

Note: Hybrid plants report the same plant code as energy generation technologies.
Source: U.S. EIA, Form EIA-860 2023.

U.S. Solar Workforce (IREC)

- At the end of 2023, more than 279,000 U.S. employees spent most of their time on solar project- or manufacturing- related work. An additional 85,907 workers spent less than half their time on solar-related work.

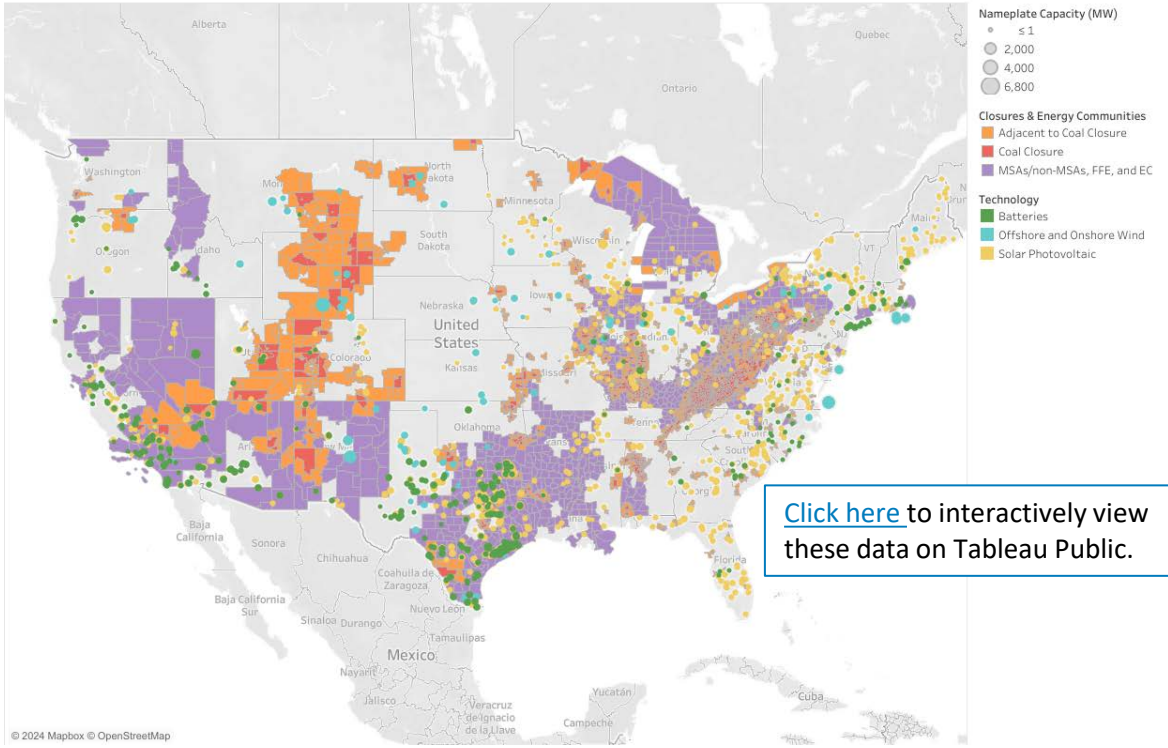


- This represents an increase of 15,564 jobs, or 5.9% growth since 2022.
  - Nationwide, the utility-scale solar market gained about 1,888 jobs (+6.8%) in 2023. Residential solar jobs grew by 5,945 jobs, or 6.3%, which marks a slowdown from 2022, when residential solar jobs grew 11%.
- Solar jobs grew in 47 states in 2023. Florida added the most jobs in 2023 (+1,841 jobs, +15%) followed by Arizona (+1,388, +17%), Texas (+1,171, +10%), and Nevada (+1,029, +14%).
  - Only 29% of solar industry employers said it was “very difficult” to find qualified applicants, a decrease from the record high of 44% in 2022. Manufacturing was the only sector to see an increase in hiring difficulty in 2023.
- The proportion of women in the solar workforce held steady at 30% from 2022 to 2023. Similarly, the proportion of the workforce that identifies as Black remained at 8.5%, considerably less than the proportion in the overall workforce (13%).

Source: IREC, The National Solar Jobs Census 2023. September 2024.

Planned U.S. Electric Generation Plants in Relation to Energy Communities

Planned U.S. Generation Capacity in Relation to Energy Communities, September 2024



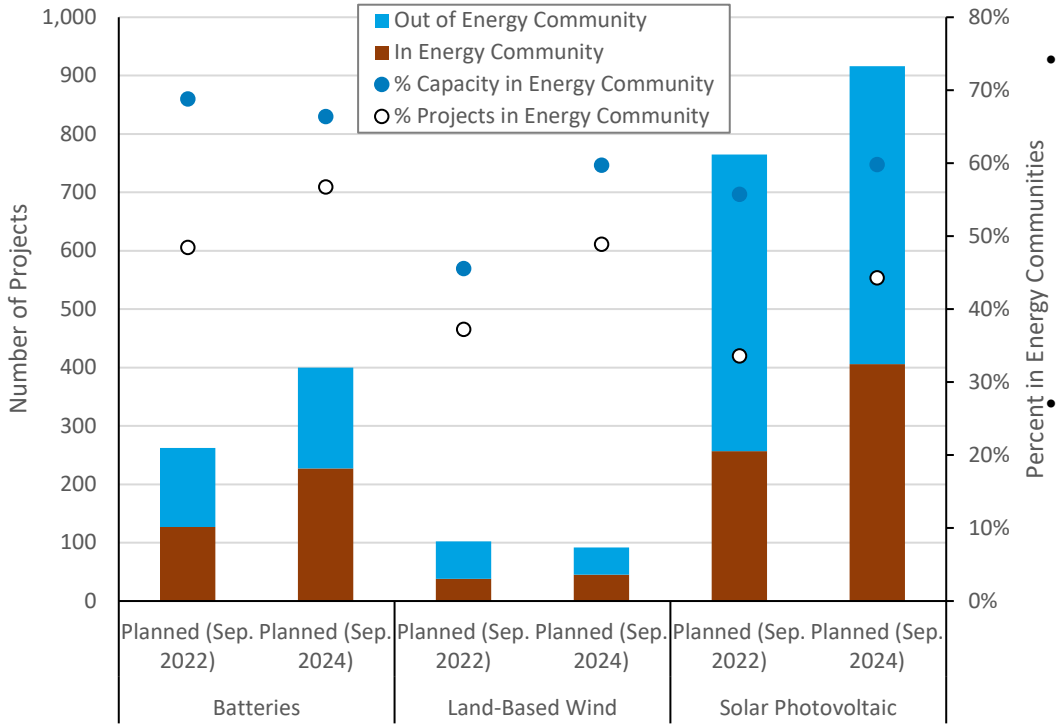
Click here to interactively view these data on Tableau Public.

- Since the passage of the Inflation Reduction Act, which provides an additional 10% tax credit for renewable energy projects located in an "Energy Community," a significant number of new planned renewable energy projects have been announced.
- In September 2022, 1 month after the passage of the Inflation Reduction Act, the EIA tracked over 1,100 planned utility-scale PV, land-based wind, and battery projects, of which 37% were located in energy communities (based on current guidelines).
  - In September 2024, there were 1,700 projects, of which 49% were in energy communities.
  - In March 2024, the IRS expanded the number of areas that qualify as an energy community. Under the previous guidelines, the percentage of planned utility-scale PV, land-based wind, and battery projects would have been 45% instead of 49%.

Note: Brownfields, which are also eligible for the energy community bonus credit, do not have the same census tract delineations and so are not included in this analysis. There is some uncertainty in the exact location in where a planned project will be built. This analysis relies on the latitude and longitude provide to EIA.
Sources: U.S. Energy Information Administration (EIA), EIA Form 860 (November 2022, November 2024).

Percent of Planned PV, Wind, and Battery Markets Located in Energy Communities

Click here to interactively view these data on Tableau Public.

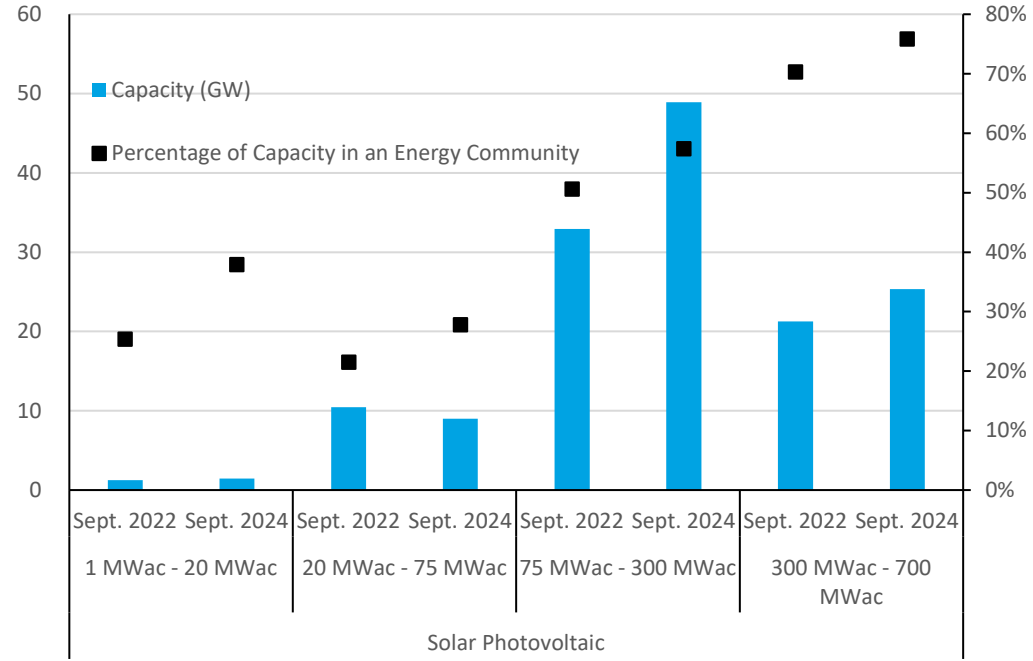


- NREL analysis found that more planned projects, across technologies, were located in energy communities in September 2024 than were in the pipeline in September 2022.
  - In September 2024, approximately 44% of PV planned projects, above 1 MW, were located in an energy community, compared to 34% in 2022.
- The percentage of capacity in energy communities was generally higher than the percentage of projects in energy communities, but the growth from September 2022 to September 2024, in terms of capacity, was not as great.
  - Energy community market share can be influenced more by large individual projects when measured in terms of capacity rather than in terms of projects.
- Large electric generating assets in the United States typically take years to develop, and EIA data are not necessarily added uniformly in terms of project development; thus, it may take years to determine any long-term trends caused by the Energy Community tax credit bonus.

Sources: U.S. Energy Information Administration (EIA), EIA Form 860 (November 2022, November 2024).

Percent of Planned PV Located in Energy Communities, by System Size

Click here to interactively view these data on Tableau Public.



- The largest increase in energy community market share for PV systems (above 1 MW), between September 2022 and September 2024, was for planned systems smaller than 20 MW.
  - The gain in market share shrank as system size increased.
- Planned larger systems, on average, were more likely to be already sited in an energy community, even before the Energy Community bonus credit was enacted.

Sources: U.S. Energy Information Administration (EIA), EIA Form 860 (November 2022, November 2024).

Percent of Planned BESS Located in Energy Communities, by System Size

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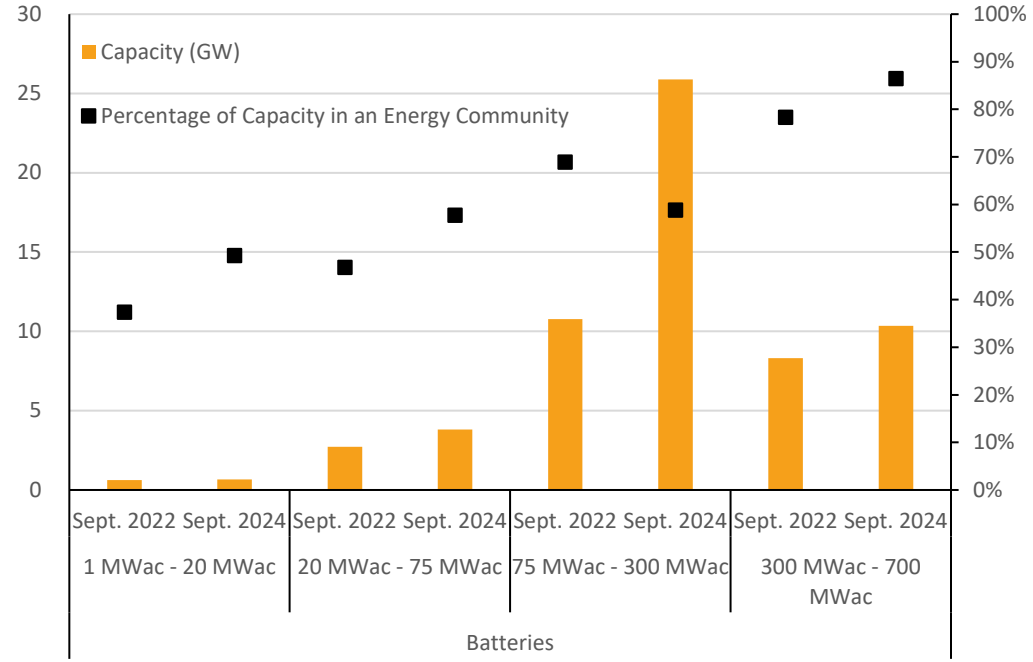
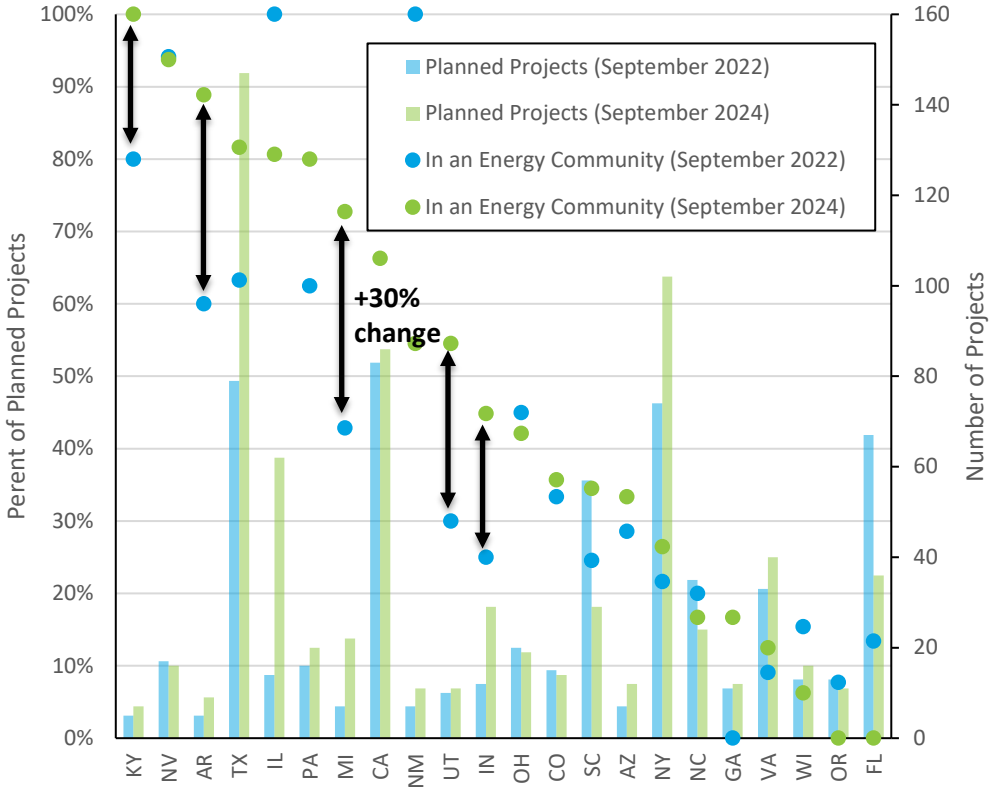


- BESS tended to follow the same trends as PV, with the largest shift in market share towards energy communities occurring in lower-capacity systems, and larger systems already tending to be located in those areas.
  - Between September 2022 and September 2024, the percentage of planned capacity of BESS systems between 75 MW_{ac} and 300 MW_{ac} in energy communities fell 10%.

Sources: U.S. Energy Information Administration (EIA), EIA Form 860 (November 2022, November 2024).

Percentage of Planned PV Capacity in Energy Communities, by State

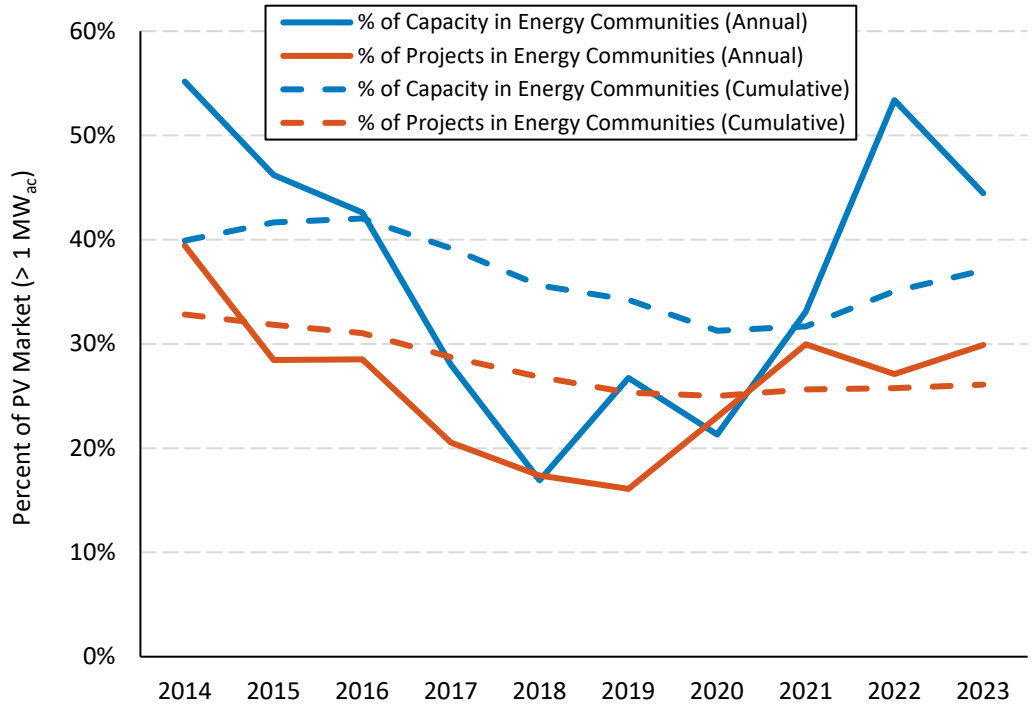


- The percentage of planned utility-scale PV capacity in an Energy Community varied by state; states whose land consists of a relatively large percentage of energy communities (e.g., Kentucky, Nevada, Arkansas, Texas) unsurprisingly had a high percentage of planned PV located in an energy community.
- The states whose market shares of planned PV capacity increased the most were Michigan (30%), Arkansas (+29%), Utah (+25%), Indiana (+20%), and Kentucky (+20%).
  - Most of these states have fewer than 15 PV projects in the pipeline; therefore, changes could come from a handful of projects.
- Planned PV projects are heavily weighted in certain states, particularly Texas, New York, and California (16%, 11%, and 9% of projects, respectively).
  - Planned PV projects are more heavily weighted in Texas in terms of capacity (34%).

Note: Graph includes only states with planned PV capacity above 1 GW.
Sources: U.S. Energy Information Administration (EIA), EIA Form 860 (November 2022, November 2023).

Percent of Operating PV Projects in Energy Communities

Click here to interactively view these data on Tableau Public.

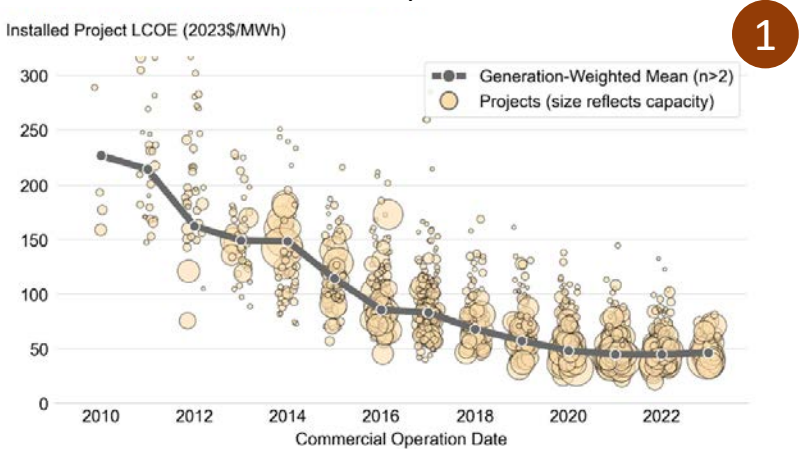


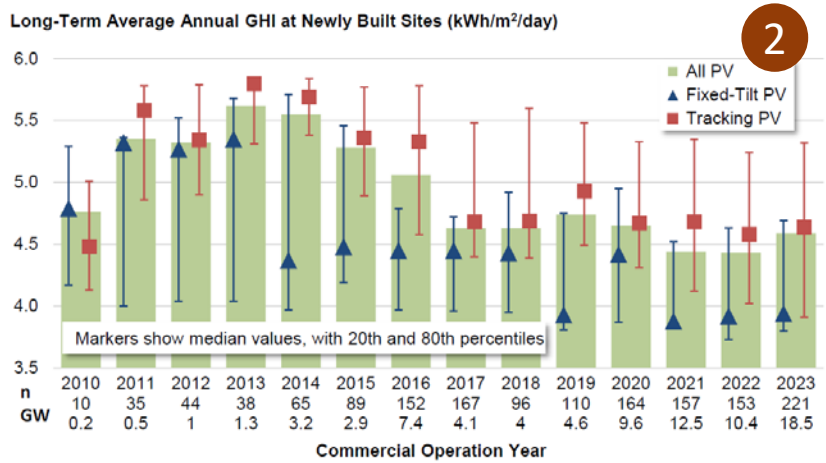
Sources: U.S. Energy Information Administration (EIA), EIA Form 860 (November 2022, November 2024).

