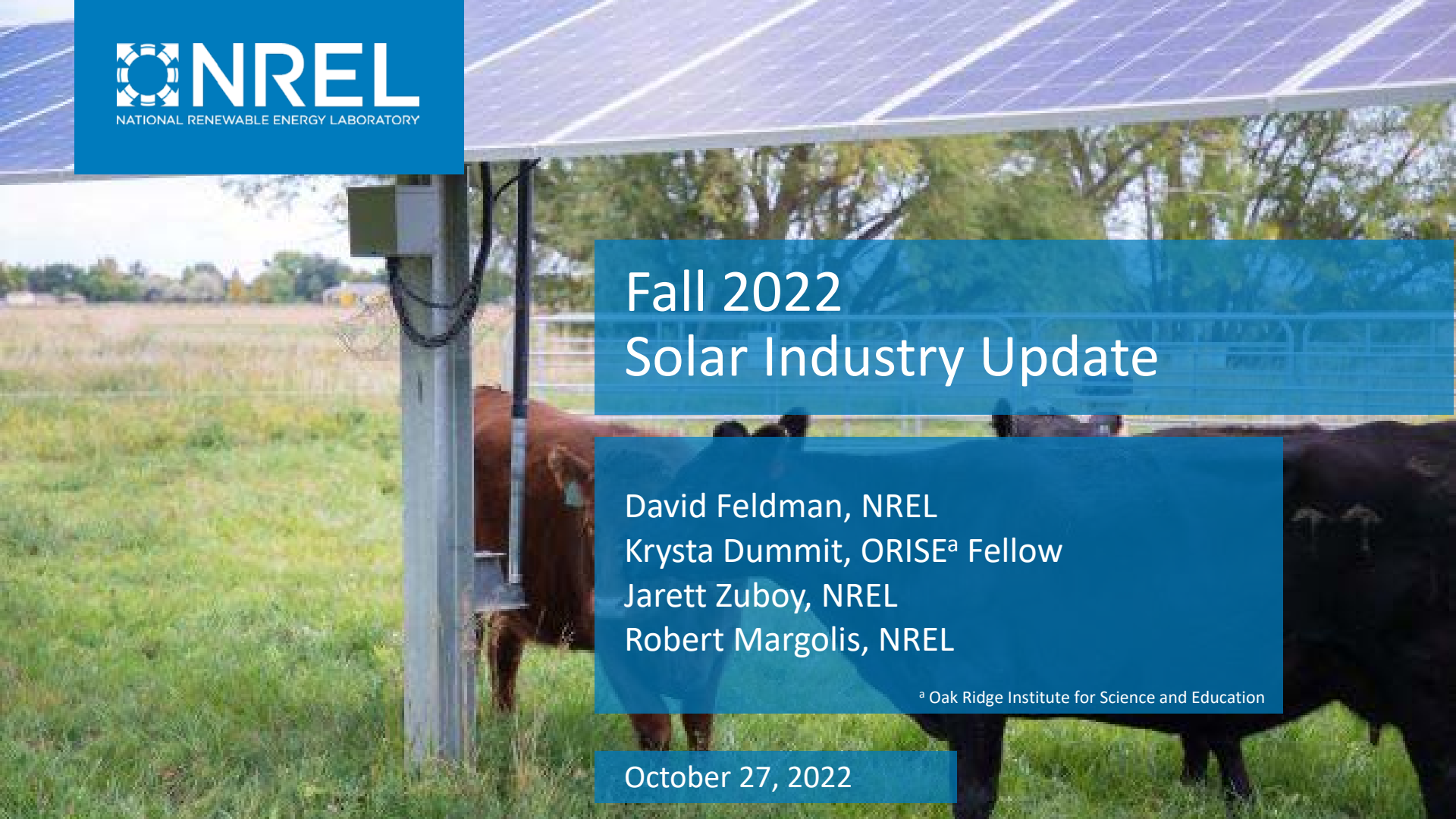

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Fall 2022
Solar Industry Update

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October 27, 2022

Agenda

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

Executive Summary

Global Solar Deployment

- H1 2022 PV installations increased significantly (y/y) in China (137%) and India (82%), and to a lesser extent Germany (16%). The United States and Australia had very sizeable installation levels in H1 2022, but they were down y/y in large part due to supply chain disruptions and price increases. About 220 GWdc of PV are projected to be installed globally in 2022. Analysts expect installations to increase to 356 GWdc by 2026, with two-thirds of the installations to occur in China, the European Union, the United States, and India.
- China currently has 30 CSP projects (approximately 3 GW) with thermal energy storage under development and to be built by 2024.