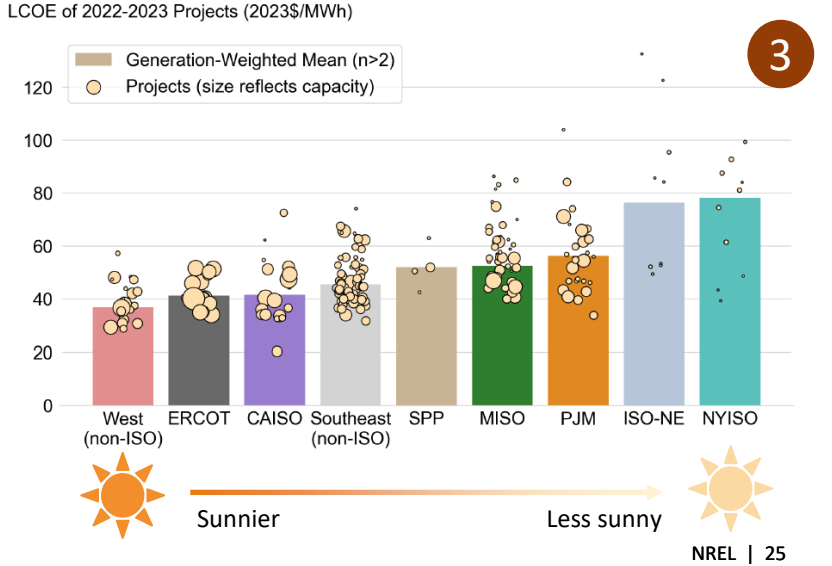
- The previous slides on energy communities focus on planned projects—to assess potential changes in plans due to the IRA bonus tax credit—whereas this slide focuses on operating projects for historical comparison.
- Over the past 10 years, the proportion of PV projects (above 1 MW_{ac}) installed in energy communities each year ranged from 16% to 39% of total projects installed; in capacity terms, the range was 17% to 55%.
- As of September 2024, the cumulative proportion of PV projects installed in energy communities (26%) was lower than the proportion of planned PV projects in these communities (44%).
  - In September 2022, a month after passage of IRA, the proportion of planned PV projects in energy communities (34%) was closer to installed averages.
- As of September 2024, the cumulative proportion of PV capacity installed in energy communities (38%) was lower than the proportion of planned PV capacity in these communities (60%).
  - However, the proportion of planned PV capacity in energy communities in September 2022 (56%) was also higher than the average, potentially because much of the capacity was located where energy communities are prevalent (e.g., Texas).

Five Things To Know From LBNL's *Utility-Scale Solar, 2024 Edition*

1. Average LCOE (excluding tax credits) of new projects increased from $45/MWh in 2022 to $46/MWh in 2023. Lower capacity factors and higher financing costs have offset better system costs and lifetimes.
2. The average project solar resource of PV systems has fallen over time as PV has expanded into less-sunny areas, but it increased slightly in 2023.
3. Average LCOE in low-sun regions was twice that in the sunniest regions.
4. The share of tracking capacity reached a record 96% in 2023, even as the price premium over fixed-tilt systems increased to $0.20/$W_{dc}$.
5. The difference in performance degradation is 0.6% per year between systems built in 2017 or later and systems built before 2013.



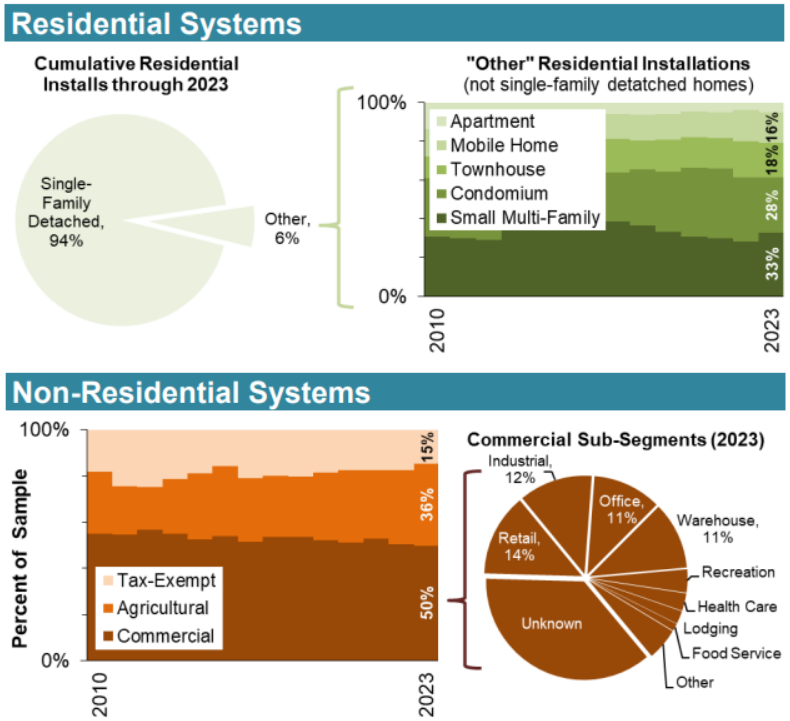




Source: Seel, Joachim, et al., 2024. *Utility-Scale Solar, 2024 Edition*. Lawrence Berkeley National Laboratory.

Five New Things To Know From *Tracking the Sun … 2024 Edition*

Customer Segmentation

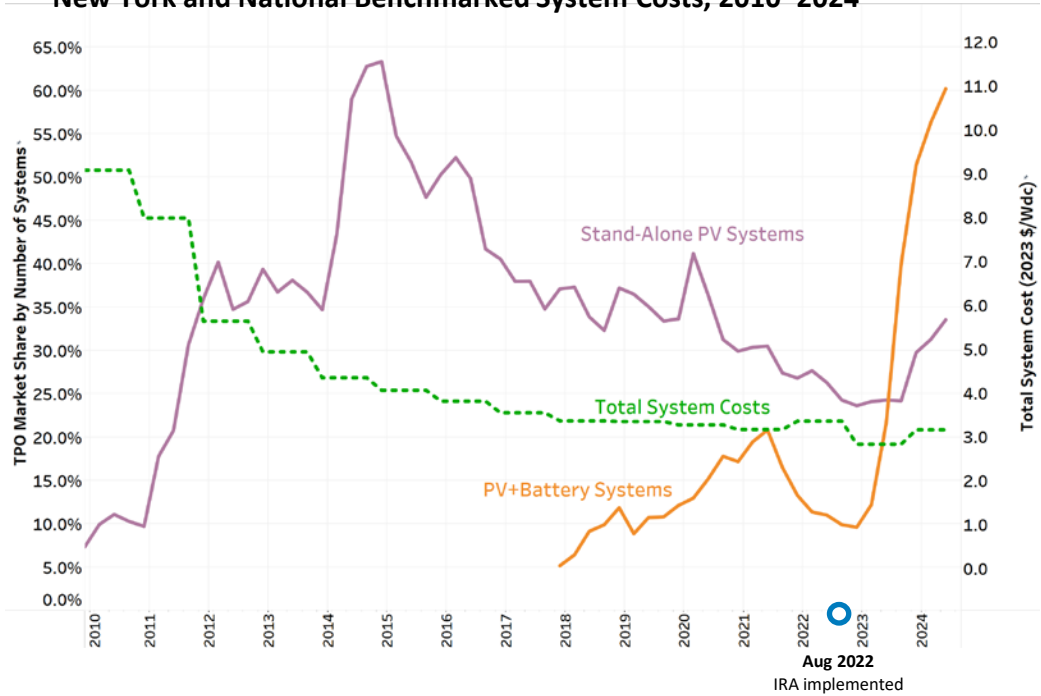


1. In 2023, the median module efficiency of U.S. residential PV systems was virtually flat, y/y, at 20.8%, though is still up 43% from 2010 efficiencies. LBNL attributes most of the increase in average residential system size to increases in module efficiency.
2. In 2023, third-party ownership market share increased for the first time since 2015, to 27%, as interest rates on solar loans rose. Market share varies a lot by state.
3. Since 2020, micro-inverters have eaten into the market share of DC-optimized inverter systems for residential and other small PV systems, as overall MLPE has remained relatively flat, at around 90%. However, for large nonresidential systems, DC optimizers represent the vast majority of all MLPE products, which represent 38% of the large nonresidential market (likely largely overlapping with the 45% that are on a rooftop).
4. Residential attachment rates have steadily risen over time, reaching 12% of the sample in 2023. Most paired residential systems are either 10 or 13.5 kWh, with a rated power output of 5 kW.
5. In 2023, 94% of residential systems were installed in detached, single-family buildings. Half of nonresidential PV systems were installed on a diverse set of commercial property, with the remainder on agricultural land (36%) and tax-exempt customers (15%).

Source: Barbose, Galen, et al., 2024. *Tracking the Sun: Pricing and Design Trends for Distributed Photovoltaic Systems in the United States 2024 Edition*. Berkeley, CA: Lawrence Berkeley National Laboratory.

Residential PV TPO Trends

Share of Residential TPO Systems in Arizona, California, Massachusetts, and New York and National Benchmarked System Costs, 2010–2024



Note: PV+Battery TPO share before 2018 not plotted because of very low deployment (<500 systems).
Sources: Arizona Goes Solar (11/04/24); California Distributed Generation (10/1/24); DOE Solar PV System Cost Benchmarks (accessed 11/24); Massachusetts Lists of Qualified Generation Units (10/10/2024); NREL Solar Installed System Cost Analysis (accessed 11/24); Solar Electric Programs Reported by NYSERDA (11/04/24); Wood Mackenzie & SEIA, US Solar Market Insight (2012 & 2015); Wood Mackenzie, US Residential Solar Finance Update (2024).

The third-party ownership (TPO) share of U.S. residential PV systems increased sharply in 2024.

- High interest rates have made taking loans to buy PV systems less attractive for homeowners.
- Bonus tax credits under the IRA—which PV companies can receive but homeowners cannot—incentivize TPO arrangements.
- TPO market share increased significantly for PV+BESS systems. This increase may also have been driven by TPO business models in California switching to hybrid systems with the change to NEM 3.0.

Interest rates, PV system prices, financial product development, and government policies have influenced TPO historically.

- TPO gained popularity in the early 2010s by enabling homeowners to avoid high upfront costs.
- Direct ownership became more popular after the mid-2010s as system costs continued to fall and interest rates remained relatively low.
  - New loan products offered savings on upfront and maintenance costs.
  - Solar companies and state policies incentivized customer-owned solar.

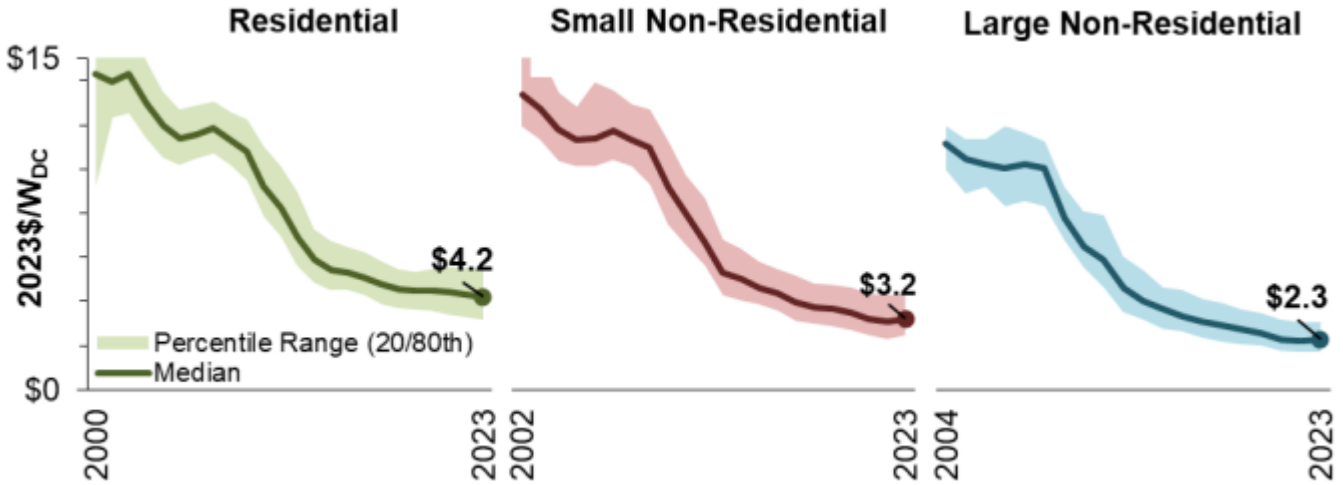
Agenda

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

- **Most data suggest decreases in CAPEX in the first half of 2024, but energy pricing across market segments varied because of other factors.**
- **U.S. PV system pricing, or cost, is estimated and quoted in a variety of ways, including:**
  - **Reported price (backward-looking)**
  - **Reported costs (backward-looking and may not include profit, unless incorporating "value")**
  - **Developer quotes (forward-looking)**
  - **Bottom-up cost benchmarking (forward-looking).**
- **In 2023, the ranges in average U.S. PV system pricing across methods were reported to be:**
  - **$2.3/W–$4.4/W for residential solar**
  - **$1.5/W–$3.2/W for nonresidential solar**
  - **$1.0/W–$1.3/W for utility-scale solar.**
- **In the first half of 2024, the ranges in average U.S. PV system pricing across a *smaller set of* methods were reported to be:**
  - **$2.7/W–$4.2/W for residential solar**
  - **$1.6/W–$3.4/W for nonresidential solar**
  - **$1.1/W for utility-scale solar.**

Tracking the Sun: National Price, 2000–2023

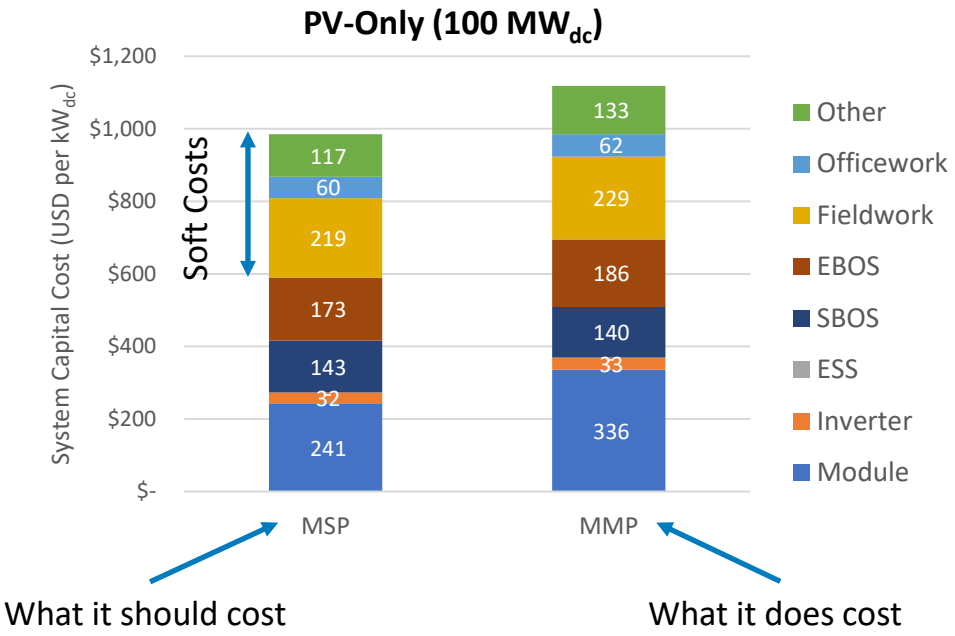
- Price declines averaged \$0.1–\$0.2/W_{dc} across segments for the past decade, following a period of steeper price declines, owing to the trajectory of module costs.
- The inflation-adjusted median installed price for residential systems dropped by around \$0.10/W_{dc} from 2022 to 2023; however, it increased for nonresidential systems by \$0.10–\$0.20/W_{dc}—the first increase in 15 years.

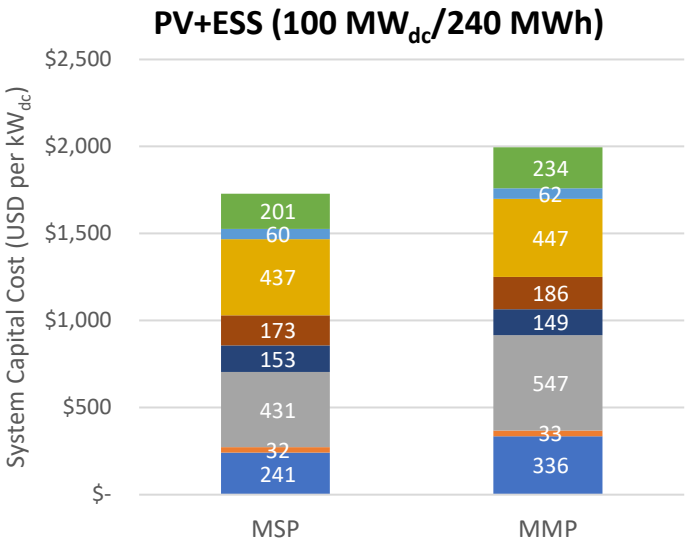


Source: Barbose, Galen, et al., 2024. *Tracking the Sun: Pricing and Design Trends for Distributed Photovoltaic Systems in the United States.* 2024 Edition. Berkeley, CA: Lawrence Berkeley National Laboratory. September 2024.

DOE-Estimated Utility-Scale PV/ESS System Cost Breakdown, Q1 2024

- DOE estimates that, in Q1 2024, utility-scale PV systems cost approximately \$1.12/W_{dc} (i.e., modeled market price, or MMP). Without market distortions, such as tariffs or nonsustainable margins, DOE estimates the price would have been \$0.98/W_{dc} (i.e., minimum sustainable price, or MSP).
  - With 2.4 hours of battery storage, relative to PV capacity, the costs increase to \$1.99/W_{dc} (MMP) and \$1.73/W_{dc} (MSP).

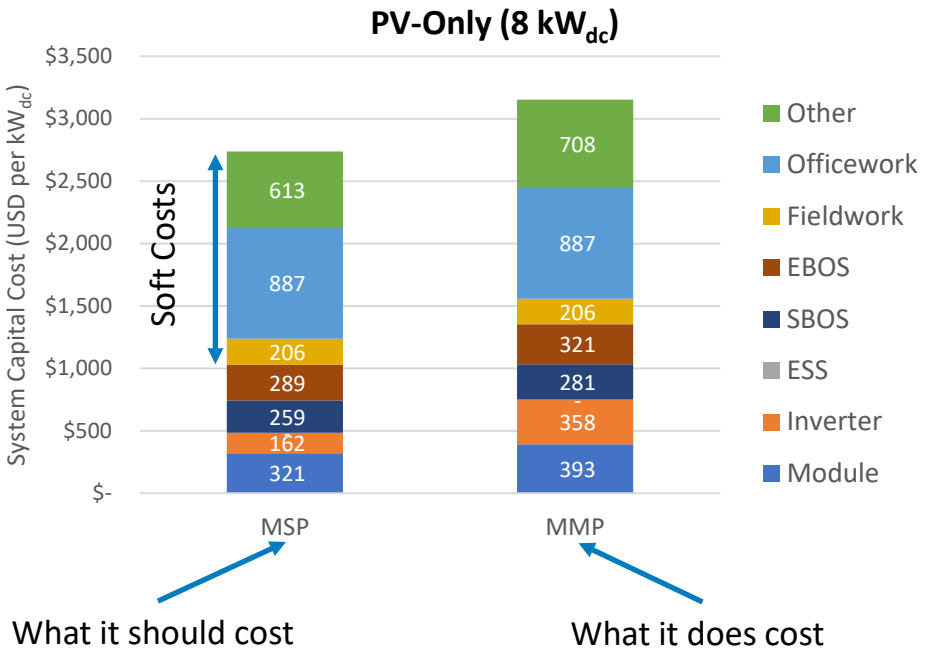


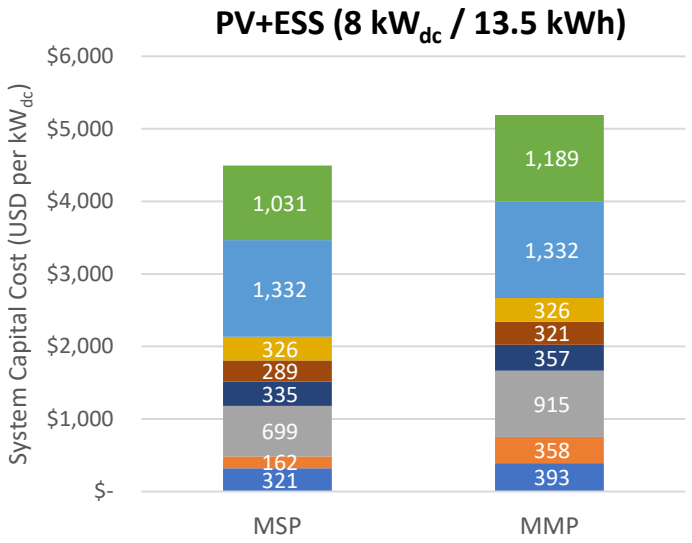


Note: All costs are for the first quarter of 2024 and reported in 2023 U.S. dollars.
Source: Solar Photovoltaic System Cost Benchmarks | Department of Energy.

DOE-Estimated Residential PV/ESS System Cost Breakdown, Q1 2024

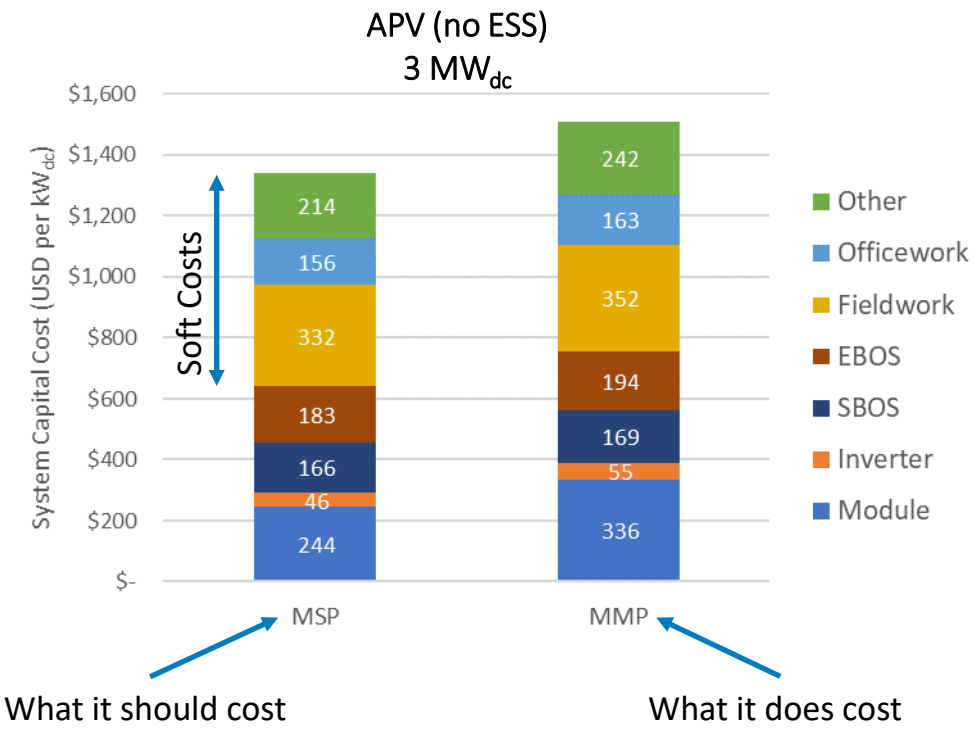
- DOE estimates that in Q1 2024, residential PV systems cost approximately $3.15/W$_{dc}$ (i.e., modeled market price, or MMP). Without market distortions, such as tariffs or nonsustainable margins, DOE estimates the price would have been $2.74/W$_{dc}$ (i.e., minimum sustainable price, or MSP).
  - With 2.4 hours of battery storage, relative to PV capacity, the costs increase to $5.19/W$_{dc}$ (MMP) and $4.50/W$_{dc}$ (MSP).





Note: All costs are for the first quarter of 2024 and are reported in 2023 U.S. dollars.
Source: Solar Photovoltaic System Cost Benchmarks | Department of Energy.

Representative System Cost Breakdown (APV), Q1 2024

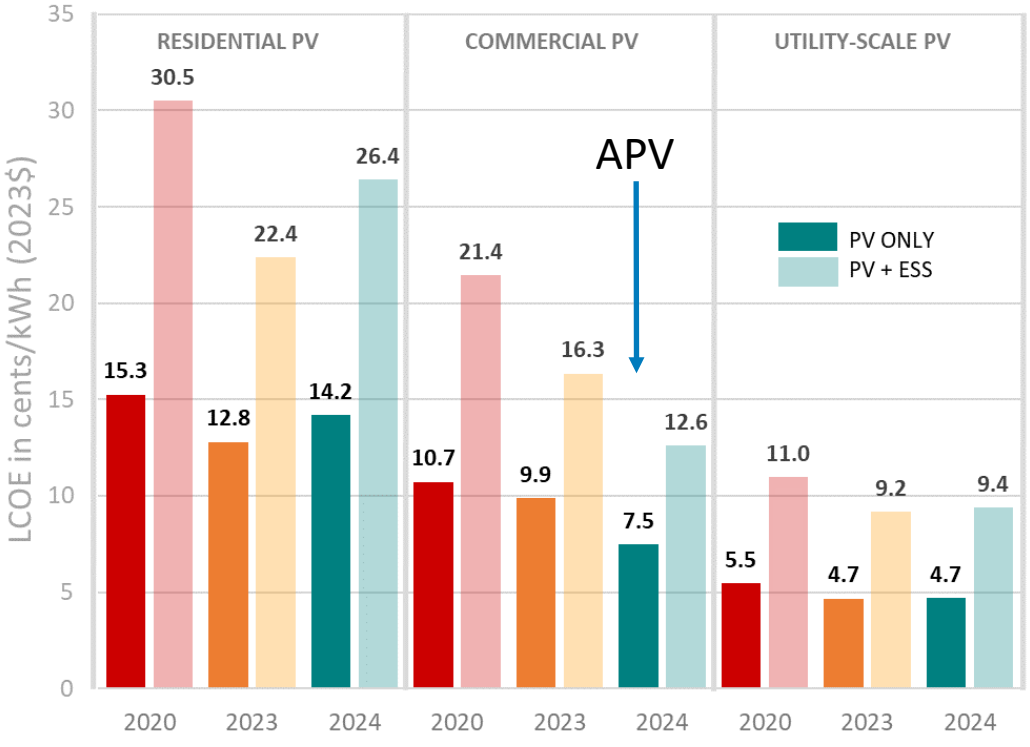


The cost of an agrivoltaic (sheep grazing) solar system was benchmarked for the first time. Both the cost of the sheep and income from selling the sheep are considered out of scope and excluded from this model.

PVSCM is implemented using an Excel spreadsheet and text parameter files for each system (RPV, UPV, and APV), which are available for download.

Note: All costs are for the first quarter of 2024 and are reported in 2023 U.S. dollars.
Source: Solar Photovoltaic System Cost Benchmarks | Department of Energy.

Representative System Levelized Cost of Energy (LCOE)



Inputs to LCOE

From PV Cost Benchmarks:

- Overnight (cash) cost using MSP
- Amortized O&M for 30-year life.

From Annual Technology Baseline:

- Energy yield (median category 5)
- Financial model (30-year lifetime).

For PV + ESS:

- Add ESS costs, including O&M
- Add 6% to LCOE for energy losses.

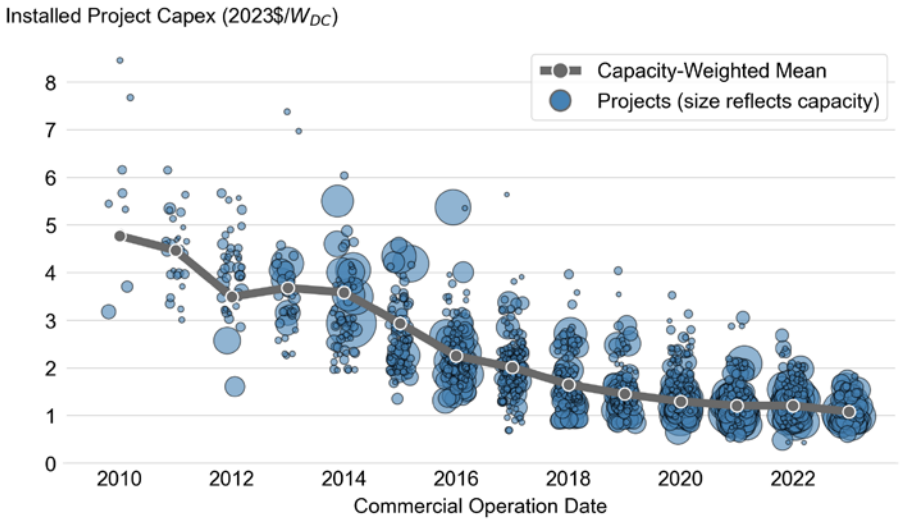
Other Factors:

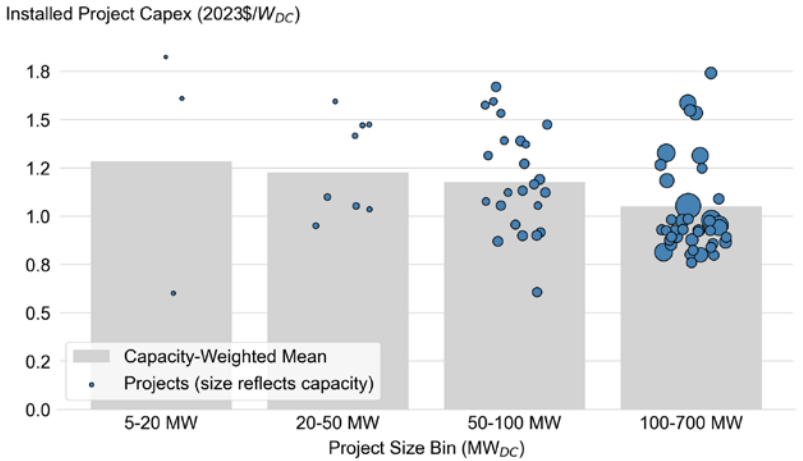
- LCOE depends on location (+/–30%).
- ITC/PTC reduces effective LCOE.

Source: Solar Photovoltaic System Cost Benchmarks | Department of Energy.

Reported Price of U.S. Utility-Scale PV Projects Over Time

- Prices for large-scale projects continue to drop in real terms, falling 8% in 2023.
- Larger systems tend to have lower prices, with the largest utility-scale systems around \$0.23/W_{dc} cheaper than smaller grid-scale systems.

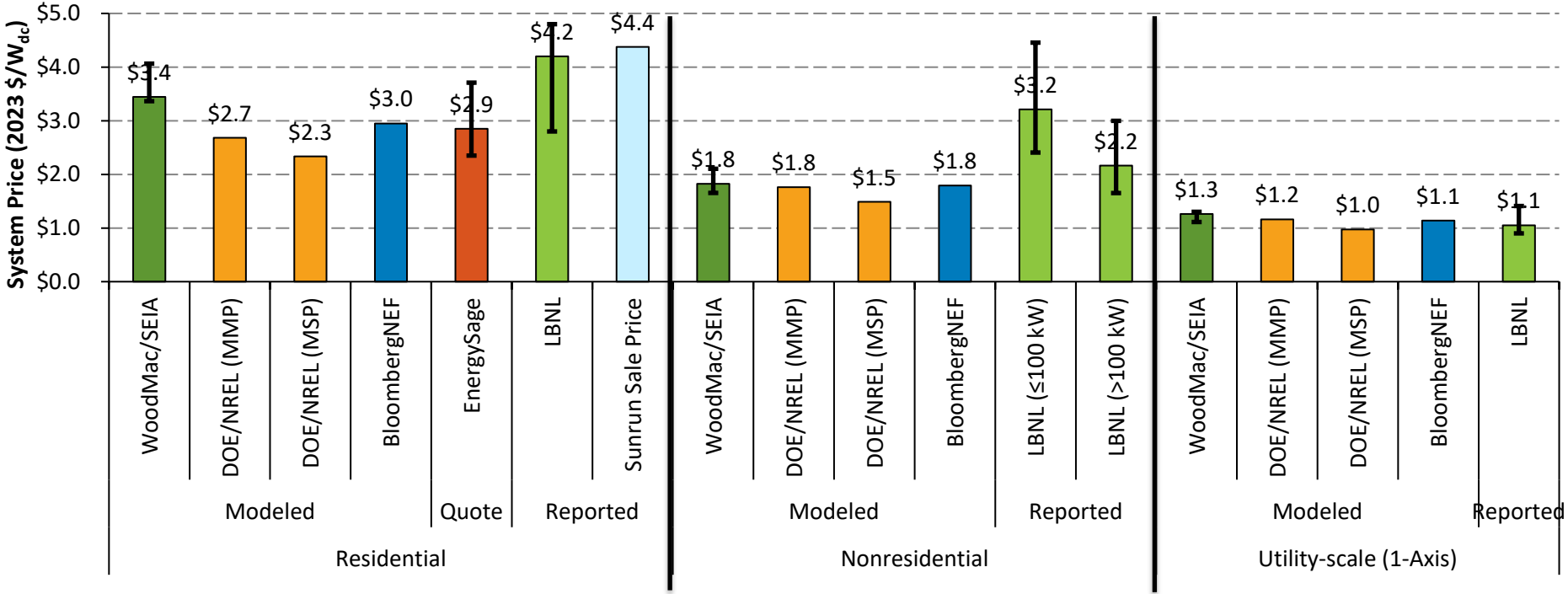




Source: Seel, Joachim, et al., 2024. *Utility-Scale Solar: 2024 Edition*. Berkeley, CA: Lawrence Berkeley National Laboratory.

2023 Modeled, Reported, and Quoted System Prices From Various Sources

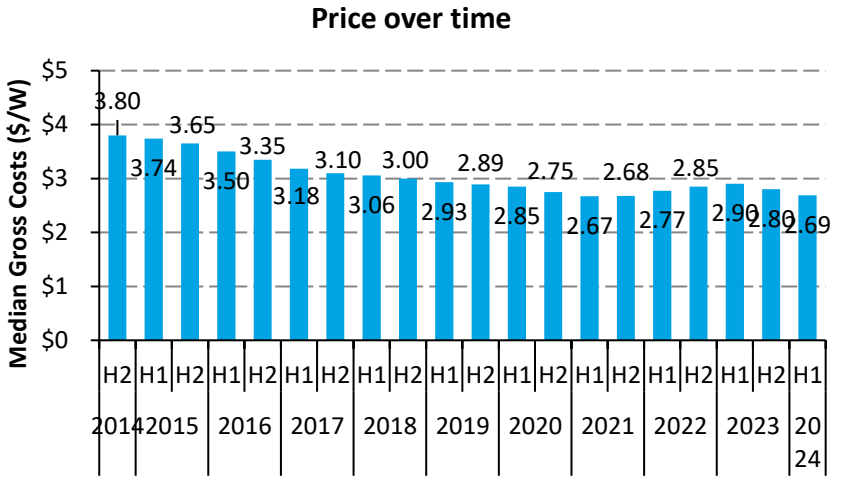
- DOE/NREL and LBNL PV system price ranges generally overlap other sources.
- Across various sources, reported system pricing is generally higher than modeled and quoted system pricing.

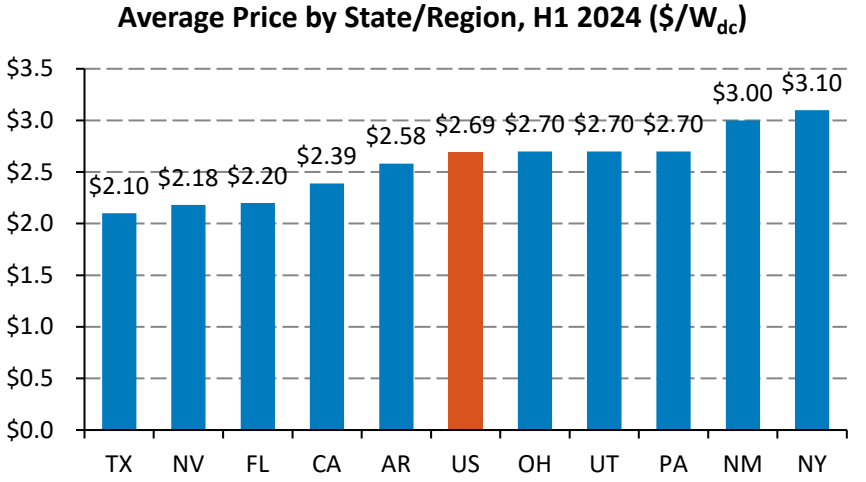


Sources: Barbose, Galen, et al., 2024; Seel, Joachim, et al., 2024; Ramasamy, Vignesh, et al., 2023; BNEF, "H2 2024 U.S. PV Market Outlook," October 2024; Wood Mackenzie, US PV System Cost Model H1 2024, July 2024; EnergySage, Solar Marketplace Intel Report H1 2023 – H2 2023; Sunrun, Investor relations.

Residential System Price Reported by EnergySage

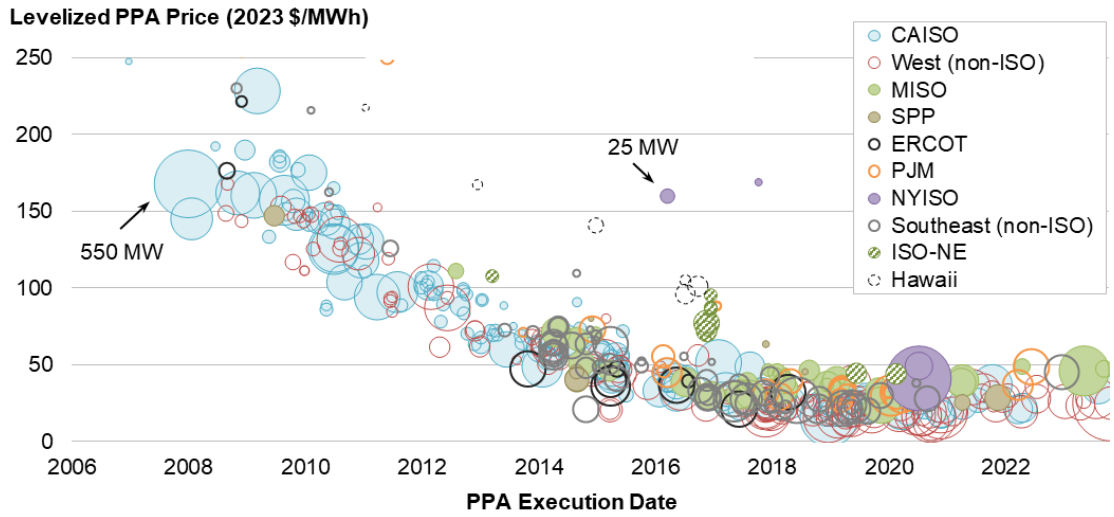
- After 2 years of price increases, in 2021 through 2023, EnergySage reported prices falling over the past year to near historical lows.
  - The median reported price by EnergySage for residential PV systems decreased 7.2% y/y.
- Residential system price varied by state, between $2/W and $3/W.
  - The median quoted price for the top four solar deployment states was below the national average.





Note: Price based on winning quoted price.
Source: EnergySage, Solar Marketplace Intel Report H2 2023 – H1 2024.

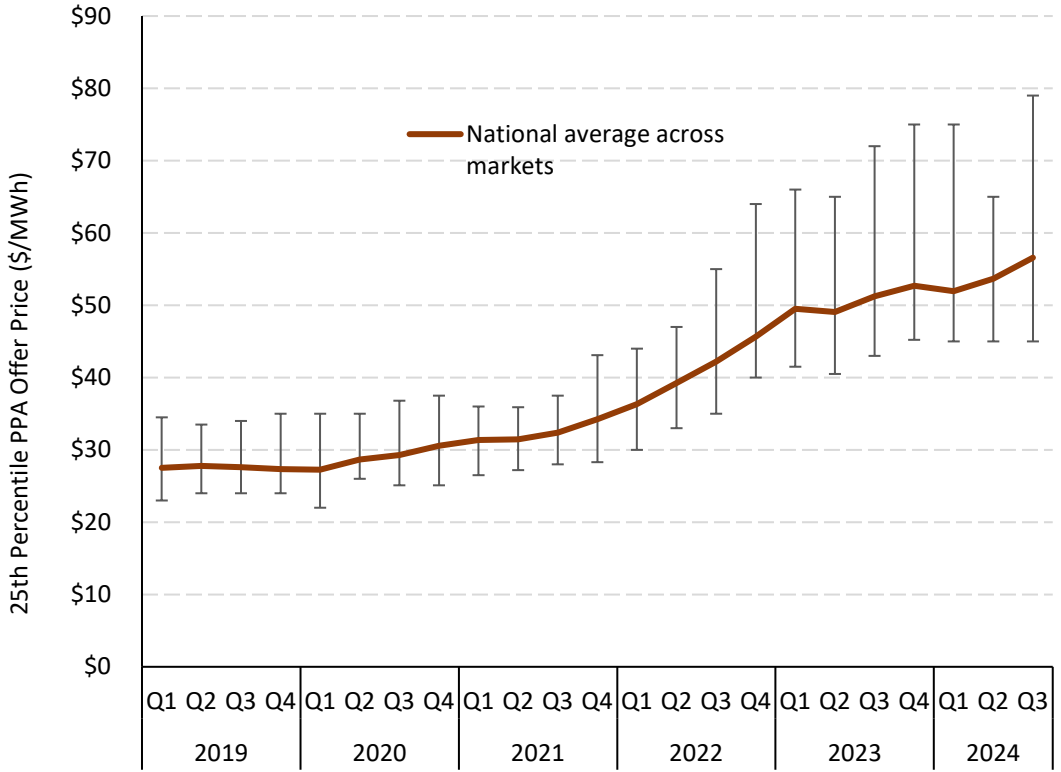
U.S. Utility-Scale Photovoltaic PPA Pricing



- PV-only PPA pricing has stagnated over the past 5 years, across different markets in the United States.
- Photovoltaic PPA pricing is still competitive with other technologies, but recent declines in gas prices have brought a slight advantage to gas-fired generators in the near term.

Source: Seel, Joachim, et al., 2024. *Utility-Scale Solar: 2024 Edition*. Berkeley, CA: Lawrence Berkeley National Laboratory.

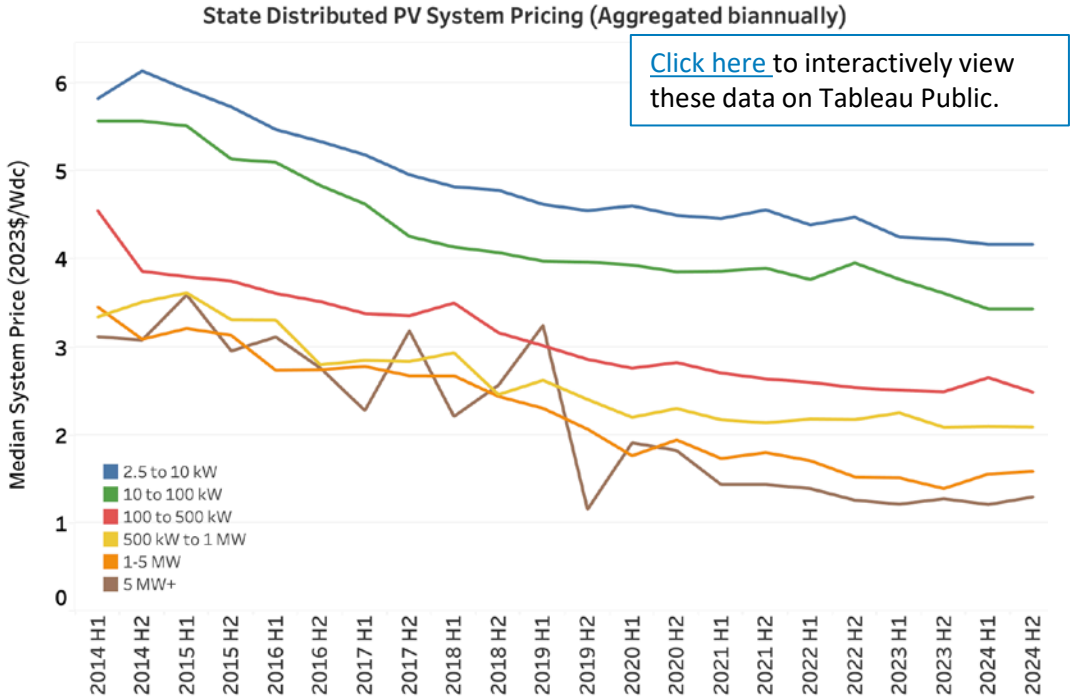
U.S. Solar PPA Pricing (LevelTen)



- LevelTen reports that the U.S. utility-scale photovoltaic PPA prices increased 5.4%, q/q, and 10.4%, y/y.
- LevelTen reports that the increase in PPA prices reflects the ongoing challenges developers face of tariffs on imported products as well as premiums on domestically produced products.
  - The increase in pricing may also reflect a growing amount of bundled storage with solar; however, LevelTen has not made that attribution.
- LevelTen reported that ERCOT was the lowest priced market in Q3 2024, because of land availability and easy permitting for solar. However, in Q3 2024, pricing increased in all markets LevelTen covers.