U.S. PV Deployment

- In August 2022, the Inflation Reduction Act (IRA) was enacted, boosting and lengthening federal incentives for domestic solar manufacturing and deployment.
- Analysts estimate the IRA will be a large contributor to annual installations, more than doubling them between 2022 and 2025.
- California's revised net metering (NEM 3.0) proposal might not be released until after the November elections.
- The United States installed 7.9 GWac of PV in H1 2022; half of that was in Texas, Florida, and California.
- The United States installed ~5.9 GWh (2.3 GWac) of energy storage onto the electric grid in H1 2022.

PV System and Component Pricing

- U.S. PV system and PPA prices have been flat or increased over the past 2 years.
- Global polysilicon spot prices were high in Q3 2022 at around $38–$39/kg, up 20% since January 2022 and 270% since January 2021.
- Module spot prices ended down 4% in Q3 2022, at $0.25/W, which may be due in part to increasing module inventories in Europe.
- In Q2 2022, the average U.S. module value ($0.37/Wdc) was about the same q/q and was up 13% y/y, trading at a 41% premium over the global spot price for monofacial monocrystalline silicon modules..

Global Manufacturing

- According to Infolink (formerly PV Infolink), the top 10 module manufacturers were responsible for 101.7 GW (+45% y/y) in H1 2022 and the top 5 cell manufacturers together shipped 59 GW of cells (+60% y/y).
- Since IRA legislation was introduced and subsequently passed, there have been numerous announcements across the solar PV supply chain of planned domestic manufacturing capacity additions. The number of announcements is weighted toward module manufacturing (~42 GW versus 10–15 GW for the other steps).
- Several leading global PV companies have made announcements to expand corporate production capacity to 50 GW or greater by 2023.

U.S. PV Imports

- 11.2 GWdc of PV modules were imported into the United States in H1 2022, down 18% y/y. However, In Q2 2022, U.S. module imports grew substantially (+28%, or 1.4 GW q/q) for the first quarter in a year. Most panels imported were exempt from Section 201 duties, and therefore likely bifacial. A significant number of thin-film modules were also imported.
- 1.2 GWdc of cells were imported in H1 2022, down 6% y/y.

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

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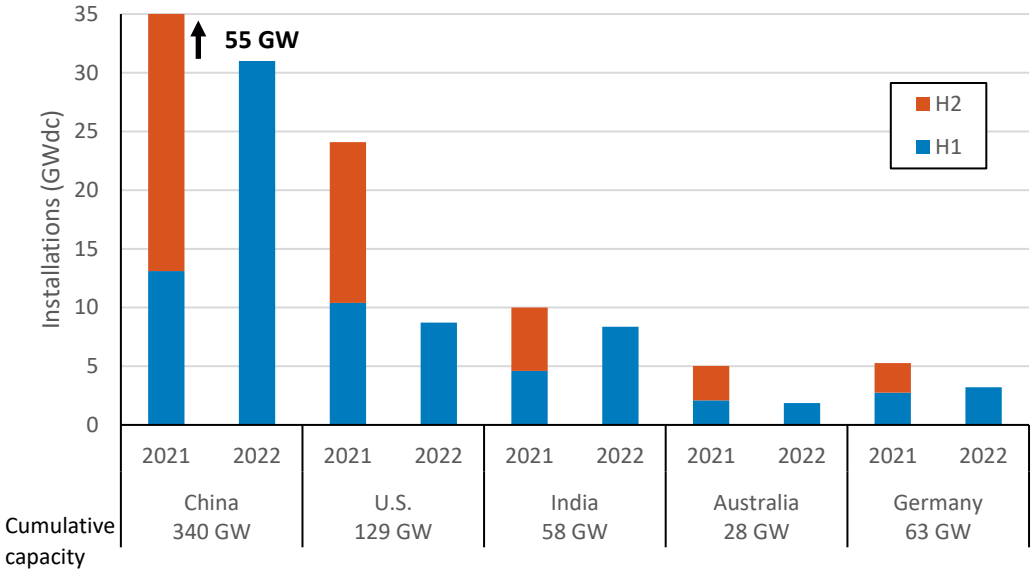
- **H1 2022 PV installations increased significantly (y/y) in China (137%) and India (82%), and to a lesser extent Germany (16%). From a historical perspective, the United States and Australia also had very sizeable installation levels in H1 2022, but they were down y/y in large part due to supply chain disruptions and price increases. At the end of June, these countries had cumulatively installed 618 GWdc of PV.**
- **About 220 GWdc of PV are projected to be installed globally in 2022. Analysts expect installations to increase to 356 GWdc by 2026, with two-thirds of the installations to occur in China, the European Union, the United States, and India.**
- **China currently has 30 CSP projects with thermal energy storage under development and to be built by 2024.**