Source: LevelTen, PPA Price Index.

Distributed PV System Pricing From Select States



From H2 2023 to H2 2024 (partial), the median reported stand-alone (no energy storage) distributed PV system price—**in 2023 (inflation-adjusted) dollars**—across Arizona, California, Massachusetts, and New York:

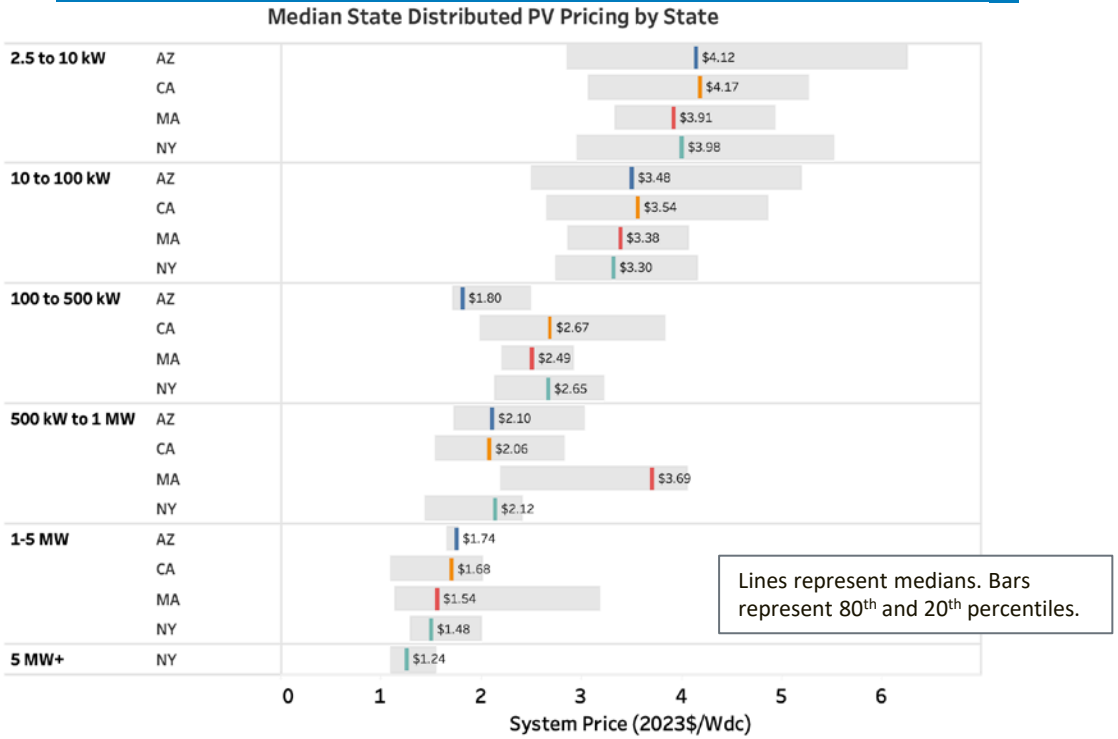
- Decreased 1% to \$4.17/W_{dc} for systems 2.5 to 10 kW
- Decreased 5% to \$3.43/W_{dc} for systems 10 to 100 kW
- Stayed constant at \$2.49/W_{dc} for systems 100 to 500 kW
- Stayed constant at \$2.09/W_{dc} for systems 500 kW to 1 MW
- Increased 14% to \$1.58/W_{dc} for systems 1 to 5 MW
- Increased 2% to \$1.30/W_{dc} for systems 5 MW+.

Adjusting for inflation reveals the generally decreasing distributed PV system price trends in real dollars over the past several years of economic volatility.

2024 MW data YTD: Arizona (100), California (1,130), Massachusetts (32), New York (628).
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 (10/10/24); California Distributed Generation (10/1/24); Massachusetts Lists of Qualified Generation Units (8/23/2024); Solar Electric Programs Reported by NYSERDA (9/30/24).

Distributed PV System Pricing From Select States, 2024 YTD

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.

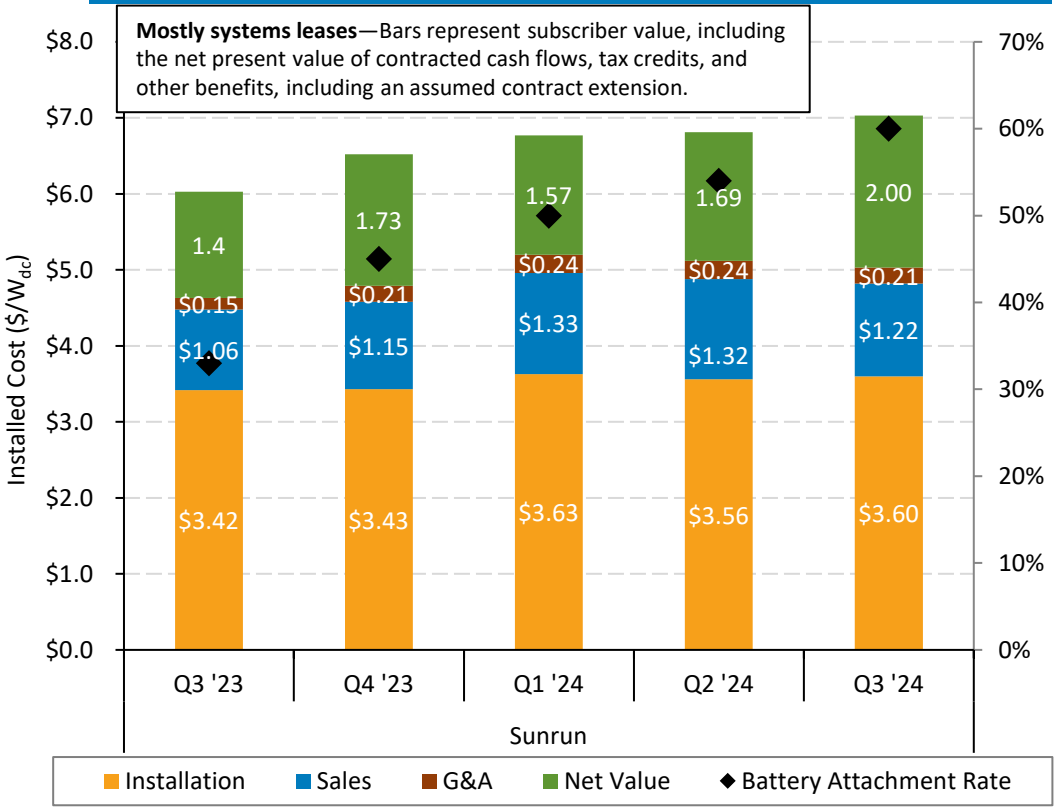
Dollar-per-watt prices generally decrease as system size increases.

For systems of 2.5–10 kW, median price changes varied between 2023 and 2024 YTD:

- –6% in Arizona, –2% in California, –2% in Massachusetts, –7% in New York.

2024 MW data YTD: Arizona (100), California (1,130), Massachusetts (32), New York (628).
Note: System prices above $10/W and below $0.75/W were removed from the dataset.
Sources: Arizona Goes Solar (10/10/24); California Distributed Generation (10/1/24); Massachusetts Lists of Qualified Generation Units (8/23/2024); Solar Electric Programs Reported by NYSERDA (9/30/24).

Large Residential Installer Cost and Value, Q3 2024



Unlike the previous slide, these totals represent "value" not "reported price" and may include storage costs.

Large residential installer Sunrun reported a system value change of +17% y/y and +3% q/q in Q3 2024.

Factors reported as supporting higher system value and/or costs (for Sunrun and fellow large residential installer Sunnova):

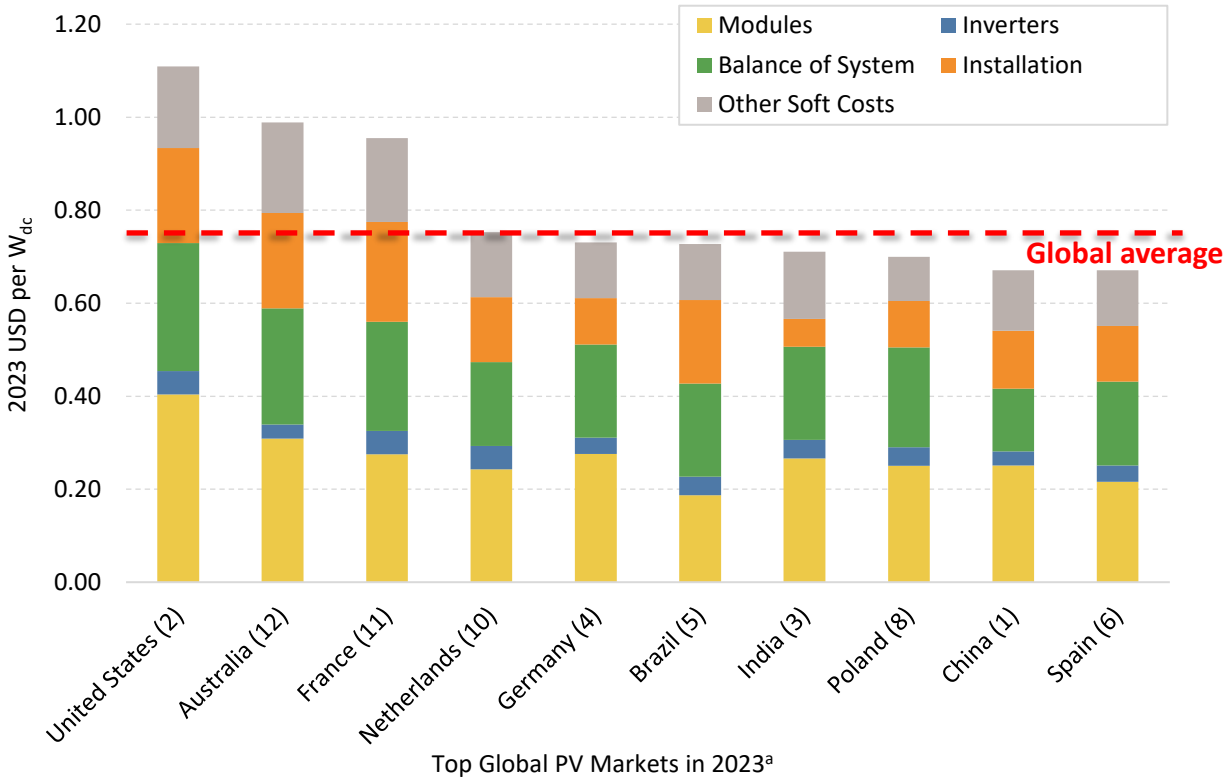
- Increasing battery attachment rates (batteries add cost but can yield higher margins)
- Increasing electricity demand and retail rates
- Decreasing reliability of electricity grid
- High interest rates.

Factors reported as supporting lower PV system costs and/or higher margins:

- Investment tax credit (ITC)—low-income, energy communities and domestic content ITC adders
  - Sunrun and Sunnova's average ITC rate was 37%–38% in Q3 2024.
- Lower operating expenses.

Sources: Corporate filings.

Utility-Scale PV Installed Costs by Country, 2023



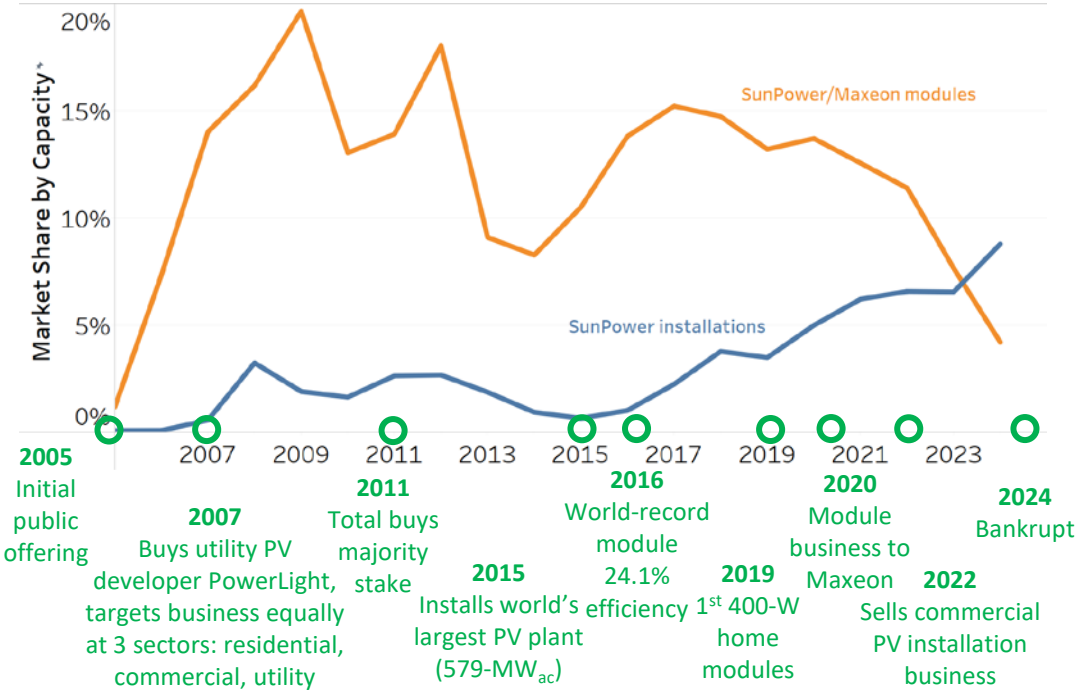
- The global capacity-weighted average total installed cost of utility-scale projects commissioned in 2023 was \$0.76/W_{dc} (in 2023 U.S. dollars [USD]), down 17% from 2022.
- Global average component costs as a percentage of total costs:
  - Module and inverter 39%
  - Balance of system hardware 26%
  - Installation 16%
  - Other soft costs 19%.
- The U.S. cost was 46% higher than the global average:
  - Module/inverter +53%
  - BOS hardware +39%
  - Installation +69%
  - Other soft costs +21%.

[a] Japan and Italy were number 7 and 9 on the total installed PV list in 2023, but their installed system cost data were not reported.

Source: International Energy Agency. 2024. Snapshot of Global PV Markets 2024; International Renewable Energy Agency. 2024. Renewable Power Generation Costs in 2023.

SunPower Bankruptcy

SunPower's Residential Market Shares in California, 2005–2024



Sources: Canary Media (8/6/24, 10/22/24); NREL (4/27/23); PV Tech (8/6/24); Renewable Energy World (11/15/2006; 8/6/24); SunPower (4/23/15, history accessed 10/23/24); Utility Dive (8/15/24).

Residential installer SunPower Corp. declared bankruptcy in August 2024.

- Interest rates, California's net-metering policy, and accounting missteps added final stresses.
  - Half of SunPower's sales were in California, where the market declined after state net metering policy was changed in April 2023.
  - SunPower's loan-based business model amplified the impacts of high interest rates.

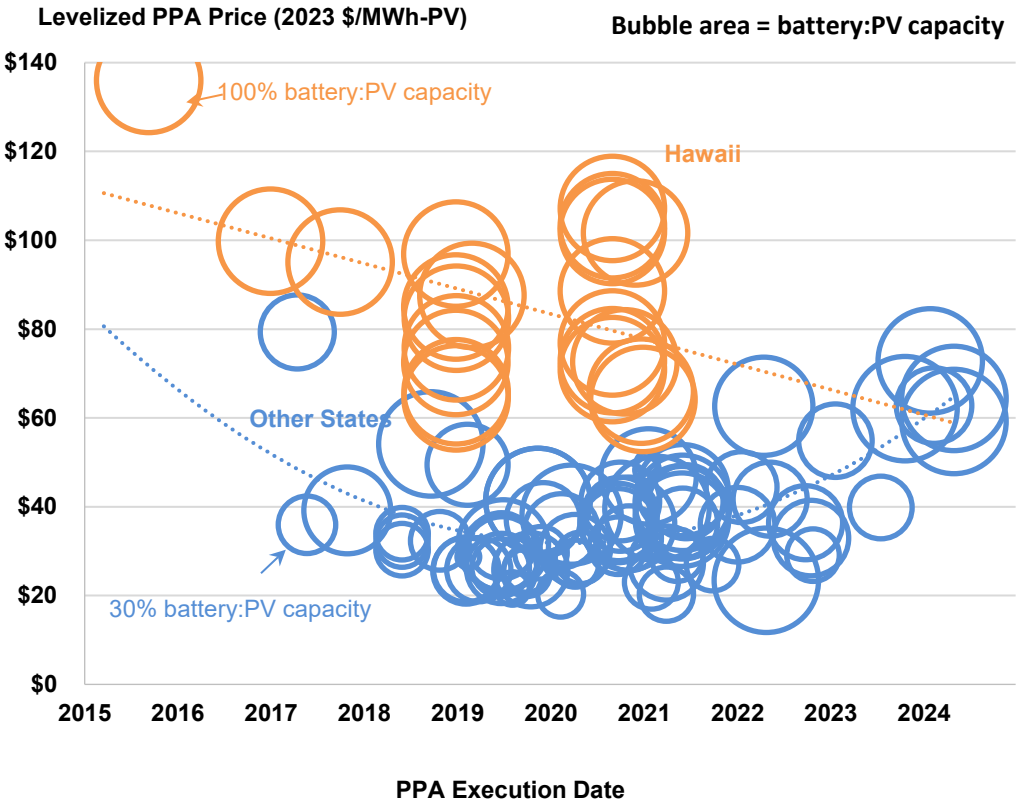
Since its founding in 1985, SunPower played multiple roles in the U.S. solar industry.

- Manufacturer of high-efficiency PV modules
- Utility-scale project developer
- Dealer and financier for residential and commercial PV and battery installations.

SunPower's back-contact module technology lives on through spin-off Maxeon Solar Technologies, which is also struggling financially.

- Its average efficiency advantage over other monocrystalline silicon products was 4 percentage points in 2010, shrinking to 1 percentage point in recent years.

U.S. Utility-Scale PV+Battery PPA Pricing From LBNL

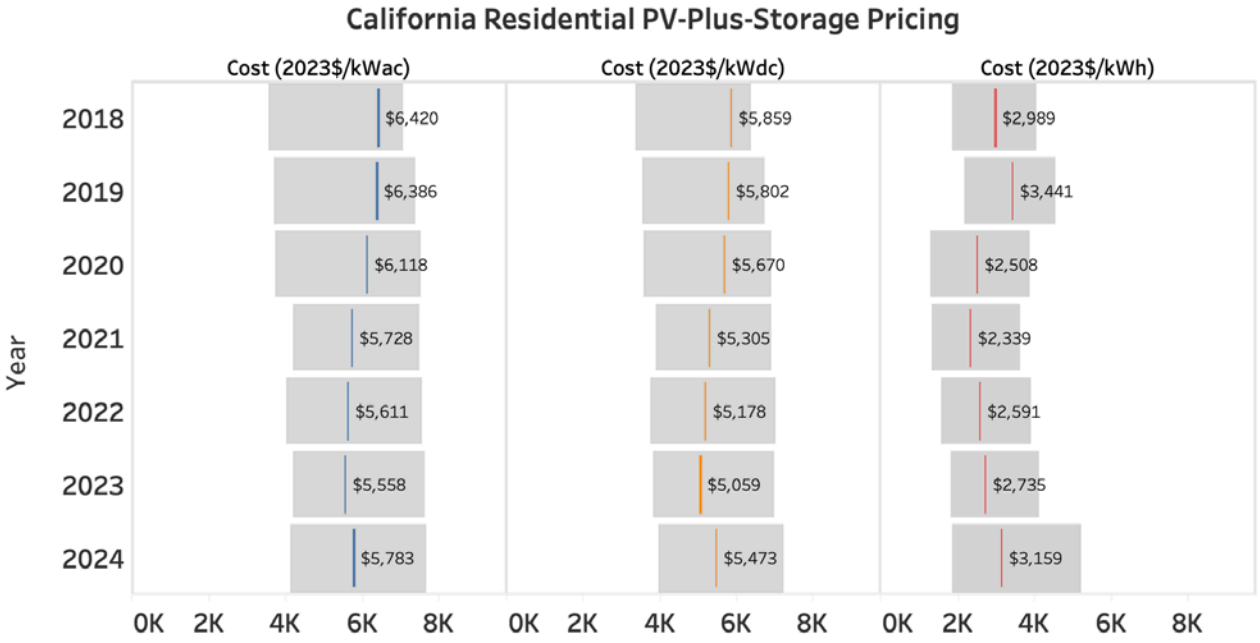


- LBNL reports that there was an upward price trend among PPAs in the continental United States, with prices in 2024 approximately twice typical prices in 2020.
- The increased storage size—in terms of hours of storage and its capacity relative to PV—explain some of the increased costs.
  - In 2023, the average storage duration increased to 3.2 hours (from 2.9 hours in 2022), and the average battery:PV ratio increased to 0.7 (from 0.6 in 2022).

Source: Seel, Joachim, et al., 2024. *Utility-Scale Solar: 2024 Edition*. Berkeley, CA: Lawrence Berkeley National Laboratory.

Residential PV + Storage Pricing in California

Click here to interactively view these data on Tableau Public.



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

In 2024 YTD, residential PV-plus-storage systems in California had a median system price of \$3,159/kWh, or \$5,783/kW_{ac} (\$5,473/kW_{dc})—up by 4%—16% from 2023 depending on the cost metric used.

- Most of these systems offer 2–3 hours of storage.
- Units represent total system price divided by the capacity of the battery (kWh) or the capacity of the PV system (kW).

The data are filtered to PV system sizes of 10 kW_{dc} or smaller.
Source: California Distributed Generation (10/1/24).

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- **According to Infolink, the top 10 module manufacturers were responsible for 226 GW of shipments (+40% y/y) in H1 2024.**
- **In H1 2024, the United States produced 4.2 GW of PV modules—an increase of 75%, y/y—roughly evenly split between thin-film and c-Si module technology.**
- **Since IRA's passage, more than 95 GW of manufacturing capacity have been added across the solar supply chain (from facilities announced pre- and post-IRA), including nearly 42 GW of new module capacity.**
  - **U.S. c-Si manufacturers added significant capacity in H1 2024.**
  - **Analysts estimated that U.S. c-Si cell production and capacity should begin to slowly ramp in the second half of 2024.**

PV Shipment Rankings

Rank	H1 2024 Shipments	
	Cells	**Modules**
1	▲ Solar Space	Jinko Solar (47.2 GW)
2	▲ Jietai	▲ JA Solar (38 GW)
3	▼ Tongwei	Trina (34 GW)
4	▼Aiko / ▲ Yingfa Ruineng	▼ LONGi (31.3 GW)
5		▲ Tongwei (18.7 GW)
6		Astronergy
7		▼ Canadian Solar (14.5 GW)
8		▲ GCL / DAS Solar (~10 GW)
9		
10		▼ Risen Energy (8 GW)

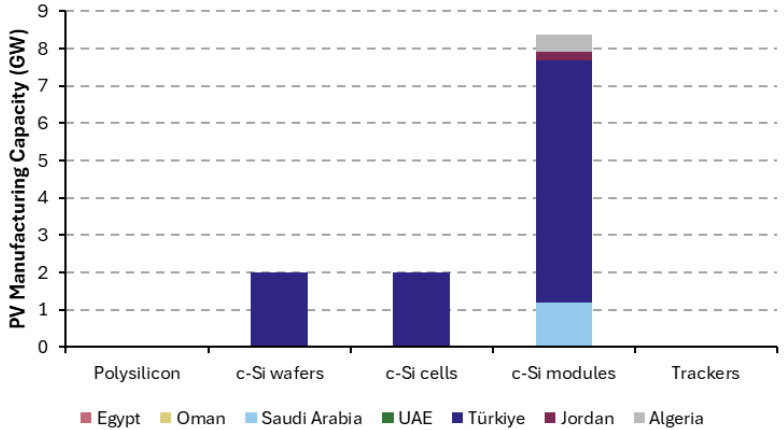
- According to InfoLink, the top 10 module manufacturers were responsible for 226 GW of shipments (+40% y/y) in H1 2024.
  - TOPCon modules accounted for 70% of sales in Q1 2024, up from all N-type modules representing 18% in Q1 2023.
- To manage reduced margins, companies are internally consuming more cells, expanding operations in overseas markets, and switching to higher-value TOPCon.

Sources: InfoLink: 2024H1 cell shipment rankings, 2024H1 Module shipment ranking, PV Magazine (09/06/24); PVTech (09/03/24; 09/18/24); Taiyang News (08/24/24; 09/03/24).

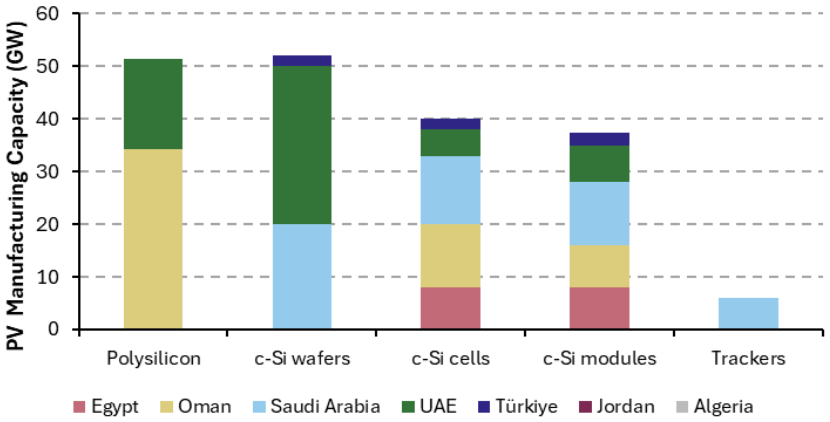
PV Manufacturing in the MENA Region

- Currently, there are just more than 8 GW of active c-Si module manufacturing capacity, 2 GW of active c-Si cell capacity, and 2 GW of active c-Si wafer capacity in the Middle East and North Africa (MENA) region.
- The majority of active PV manufacturing capacity is in Türkiye, but announcements have been made in multiple countries across the region.
- Over the past few years, there have been several large announcements of planned PV manufacturing capacity in MENA across the PV supply chain.
- Several announcements have come from Chinese companies (including Jinko Solar, Trina Solar, GCL Tech, etc.) expanding their operations into the Middle East.
- To date, there have been more than 50 GW of polysilicon, more than 50 GW of c-Si wafer, 40 GW of c-Si cell, more than 35 GW of c-Si module, and 6 GW of tracker capacity announced across 7 countries.

Currently Operating PV Capacity in MENA

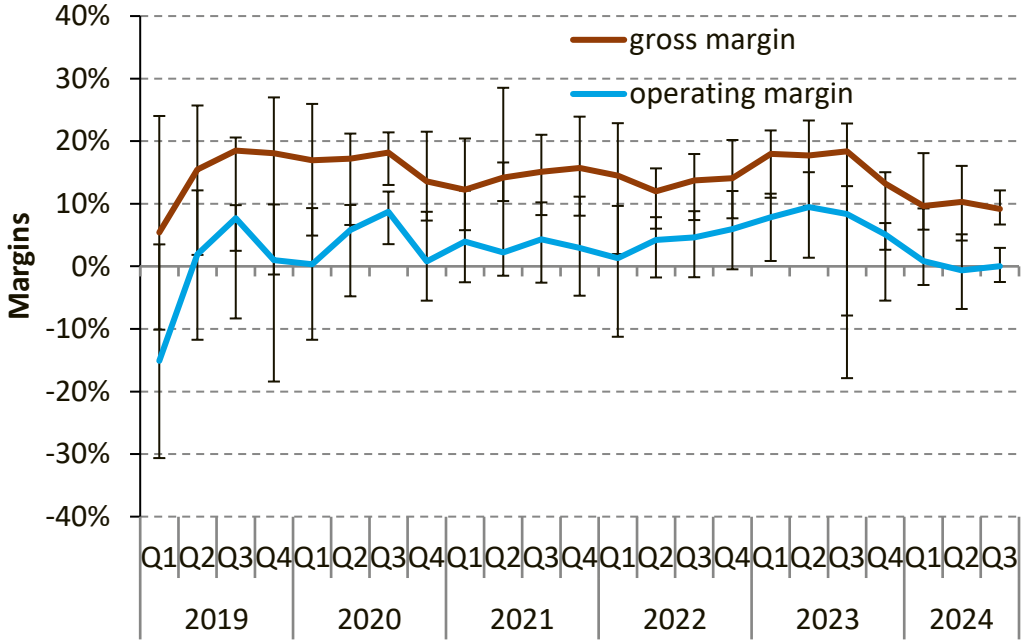


Planned PV Capacity in MENA



Sources: Internal DOE tracking of public announcements.

PV Manufacturers' Margins



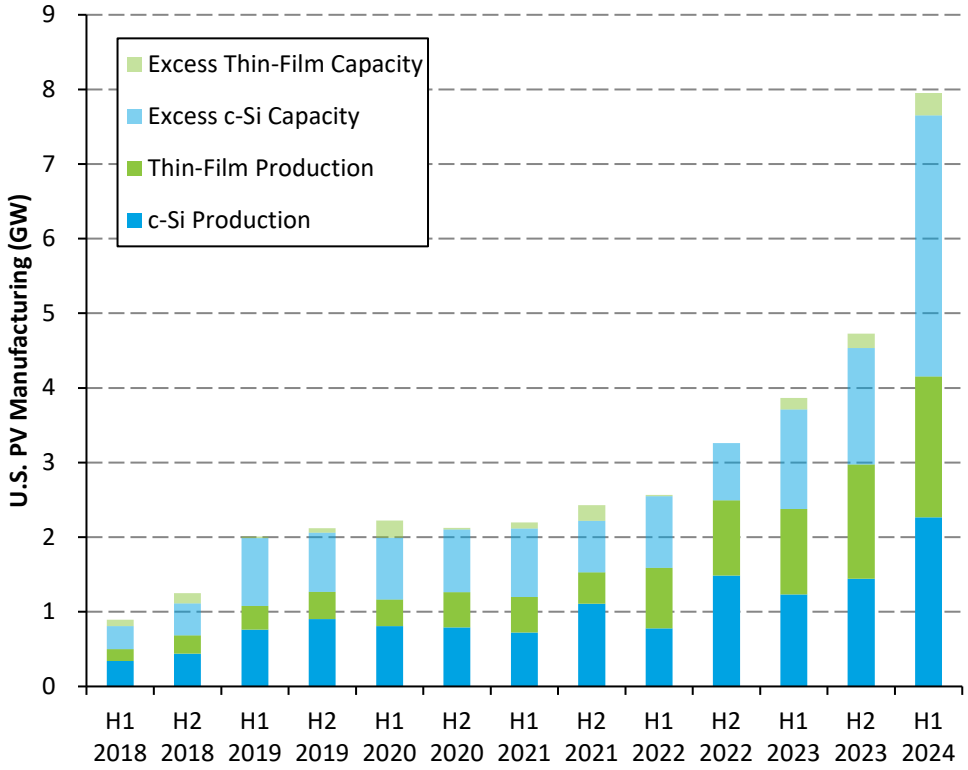
- Despite record levels of module shipments from leading companies, margins from PV manufacturers, on average, remain below historical averages.
  - In Q3 2024, average margins remained at depressed levels not experienced since 2019.
- Conversely, First Solar's gross margin increased to 50%—a level not seen in more than a decade.

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

U.S. PV Manufacturing



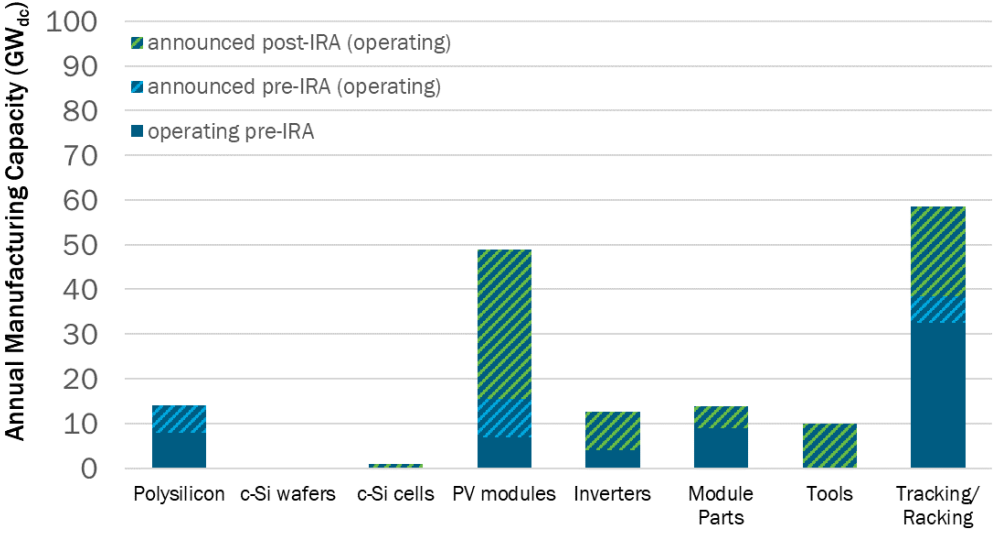
- In H1 2024, the United States produced 4.2 GW of PV modules—an increase of 75%, y/y.
  - Production was roughly evenly split between thin-film and c-Si module technology.
  - Analysts estimate that c-Si cell production and capacity should begin to slowly ramp up in the second half of 2024.
- c-Si manufacturers added significant capacity in H1 2024.
- Since 2018, U.S. module manufacturing production and capacity have increased by approximately 9–10 times.

Sources: Values represent the average of: PVTech: "PV Manufacturing & Technology Quarterly Report—Release 34—August 2024"; Wood Mackenzie/SEIA: U.S. Solar Market Insight: Q3 2024.

Domestic Manufacturing Growth

Since IRA's passage, more than 95 GW of manufacturing capacity have been added across the solar supply chain (from facilities announced pre- and post-IRA), including nearly 42 GW of new module capacity.*

Manufacturing Capacity by Supply Chain Segment*



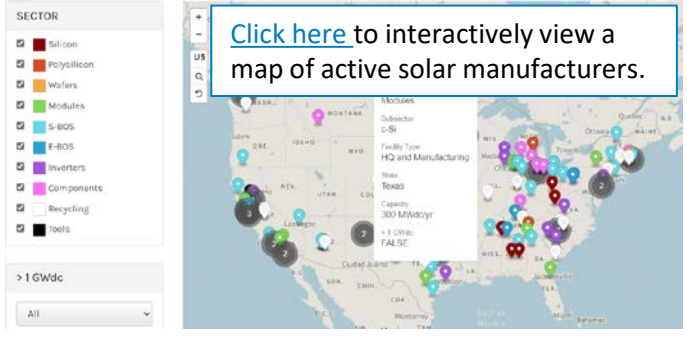
Sources: U.S. Census Bureau USA Trade Online and internal DOE tracking of public announcements.

*Not all announcements include facility locations, job, operating capacity, or investment numbers.

Several large facilities have hit big milestones in Q3 2024:

- **First Solar**: Module production in Alabama began in September for their 3.5-GW facility.
- **Runergy**: Module production in Alabama began in October for their 5-GW facility.
- **Suniva**: Cell production restarted in September at their 1-GW facility in Georgia and has officially shipped to PV module manufacturer Heliene.
- **Siemens**: Inverter production in Wisconsin began in September at their 0.8-GW facility, marking the first production of utility-scale inverters in the United States.

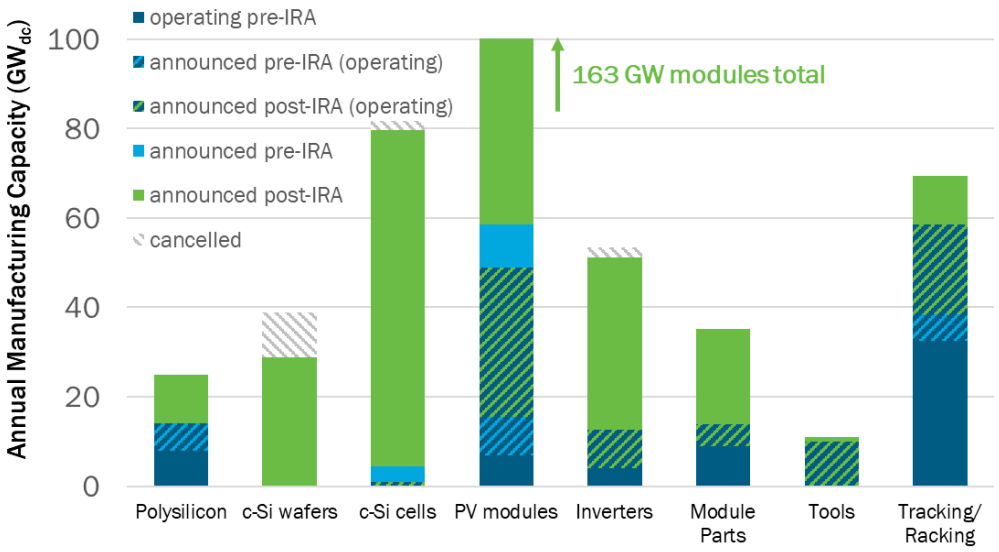
There are now nearly 50 GW of **nameplate** domestic module capacity in addition to production of terrestrial c-Si cells and utility-scale inverters for the first time. However, manufacturers are still ramping their production.



Domestic Manufacturing Announcements

Since IRA's passage, more than 370 GW of manufacturing capacity has been announced across the solar supply chain, representing nearly 37,000 potential jobs and nearly $17 billion in announced investments across 124 new facilities or expansions.*

Manufacturing Announcements by Supply Chain Segment*



Sources: U.S. Census Bureau USA Trade Online and internal DOE tracking of public announcements.

*Not all announcements include facility locations, job, operating capacity, or investment numbers.

Despite the headwinds noted by these companies (including surging construction costs, high energy prices, and collapsing solar component costs), recent announcements continue to span the different supply chain steps, including:

- **Hemlock Semiconductor** received a $325 million grant for making (semiconductor) polysilicon and was confirmed as eligible for the 48D tax credit for making c-Si wafers.
- **Boviet Solar** announced it started construction in North Carolina on its 2-GW TOPCon module facility, with cells to follow.
- **DYCM Power** and **Translucent Energy/Akcome** announced plans to build 6 GW and 1.2 GW, respectively, of vertical cell/module manufacturing.
- **Ebon Solar**, **ES Foundry**, **IRH Manufacturing**, and **Talon PV** announced plans to make solar cells in New Mexico, South Carolina, Indiana, and an undisclosed location (at 4-GW scale), respectively.

Cell manufacturing announcements, in particular, continue to see significant growth since the last update.

Click here to interactively view a map of manufacturing announcements.

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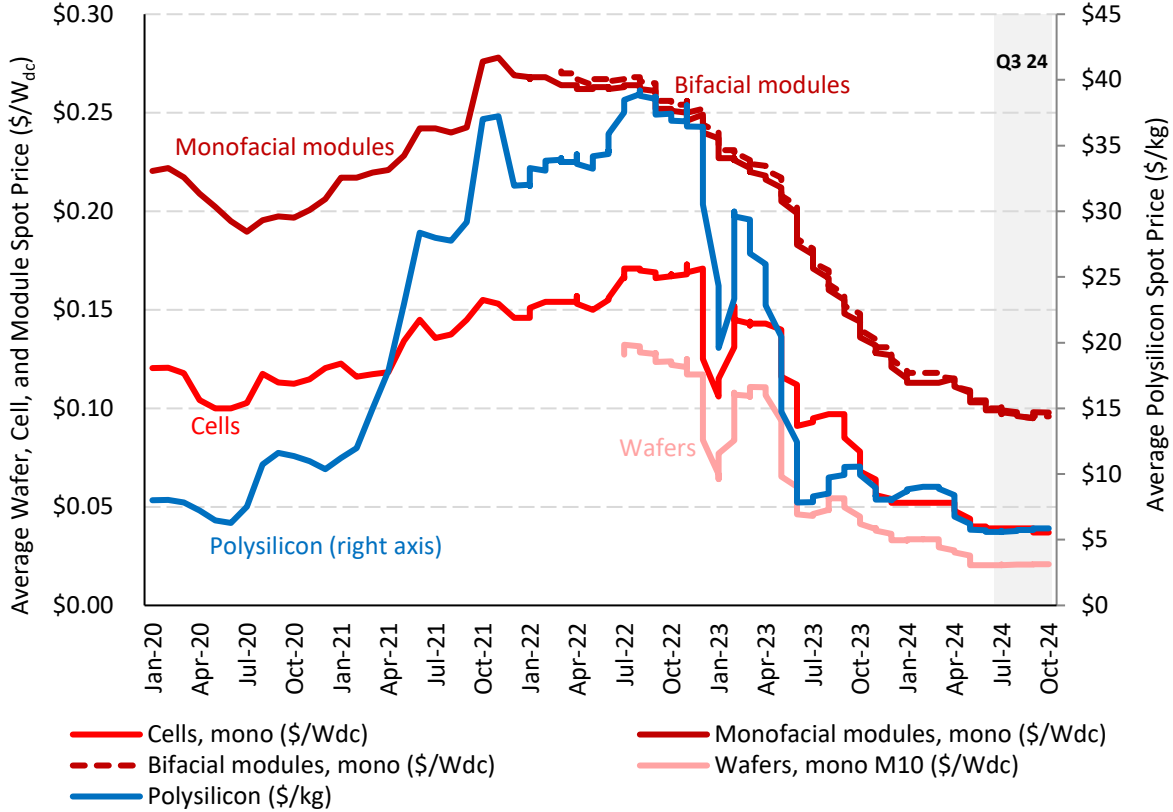
4. Global Manufacturing
5. **Component Pricing**
6. Market and Policy
7. U.S. PV Imports

- **In Q3 2024 module prices rose 1% but stayed near record lows around $0.10/$W_{dc,}$ as substantial module overcapacity continues to depress prices.**
- **Global polysilicon spot prices rose 3% from early August ($5.66/kg) to early October ($5.86/kg); however, prices are still below production costs for most manufacturers.**
- **In Q2 2024, the average U.S. module price ($0.31/$W_{dc}$) was down 6% q/q and down 16% y/y, and at a 190% premium over the global spot price.**
- **In Q3 2024, the average imported PV cell price was $0.12/W.**

PV Value Chain Global Spot Pricing



Sources: BloombergNEF, Solar Supply Chain Data (10/12/24); BloombergNEF, Solar Supply Chain Index (10/4/24).

Global polysilicon spot prices rose 3% from early August ($5.66/kg) to early October ($5.86/kg).

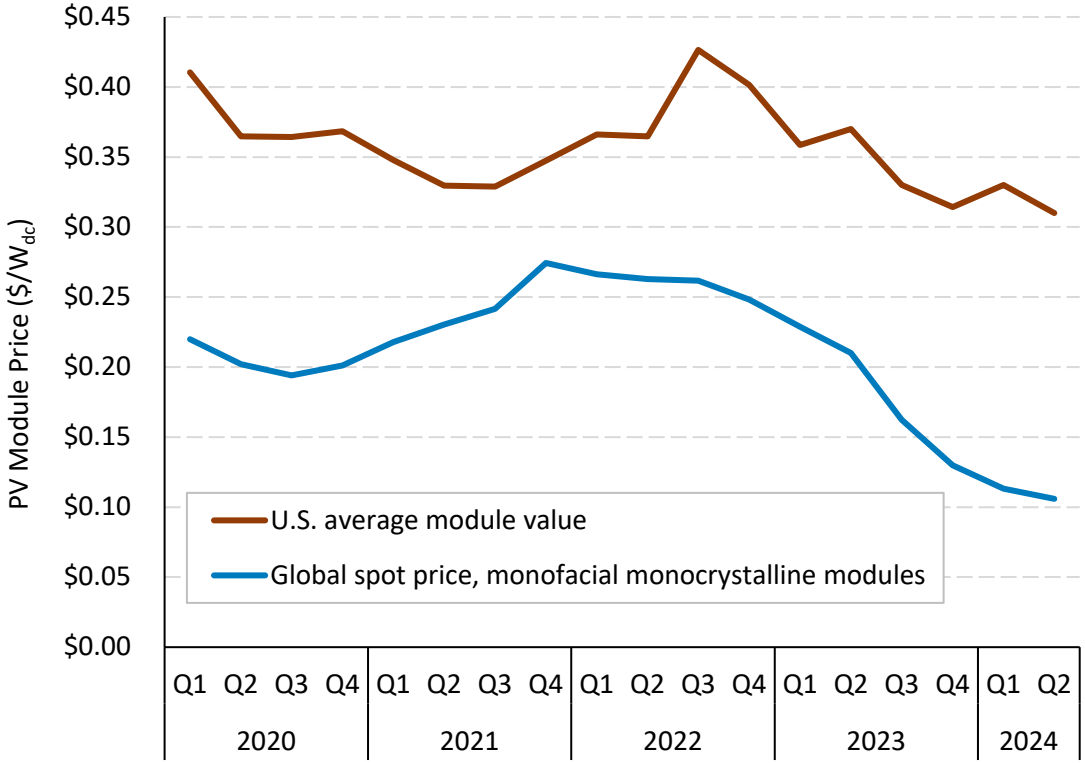
- Prices below production costs for most manufacturers.
- In Q1–Q3, enough polysilicon was produced to manufacture ~700 GW_{dc} of wafers, a pace well above global demand.
- BNEF expects prices to remain at $5–$6/kg this year, enabling leading factories to break even.