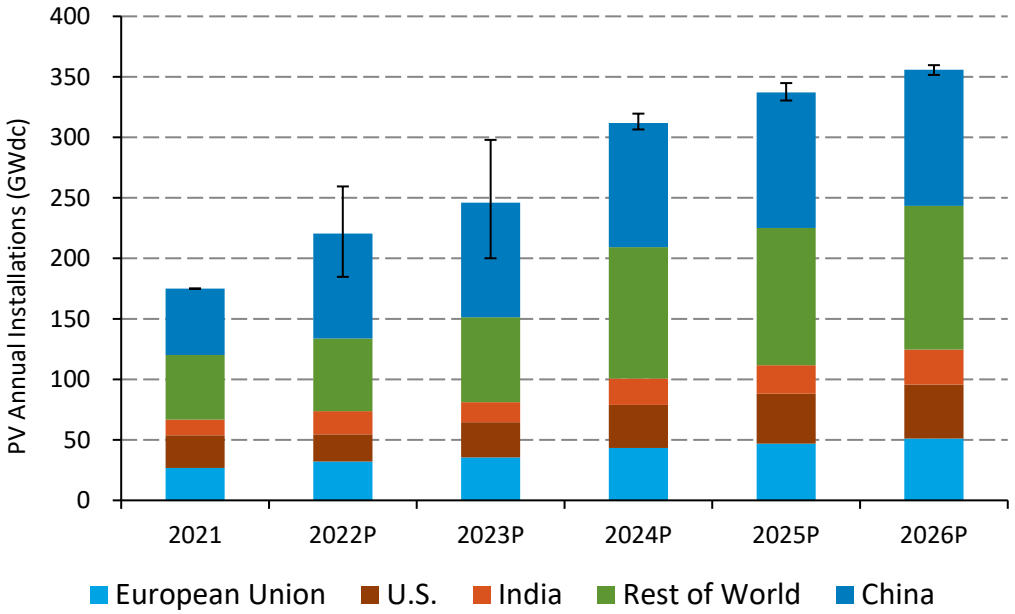
International H1 2022 Installations



- H1 2022 PV installations increased significantly (y/y) in China (137%) and India (82%), and to a lesser extent Germany (16%).
  - The China Photovoltaic Industry Association expects total 2022 installations in China to be 75 GW–90 GW, far exceeding last year's record of 55 GW.
  - JMK Research expects India to install 20 GW in 2022.
    - India's 2022 cumulative solar targets are 60 GW for utility-scale solar and 40 GW for rooftop solar. It is expected to come close to achieving its utility-scale PV target, but it will likely fall short of its rooftop solar target by 25 GW.
- From a historical perspective, the U.S. and Australia also had very sizeable installation levels in H1 2022, but they were down y/y in large part due to supply chain disruptions and price increases.
- At the end of June, these countries had cumulatively installed 618 GWdc of PV.

Sources: Australian Photovoltaic Institute. Clean Energy Associates PV Supplier Market Intelligence Report Q2 2022; IEEFA (07/21/22). Mercom (02/28/22, 10/03/22). PV Magazine (08/08/22, 07/22/22); Wood Mackenzie/SEIA: U.S. Solar Market Insight: Q3 2021; Reuters (07/21/22).