During the same period, global prices rose 1% for wafers while falling 5% for cells.

Module prices rose 1% but stayed near record lows, around $0.10/$W_{dc}$.

- Substantial module overcapacity continues to depress prices.
- BNEF expects further price reductions this year, even as losses to companies increase.

Module Prices: Global versus United States



In Q2 2024, the average U.S. module price ($0.31/$W_{dc}$) was down 6% q/q and down 16% y/y, and at a 190% premium over the global spot price.

Several factors may be contributing to the declining trend in U.S. module prices:

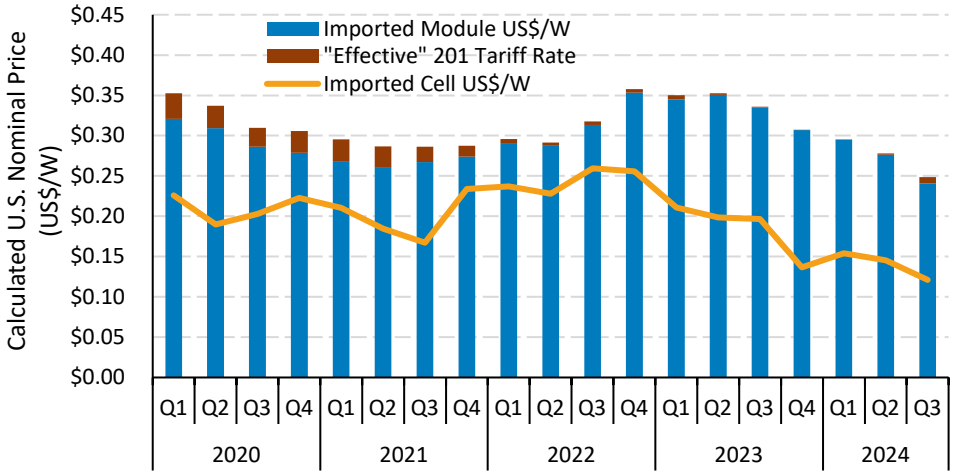
- Reductions in upstream component prices
- Increased competition from imported modules
- The opening of large-scale U.S. module manufacturing facilities with improved economies of scale.

The price difference between U.S. modules and global modules shrank slightly to $0.20/$W_{dc}$ in Q2.

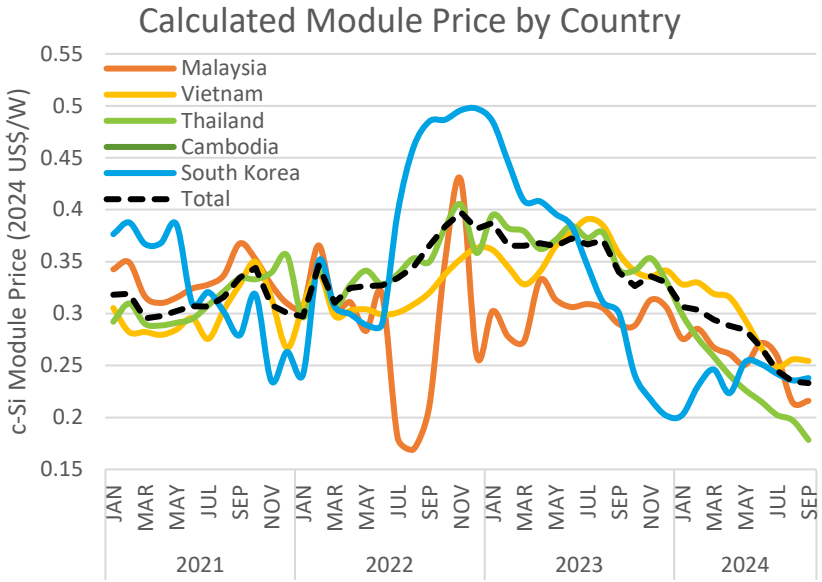
Sources: BloombergNEF, Solar Supply Chain Data (10/12/24); EIA, Monthly Solar Photovoltaic Module Shipments Report (10/12/24); Wood Mackenzie and SEIA, US Solar Market Insight: Q3 2024 (9/24).

Calculated U.S. Module and Cell Import Pricing

- Based on the reported value and capacity of imported PV modules and cells, in Q3 2024, the average price of U.S. module fell further to just under $\$0.25/W_{dc}$, while cell prices declined to $\$0.12/W_{dc}$.
  - In Q3 approximately 23% of modules reported paying a tariff, up from 3% in Q2 and less than 1% in Q1.



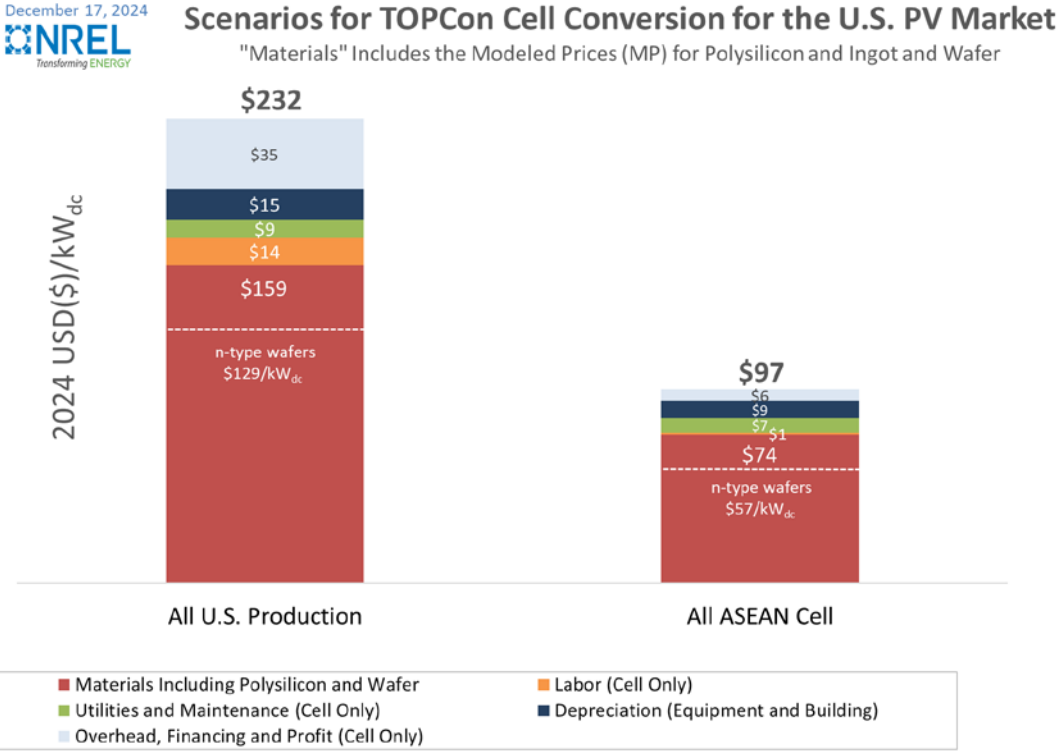
- These module price declines were observed across all countries of import. However, prices declined most steeply over the past several months for modules from Thailand. Current prices are now hitting all-time domestic lows, when adjusted for inflation.



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 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.

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 Nov. 8, 2024.

Cost Challenges of Domestic Cell and Wafer Manufacturing



- Analysis from NREL in December estimated that c-Si PV cells produced domestically from domestic wafers and poly would have a cost premium of $0.135/W over cells produced in Southeast Asia (the primary source of PV cells used in the United States).
  - The primary drivers behind the higher U.S. costs are a less developed supply chain, higher cost of capital, higher labor cost, and more rigorous environmental controls.

Note: This analysis excludes federal incentives currently available to solar manufacturers in the United States.

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- **The Invesco Solar ETF rose 10% in Q3 2024, countering a years-long declining trend, with analysts citing decreased inflation and expectations of an interest rate cut. For comparison, the S&P 500 rose 5%, and the Russell 2000 rose 10% in Q3.**
- **On October 22, the IRS clarified that domestic solar ingot and wafer producers can receive the 25% 48D investment tax credit.**
- **Rhode Island became the most recent state to enact an energy storage goal. The state has a clean energy target of 100% by 2033, and their new Energy Storage Systems Act will help them achieve this goal by ensuring 600 MW of energy storage deployment by 2033.**

States: Q2 2024 Updates

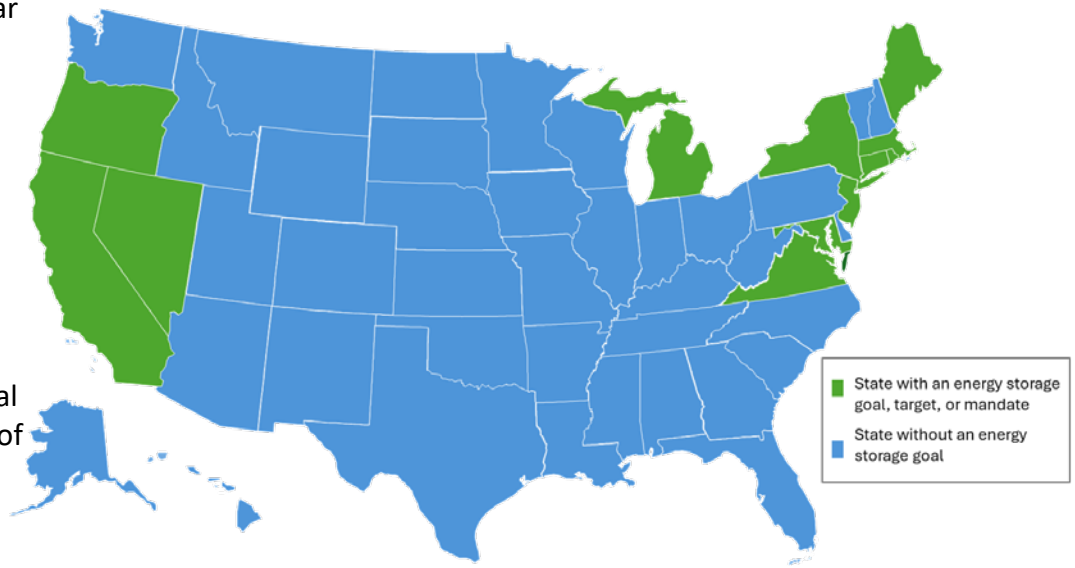
Rhode Island became the most recent state to enact an energy storage goal. The state has a clean energy target of 100% by 2033, and their new Energy Storage Systems Act will help them achieve this goal by ensuring 600 MW of energy storage deployment by 2033.

California's governor vetoed a bill that would have allowed properties with multiple meters (including schools, farms, and multifamily homes) to use the electricity produced by their solar array. Multimetered customers currently must sell their electricity to the grid and then buy it back.

Colorado's energy office announced that it will reopen its Automated Permit Processing for Solar (APPS) grant program aimed at helping local and Tribal governments implement automated residential rooftop permitting software. They will award $1 million in grants.

Connecticut's Public Utilities Regulatory Authority authorized new rules for multifamily building participation in the residential net metering program. The rules also outline how the benefits of net metering must pass on to tenants via qualified building upgrades.

New Mexico expanded their community solar program by 300 MW, more than doubling the state's current approved capacity.



Sources: Table of State Energy Storage Targets and Progress, Clean Energy States Alliance, accessed 10/7/24; Rhode Island governor signs bill to create new incentives for energy storage, Solar Power World, 6/27/24; State of Colorado revives automated solar permitting grant program, Solar Power World, 9/19/24; Newsom rules that California schools and farms cannot use their own solar energy production, PV Magazine, 9/30/24; New Mexico increases community solar programme by 300MW, PV Tech, 10/7/24; Illinois moving to "Smart Solar Billing" in 2025, Solar Power World, 10/1/24; 50 States of Solar: Q3 2024 Quarterly Report, NC Clean Energy Technology Center, October 2024.

Tax Credit Updates

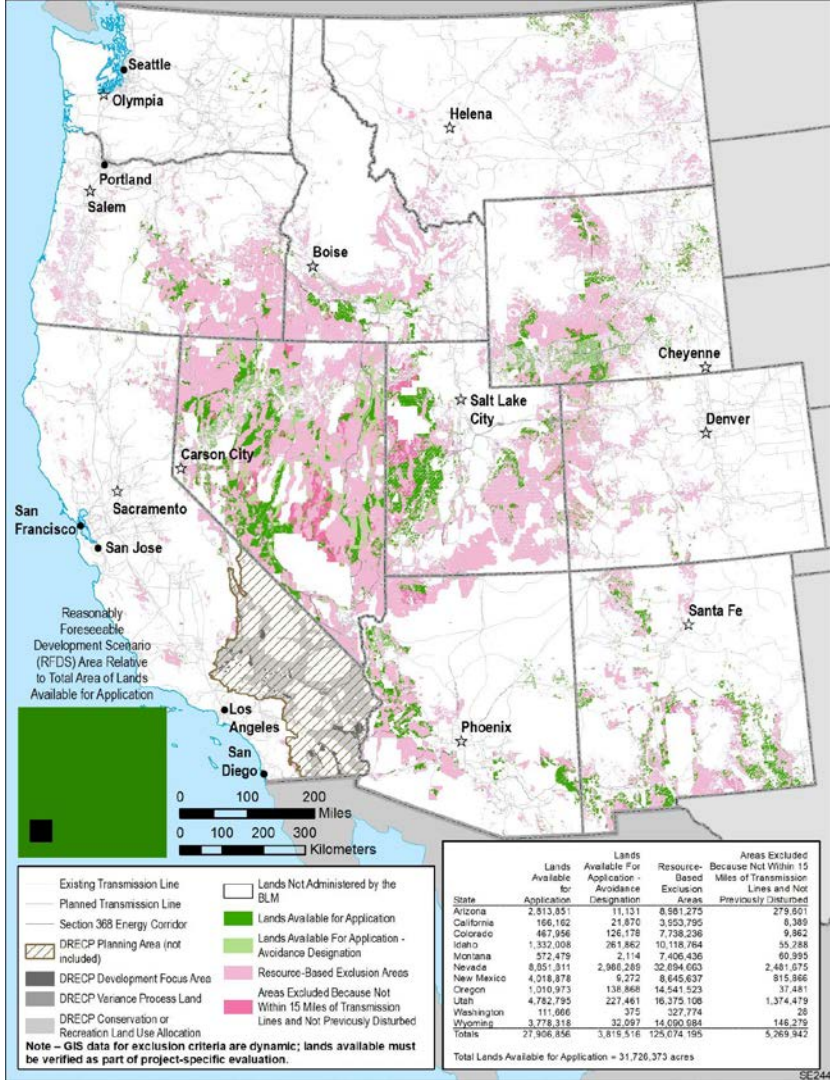
- On Oct. 22, the U.S. Department of Treasury and Internal Revenue Service (IRS) released final guidance on the Advanced Manufacturing Investment Credit (CHIPS ITC, or 48D).
  - In the final guidance, they clarified that semiconductor wafer production includes the production of ingots and wafers used for photovoltaic solar energy generation, enabling domestic solar ingot and wafer producers to receive the 25% tax credit.
  - New regulations are effective starting December 23, 2024, and will include manufacturing facilities that began production after the end of 2022 or are scheduled to begin operating before the end of 2026.
- On Oct. 24, Treasury and IRS released final guidance on the Advanced Manufacturing Production Credit (45X).
  - The final rules are largely in line with the proposed regulations released in December 2023, but they clarify definitions and confirm credit amounts for eligible components included under the credit.
  - The full listed credit will be given to anything sold through Dec. 31, 2029, after which the credits begin phasing out.

BLM Solar Plan Released

In August, the Bureau of Land Management (BLM) released its final proposed roadmap for solar development on BLM lands—updating its 2012 plan.

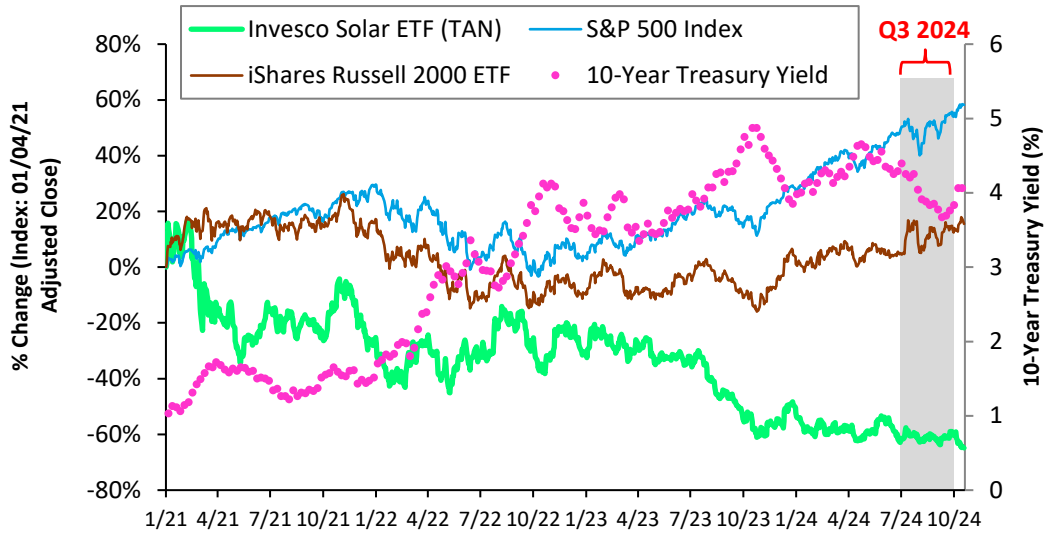
- Goal is to guide solar applications away from lands with high potential for resource conflict while maintaining flexibility to adjust for site-specific resource concerns.
- Number of states covered expanded from 6 (AZ, CA, CO, NV, NM, UT) to 11 (+ ID, MT, OR, WA, WY).
- Makes 31.7 million acres available for development; a "reasonably foreseeable development scenario" projects 700,000 of those acres may be developed by 2045.
- Exclusion categories modified: removing insolation minimum, increasing allowable slope, refining resource-based exclusion areas (e.g., related to migration corridors), requiring siting within 15 miles of existing or planned transmission unless previously disturbed land is used.
- To be published after BLM addresses any issues arising from a 30-day protest period and 60-day governor's consistency review.

Sources: BLM, Press Release (8/29/24); BLM, Final PEIS (8/28/24); Heidi Hartmann, Argonne National Laboratory, Personal Communication. Also see coverage in NREL's Spring 2024 Solar Industry Update.

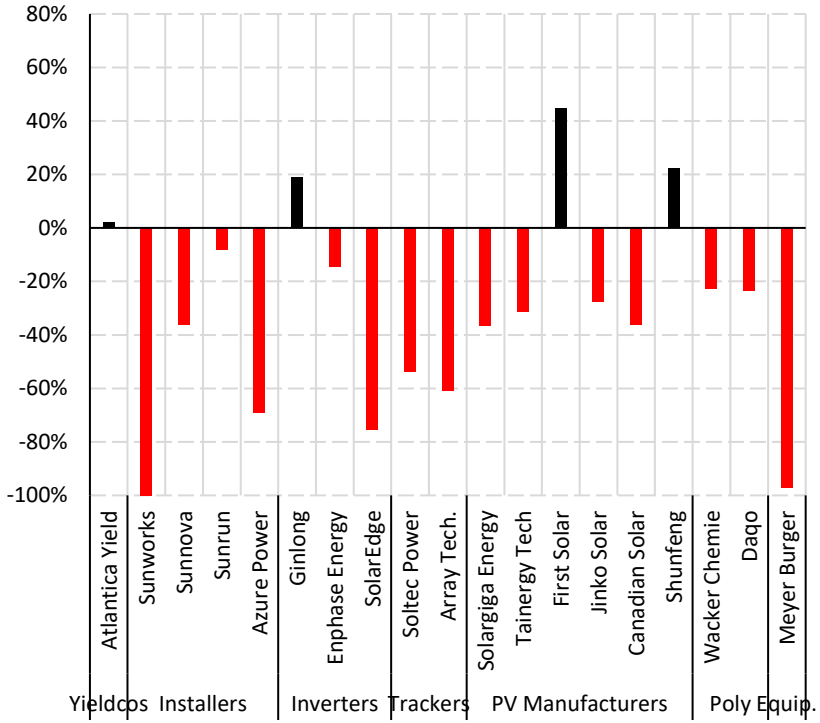


Stock Market Activity

The Invesco Solar ETF rose 10% in Q3 2024, countering a years-long declining trend. For comparison, the S&P 500 rose 5%, and the Russell 2000 rose 10% in Q3. Citing decreased inflation, the US Federal Reserve cut its benchmark interest rate by 0.5% in mid-September and indicated further cuts would be forthcoming. The cut and anticipated cuts are benefiting the solar industry and stocks, because solar projects—with their high upfront costs—are particularly sensitive to interest rates.



Individual Stock Performance (Q1–Q3 2024)

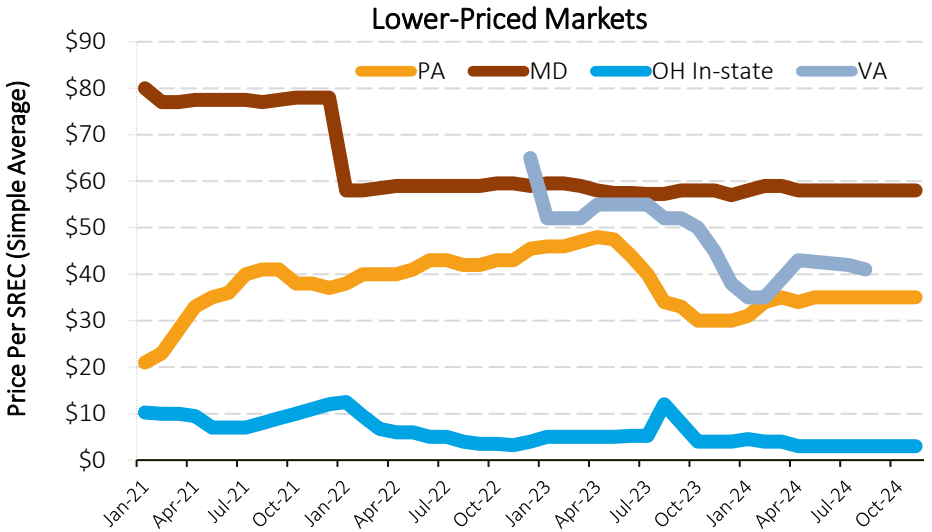


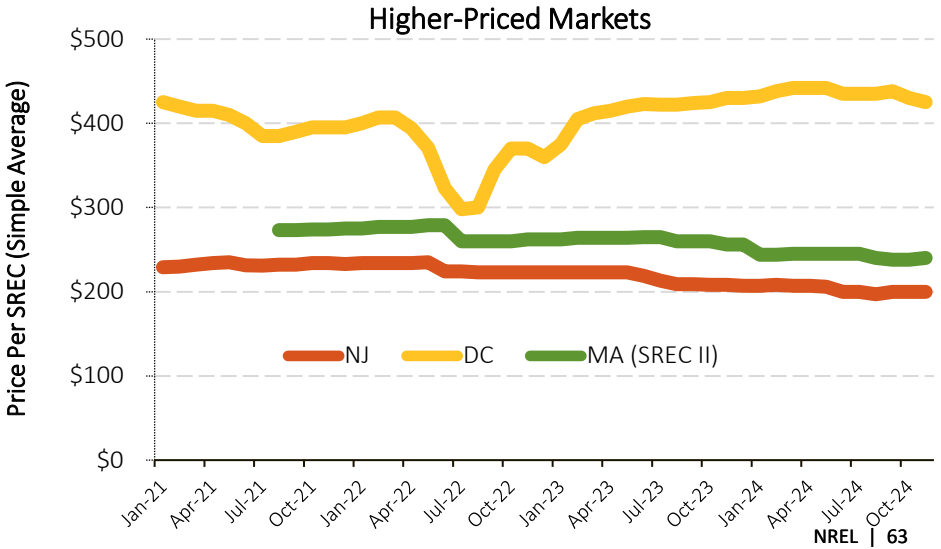
Note: The TAN index is weighted toward particular countries and sectors. As of 10/21/24, 47% of its funds were in U.S. companies, and 19% were in Chinese companies. Its top 10 holdings, representing 56% of its value, were First Solar, Enphase, NEXTracker, GCL, Sunrun, Xinyi, Encavis, HA Sustainable Infrastructure Capital, Neoen, and SolarEdge.

Sources: Federal Reserve Bank of St. Louis (accessed 10/22/24); Invesco (10/21/24); Reuters (9/18/24); Utility Dive (9/19/24); Yahoo Finance (accessed 10/22/24).

SREC Pricing

- Solar renewable energy certificate (SREC) pricing has been relatively stable in 2024, though some price movement occurred as states switched to a new energy year in June.
- Prices vary depending on whether SRECs are sold in the spot market or for a forward contract. For example, RECMint estimates an 11%–24% and 33%–46% discount over spot prices for 3- and 5-year contracts, respectively.





Sources: SRECTrade, RECMint, accessed 11/8/24.

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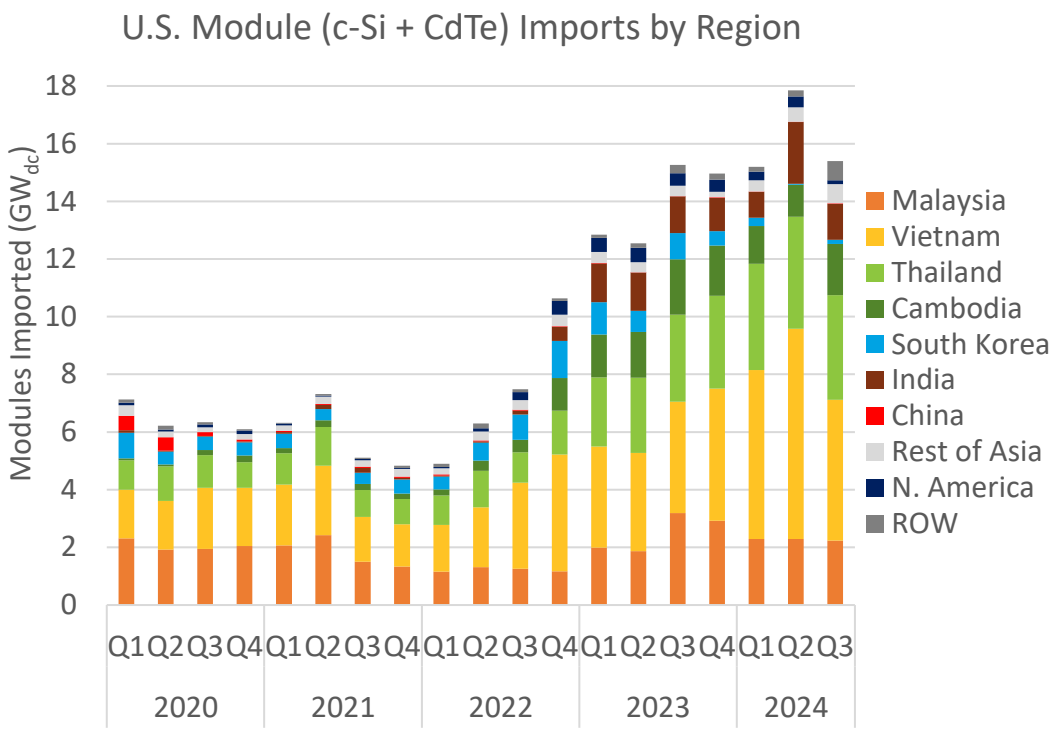
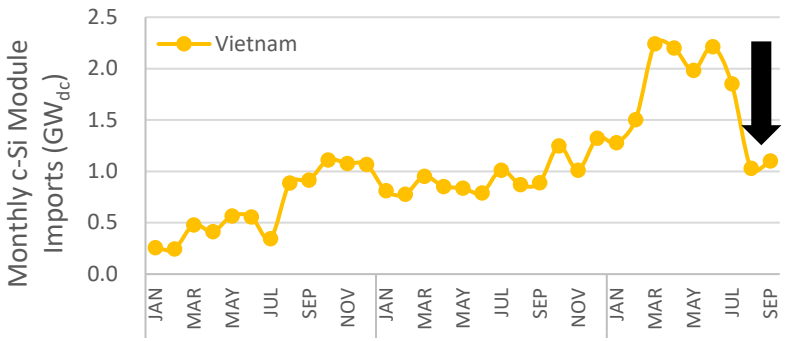
- **According to U.S. Census data, in Q3 2024, U.S. module imports grew again to nearly 15.4 GW_{dc} or 48.5 GW_{dc} for the first 9 months of 2024.**
- **On Oct. 1, the Department of Commerce (DOC) issued a preliminary decision to impose countervailing duties (CVD) on c-Si panels and cells produced in Vietnam, Malaysia, Thailand, and Cambodia. Tariffs ranged from 0% to 300%; a preliminary decision on antidumping duties is expected later this fall.**
- **According to CBP Commodity Status Reports, since the President raised the annual tariff rate quota for cells to 12.5 GW in August, imports have continued to accelerate. As of 10/28/24, more than 9.4 GW (75% of the TRQ) of cells have been imported.**

U.S. Module Imports Q3 2024 by Region



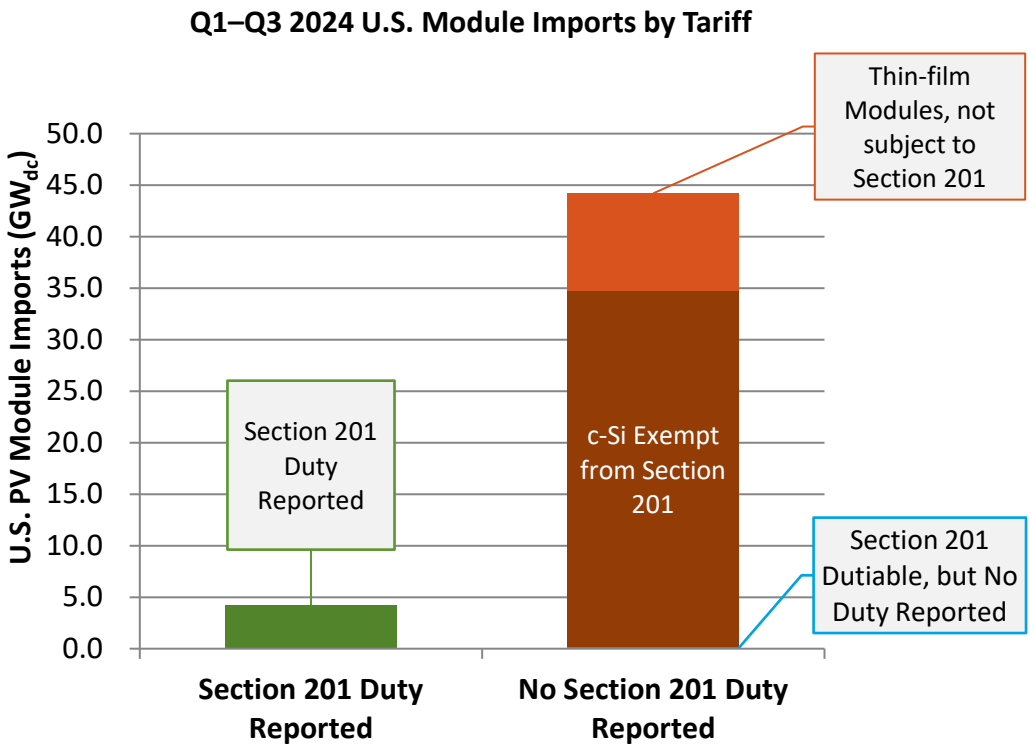
According to U.S. Census data, in Q3 2024, U.S. module imports were 15.4 GW_{dc}, or 48.5 GW_{dc} for YTD 2024.

- Vietnamese c-Si module imports, after growing significantly in 2024, fell by more than 1 GW from June to August.
- This could be a delayed response to the end of the moratorium on AD/CVD circumvention duties in June.



Note: 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. **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 10/8/24.

U.S. Module Imports Q1–Q3 2024 by Tariff



According to U.S. Census data, in Q1–Q3 2024, 4.2 GW_{dc} (9%) of modules imported reported paying a tariff.

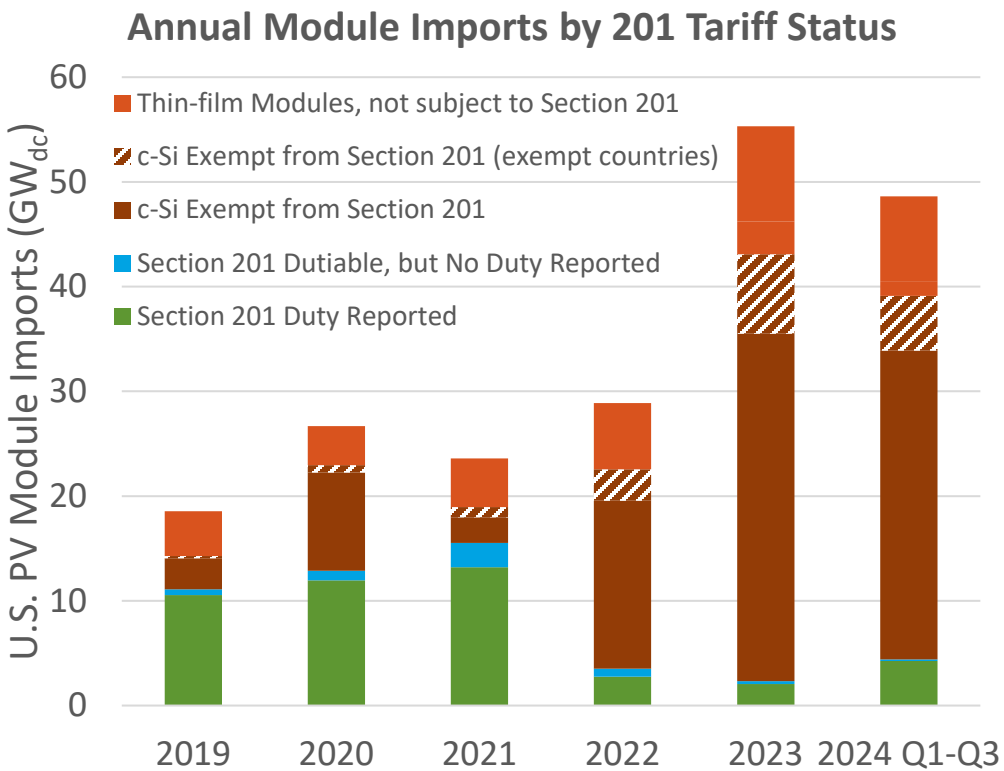
– The majority of imports reporting a tariff (3.5 GW_{dc}, 84%) arrived in Q3. This is likely a result of the bifacial exemption having been revoked in May 2024.

Most modules that did not report paying a tariff were c-Si technology panels exempt from section 201 tariffs (34.6 GW_{dc}) or thin-film modules (9.4 GW_{dc}).[a]

– Countries exempt from section 201 tariffs accounted for 5.2 GW_{dc} of c-Si imports.

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 10/8/24. [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.

U.S. Module Imports by Tariff Over Time



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

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 (IBC) 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 10/8/24. [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.

Preliminary CVD Determination for SE Asian Countries

Country	Finding	Company Investigated	Duty Rate
Malaysia (12%)	Positive	**Hanwha Qcells**	14.72%
		JinkoSolar	9.92%
		Baojia New Energy, Pax Union Resources, SunMax Energy	123.94%
		All others	9.13%
Vietnam (37%)	Positive	**Boviet Solar**	0.81%
		GEP New Energy, Shengtian New Energy Vina, HT Solar, Vietnam Green Energy	292.61%
		All others (including **JA Solar**)	2.85%
Thailand (23%)	Positive	**Trina Solar**	0.14%
		Taihua New Energy, Sunshine Electrical Energy	34.52%
		All others	23.06%
Cambodia (7%)	Positive	**Jintek PV Tech** and ISC Cambodia	68.45%
		All others (including **SolarSpace New Energy**)	8.25%

^Percentages for each country are of total H1 2024 cell and module imports combined.

Sources: U.S. Department of Commerce preliminary determination and update.

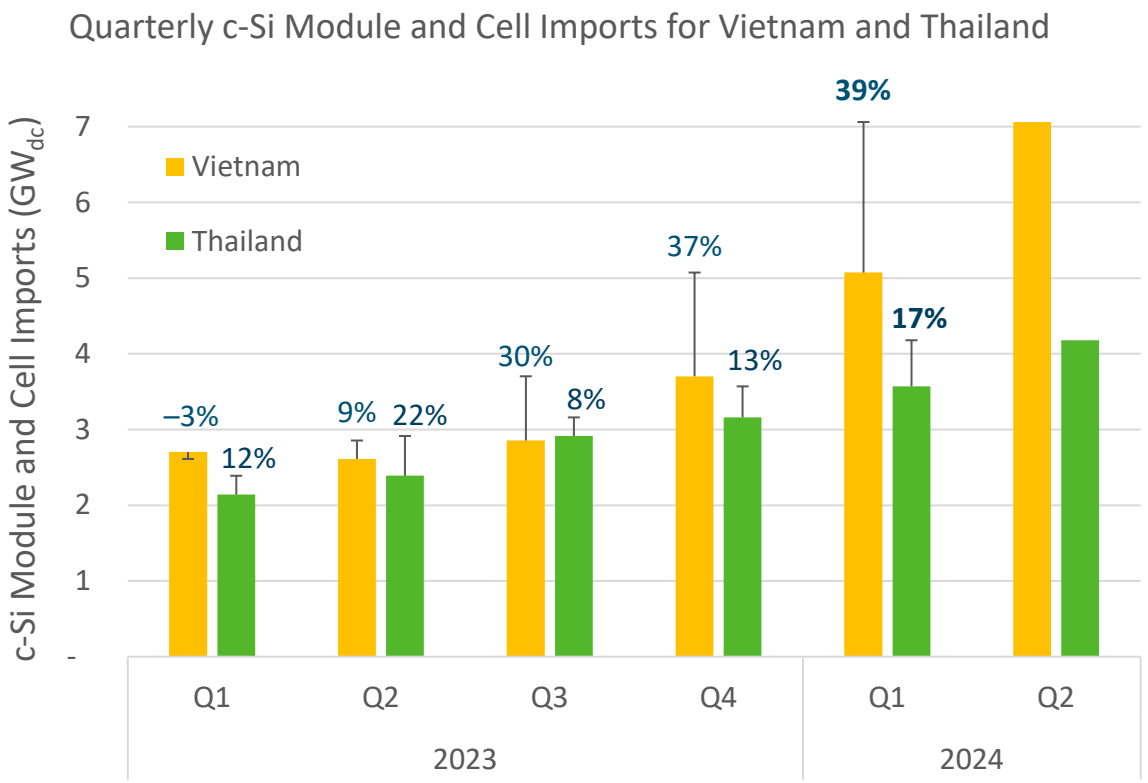
On Oct. 1, the Department of Commerce (DOC) issued a preliminary decision to impose countervailing duties (CVD) on c-Si panels and cells produced in Vietnam, Malaysia, Thailand, and Cambodia.

Countervailable subsidy is when foreign governments provide financial assistance to foreign producers that is deemed unfair. CVD are imposed to level the playing field for domestic manufacturers. U.S. Customs and Border Protection began collecting these duties immediately.

These duties are preliminary and are subject to change. They will also be adjusted annually.

Boldfaced companies are the top 1–2 companies by volume in each country in 2023 according to DOC.

Preliminary CVD Determination for SE Asian Countries



DOC also found critical circumstances for imports from Vietnam and Thailand because they identified recent imports from those two countries as surging.

If the USITC rules positively that this surge resulted in injury to the U.S. industry, retroactive duties (potentially up to 90 days retroactive) would be applied for Vietnamese and Thai imports.

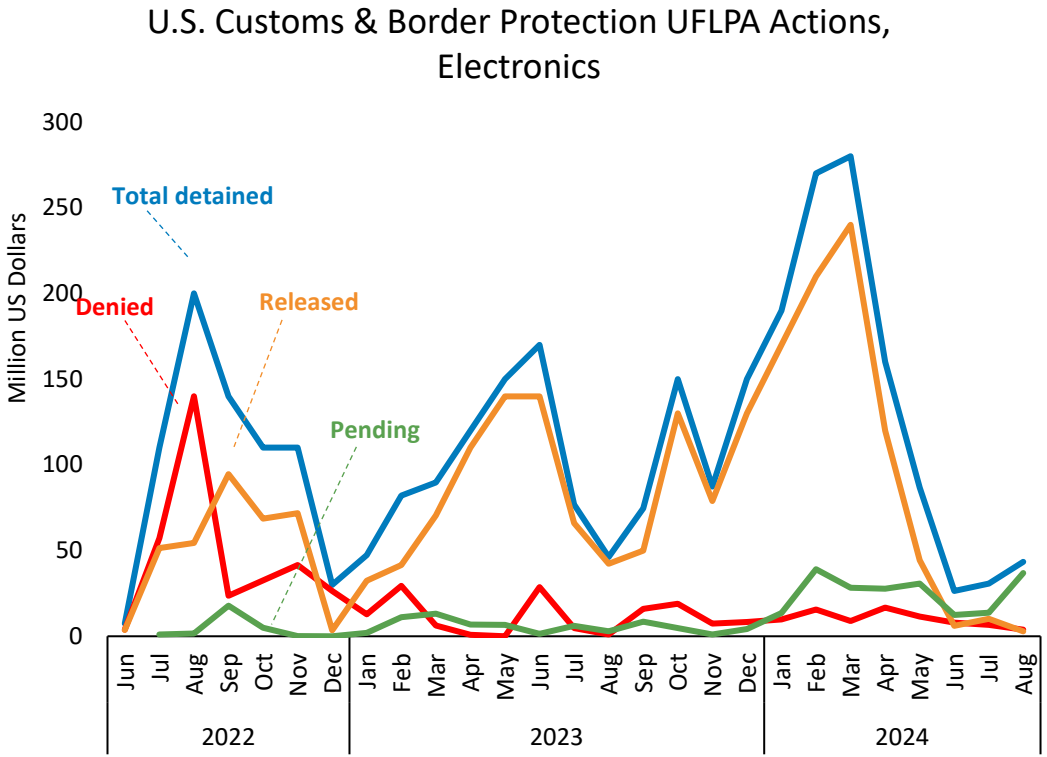
- **Boviet Solar**, **Trina Solar**, and **JA Solar** will be exempt from retroactive duties.

The final CVD determination is expected Feb. 10, 2025.

The related preliminary antidumping (AD) determination is expected Nov. 27, 2024.

Sources: U.S. Department of Commerce preliminary determination and update.
U.S. Census Bureau USA Trade Online tool and corrections page as of 9/4/24.

UFLPA Actions, 2022–2024



U.S. Customs & Border Protection (CBP) has detained electronics shipments under the Uyghur Forced Labor Prevention Act (UFLPA) at a rate of around $1 billion per year.

- Reached $280 million in March 2024 before dropping to $30 million in June.
- Malaysia accounted for 50% of detainments during 2022–2024, followed by Vietnam (30%) and Thailand (17%).
- Electronics include solar, information tech, integrated circuits, automated data processing equipment, and consumer electronics.

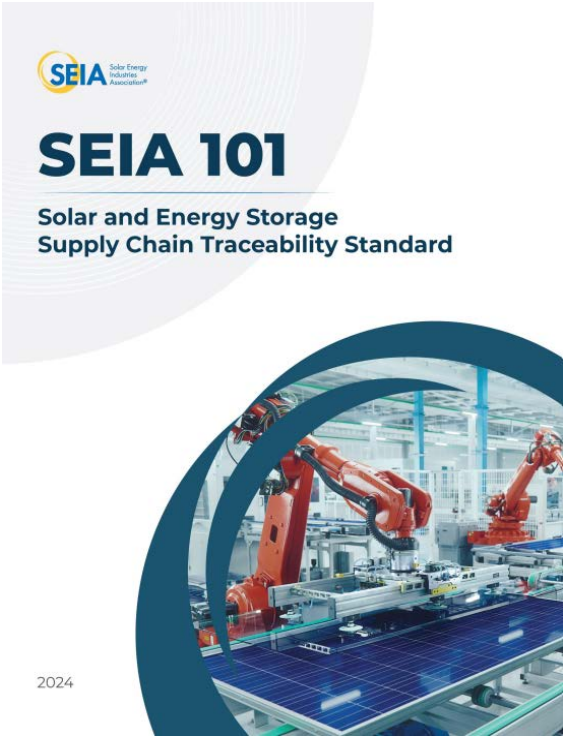
The proportion of electronics shipments denied entry to the U.S. has dropped over time.

- In 7 months of 2022, $325 million (46% of total detainments) were denied vs. $134 million (11%) in 2023 and $80 million (7%) in 8 months of 2024.
- During 2022–2024, 14% of Malaysia's detained products were denied vs. 22% for Vietnam and 20% for Thailand.

Source: CBP, Uyghur Forced Labor Prevention Act Statistics (9/16/24).

SEIA Introduces New ANSI Standard

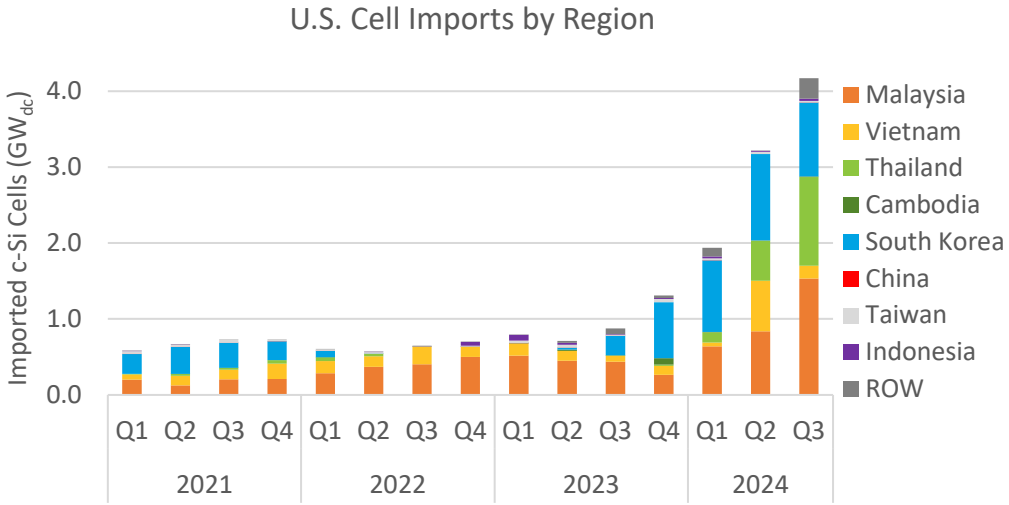
- SEIA released their third draft ANSI standard, Standard 101, which will help companies comply with U.S. Customs and Border Protection's (CBP's) supply chain traceability standards.
- The standard explains specifically how to conduct due diligence on forced labor in the solar and storage supply chains, including how to develop a material traceability system and how to identify and address indicators of forced labor in a supply chain.
- The standard also includes a rubric that manufacturers and importers can use to help them trace their products' supply chains from raw materials to end product.
- The draft released is based on real examples of shipments that were detained by CBP and contains input from manufacturers, developers, and third-party auditors.
- Manufacturers can use the standard to certify a product, their supply chain management system, or their entire business.
- Once the standard is published, SEIA will work with third-party auditors to certify that a product's supply chain has been properly tracked.
- Public comments for Standard 101 closed on Nov. 4, 2024.



c-Si PV Cell Import Data July/August 2024

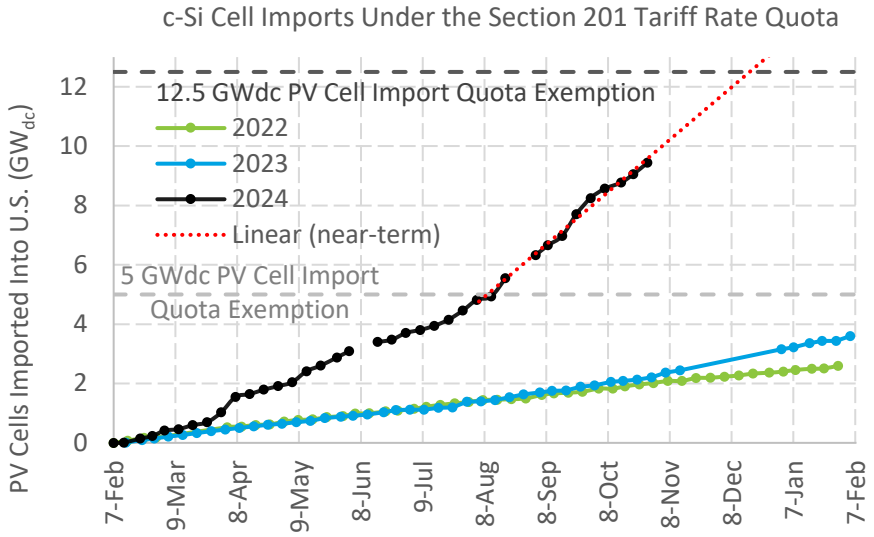
According to U.S. Census data, the U.S. imported more than 4.2 GW_{dc} of PV cells in Q3 2024, the fifth quarter of >20% q/q growth.

– Most of the growth has come from Thailand and Malaysia, which represented 28% (1.2 GW) and 36% (1.5 GW), respectively.



According to CBP Commodity Status Reports, since the President raised the annual tariff rate quota for cells to 12.5 GW in August, imports have continued to accelerate. As of 10/28/24, more than 9.4 GW (75% of the TRQ) of cells have been imported.

If imports continue to increase at the current rate (since the TRQ was raised), the new limit will be reached in December.

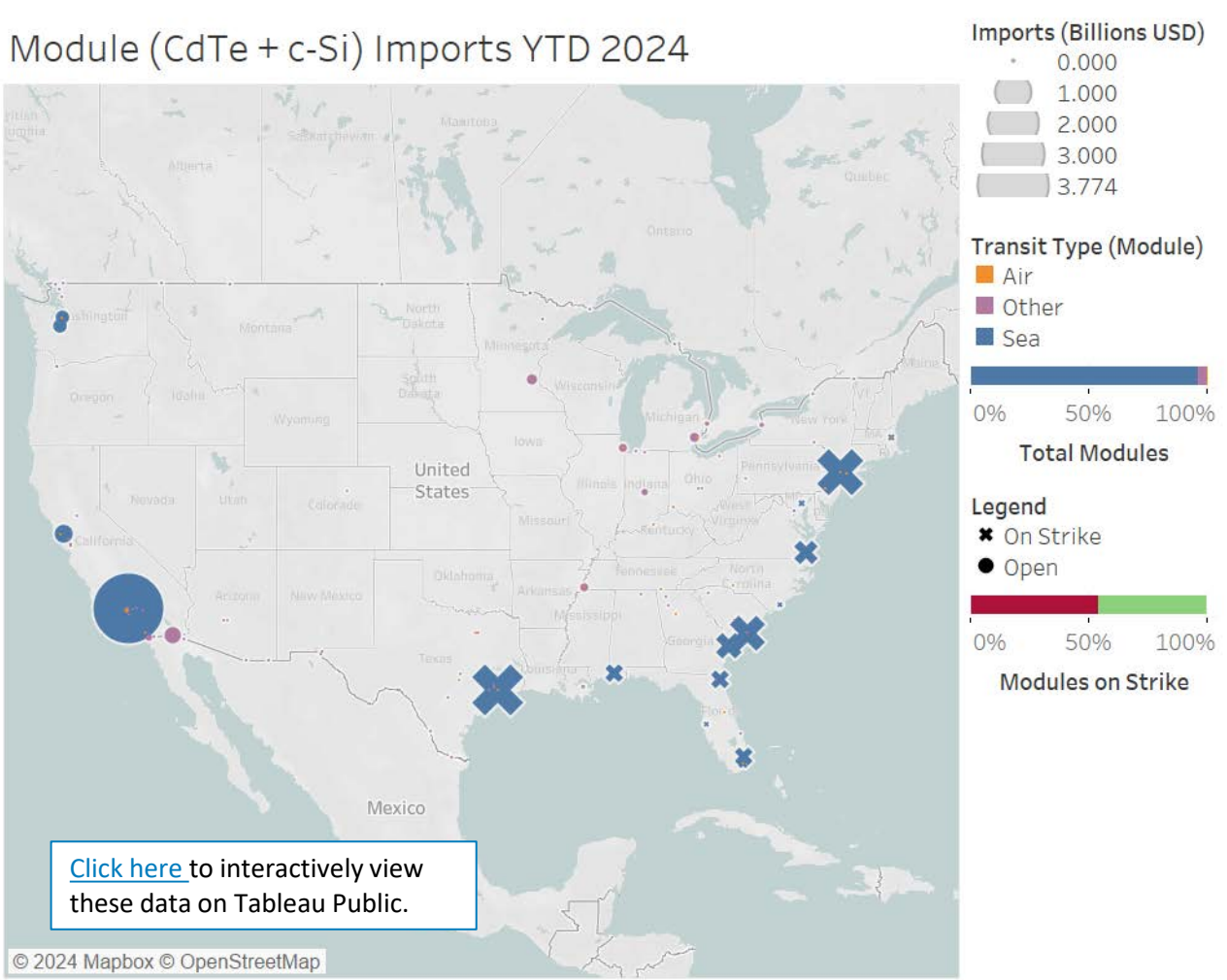


Sources: Imports by HTS code: 8541460025(2018–2021)/8541420010(2022–), Second Quantity (watts) from U.S. Census Bureau USA Trade Online tool and corrections page as of 10/8/24; U.S. Customs and Border Protection Commodity Status Reports February 2019–October 2024.

Longshoremen Strike Impacts

On Oct. 1, 2024, ~45,000 dockworkers went on strike at East and Gulf Coast ports.

- The strike lasted only 3 days but had the potential to massively impact imports.
- The impact on modules imports would potentially have been significant as the vast majority arrive by sea (96% of modules), with 55% of modules impacted.



Sources: Imports by HTS code: 854143 and 854142 from the U.S. Census Bureau USA Trade Online tool as of 10/8/24 and DOE internal tracking of manufacturing capacity. Dockworkers' union suspends strike until Jan. 15 | AP News.

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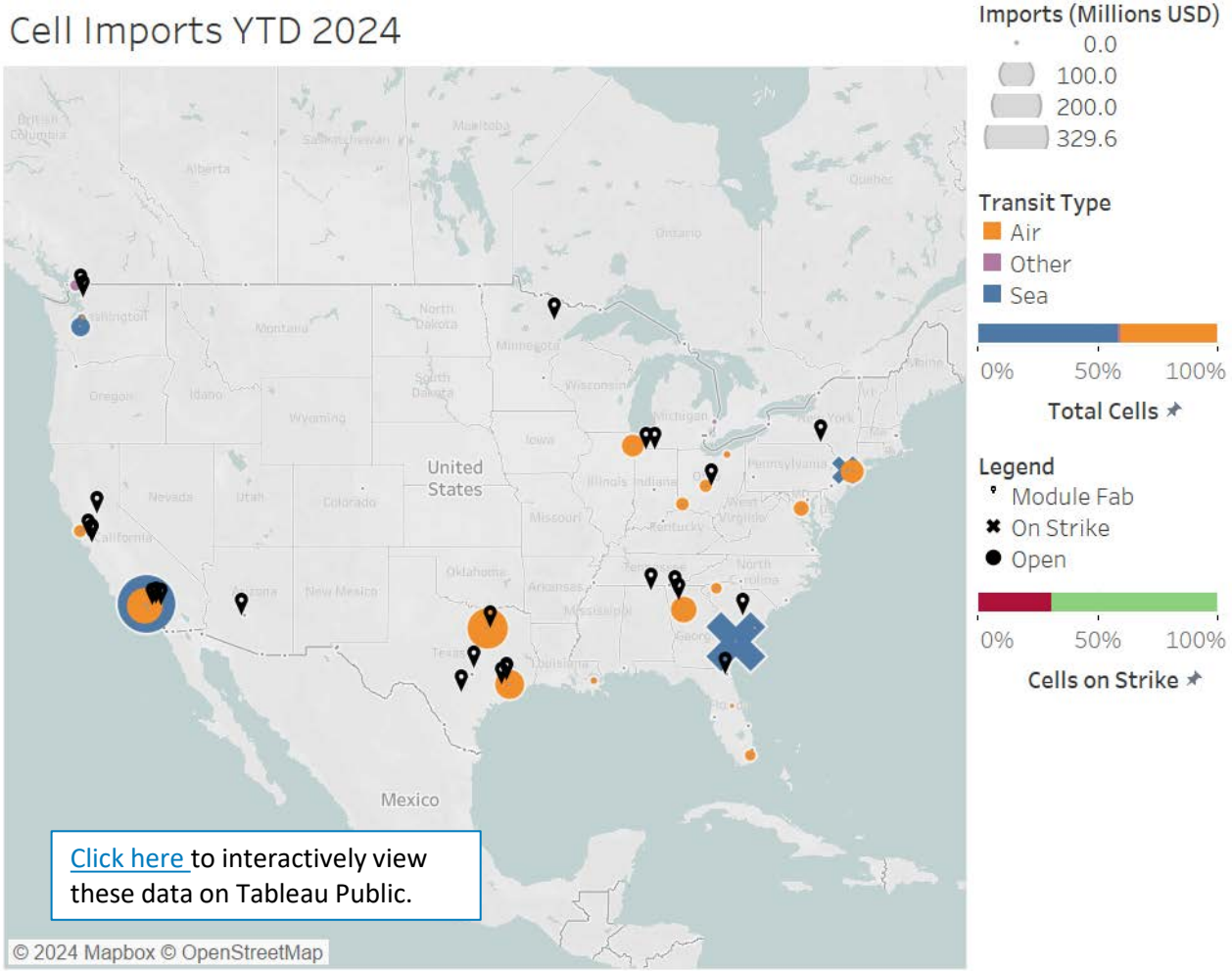

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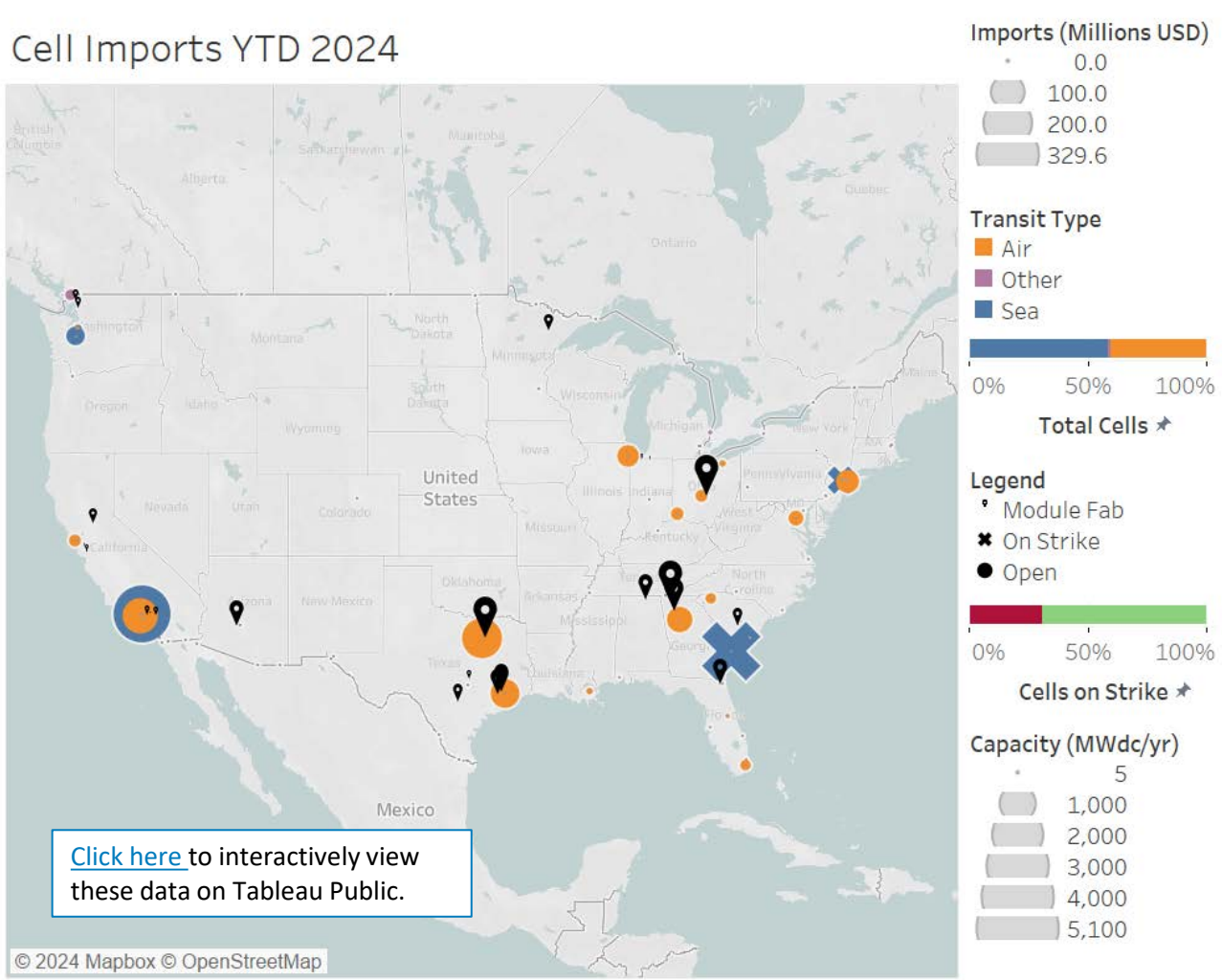
  - The bulk of imports are concentrated at airports near large capacity facilities.



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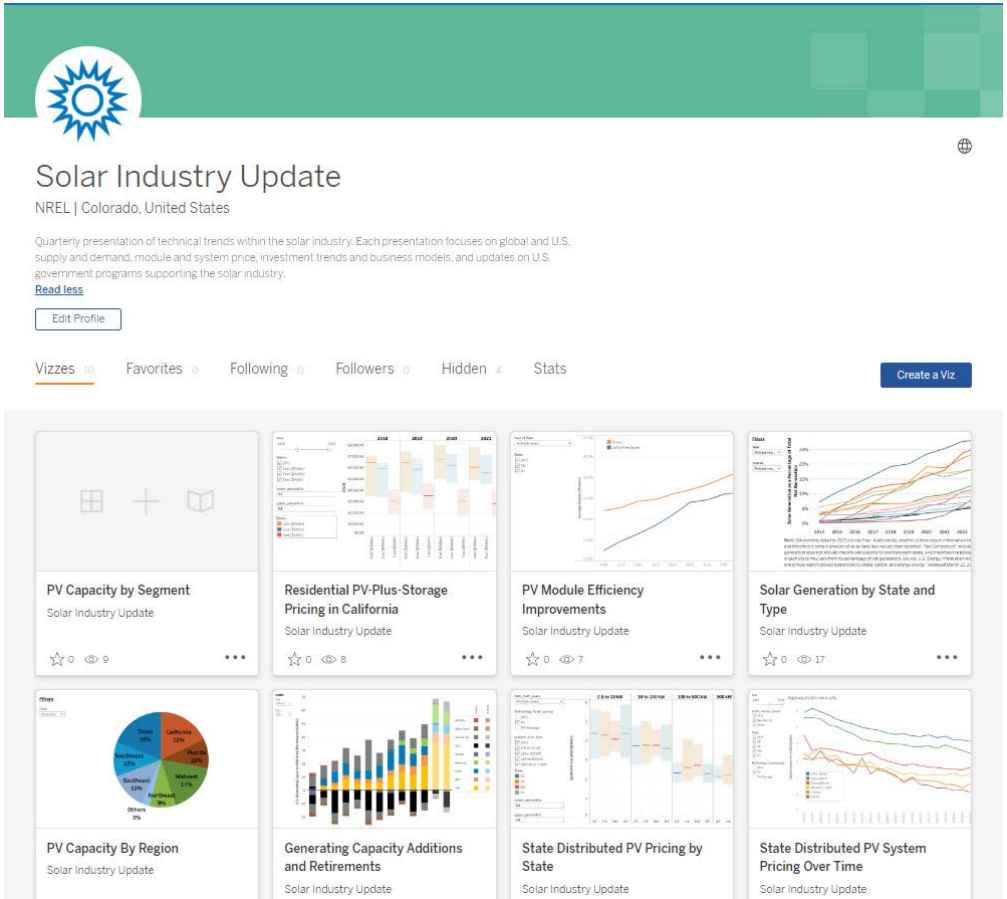

Interested in checking out more of our data in Tableau? Click here

Thank You

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NREL/PR-7A40-92257

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List of Acronyms and Abbreviations

ac: alternating current
AD: antidumping
ANSI: American National Standards Institute
APV: agrivoltaic
ARPA-E: Advanced Research Projects Agency - Energy
ASP: average selling price
BESS: battery energy storage system
BLM: Bureau of Land Management
BoP: balance of plant
BOS: balance of system
c-Si: crystalline silicon
CAISO: California Independent System Operator
CAPEX: capital expenditures
CBP: U.S. Customs and Border Protection
CCI: Community, commercial, and industrial
CdTe: cadmium telluride
CSP: concentrating solar power
CVD: countervailing duty
dc: direct current
DOC: U.S. Department of Commerce
DOE: U.S. Department of Energy
DPV: distributed photovoltaic
EBOS: electrical balance of system
EIA: U.S. Energy Information Administration
ERCOT: Electric Reliability Council of Texas
ESS: energy storage system
ETF: exchange traded fund
ETS: Economic Transition Scenario
GW: gigawatt
GWh: gigawatt-hour
H1: first half of year
H2: second half of year
HTF: heat transfer fluid
HTS: harmonized tariff schedule
ISO: Independent System Operator
ISO-NE: ISO New England
IRA: Inflation Reduction Act of 2022
IREC: Interstate Renewable Energy Council
IRENA: International Renewable Energy Agency
IRS: Internal Revenue Service
ITC: investment tax credit
kW: kilowatt
kWh: kilowatt-hour
LBNL: Lawrence Berkeley National Laboratory
LCOE: levelized cost of energy
MISO: Midcontinent Independent System Operator
MLPE: module level power electronics
MMP: modeled market price
MSP: minimum sustainable price
MW: megawatt
MWh: megawatt-hour
NEM: net energy metering
NREL: National Renewable Energy Laboratory
NYISO: New York Independent System Operator
NYSERDA: New York State Energy Research & Development Authority
O&M: operations and maintenance
PPA: power purchase agreement
PTC: production tax credit
PV: photovoltaics
PVSCM: The Photovoltaic System Cost Model
Q: quarter
q/q: quarter over quarter
RE: renewable energy
ROW: rest of world
RPV: residential photovoltaic
SBOS: structural balance of system
SEIA: Solar Energy Industries Association
SETO: Solar Energy Technology Office
SPP: Southwest Power Pool
TAN: Invesco Solar ETF
TOPCon: tunnel oxide passivated contact
TPO: third-party owner
TRQ: tariff rate quota
TW: terawatt
TWh: terawatt-hour
UFLPA: Uyghur Forced Labor Prevention Act
UPV: utility-scale photovoltaic
USD: U.S. dollars
W: watt
Wt avg: weighted average
y/y: year over year
YTD: year to date