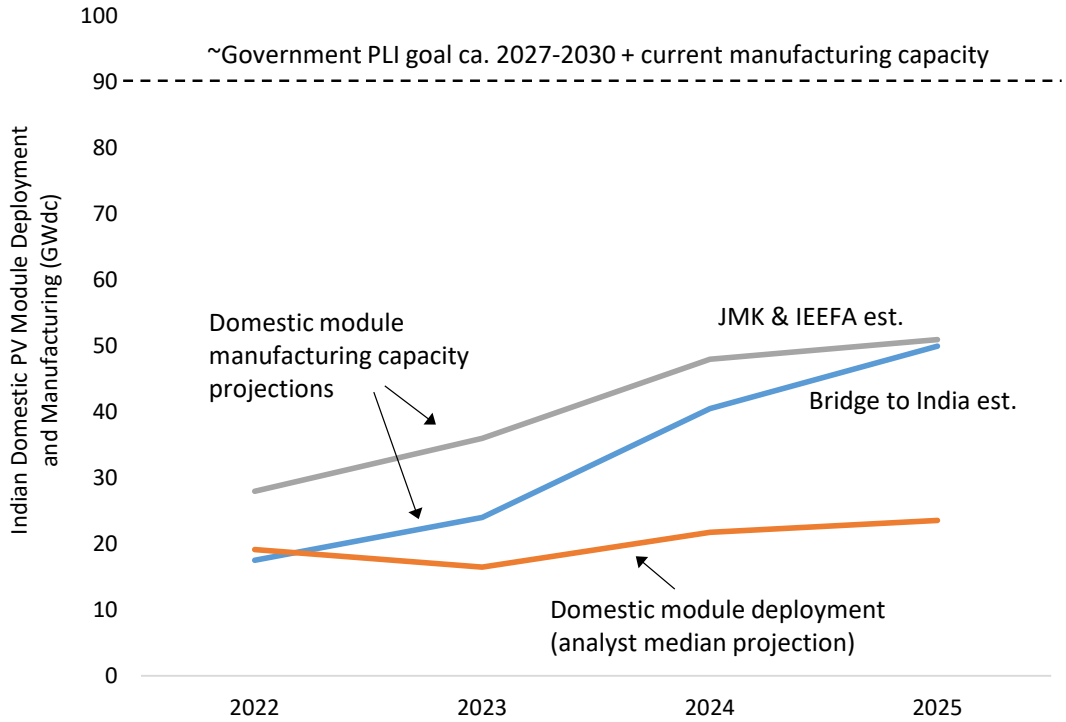
Annual Global PV Demand



Notes: P = projection. Colored bars represent median projections for country-level estimates. Error bars represent high and low global projections. Not all sources have data for all categories.
Sources: BNEF, 3Q 2022 Global PV Market Outlook, 8/26/22; BNEF, 2H 2022 US Clean Energy Market Outlook, 10/19/22; IEA, Snapshot of Global PV Markets: 2022, 4/22; IEA, Renewable Energy Market Update: Outlook for 2022 and 2023, 5/22; SolarPower Europe, Global Market Outlook For Solar Power: 2022-2026, 5/22; Wood Mackenzie and SEIA, Q3 2022 US Solar Market Insight, 9/22.

- About 220 GWdc of PV are projected to be installed globally in 2022.
- Analysts project continued increases in annual global PV installations. Median projections are:
  - 246 GWdc in 2023 (12% y/y growth)
  - 312 GWdc in 2024 (27%)
  - 337 GWdc in 2025 (8%)
  - 356 GWdc in 2026 (6%)
- All analysts who provided global projections increased them since the previous edition of their projections was released (e.g., SolarPower Europe increased its 2025 projection by 48 GW [18%] between 2021 and 2022).
- China, the European Union, the United States, and India are projected to account for about two-thirds of global PV installations over the period shown.

India's Potential as PV Exporter



- India's policies to promote domestic PV manufacturing could produce significant surpluses over several years.
  - Protectionist policies—including a 40% basic customs duty on modules and the Approved List of Models and Manufacturers—are promoting domestic manufacturing.
  - If India's production-linked incentive (PLI) for PV manufacturing is successful, module manufacturing might outpace demand.
  - The PLI is also incentivizing manufacturing of polysilicon, wafers, and cells.
- Although the United States imports a small share of PV components from India today, India could represent a larger potential source in future.
  - The United States is the largest destination for Indian exports of all goods and services.
  - The United States has recently been the largest destination for Indian module exports.

Sources: BNEF, 3Q 2022 Global PV Market Outlook (8/26/22); Business Standard (10/17/22); IEA, Renewable Energy Market Update: Outlook for 2022 and 2023 (5/22); JMK Research and Institute for Energy Economics & Financial Analysis (2/22); PV Magazine Australia (10/1/22); PV Magazine India (3/7/22); SolarPower Europe, Global Market Outlook For Solar Power: 2022-2026 (5/22); TaiyangNews (9/22/22); U.S. International Trade Administration (9/7/22).

CSP Update

- China currently has 30 CSP projects (approximately 3 GW) with thermal energy storage under development and to be built by 2024.
  - The projects are part of gigawatt-scale wind, PV, and CSP energy complexes in each Chinese province.
  - Other international CSP projects continue to move forward including the Noor Energy 1 project in UAE, the Redstone project in South Africa, and the Minos project in Greece. Additionally, Spain is in the final stage of awarding 200 MW of CSP bids, and Namibia (50 MW) and Botswana (200 MW) have also started bidding for CSP projects recently.
- DLR Institute found that despite Germany's relatively low DNI, CSP may be the most economical way for it to decarbonize industrial heat. Germany has historically been dependent on Russian gas.
  - The study found that CSP was more economical than green hydrogen and more abundant than geothermal and biomass.
  - Germany's government has offered a 55% subsidy to rapidly transition to renewable industrial heat.

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- **In August 2022, the Inflation Reduction Act (IRA) was enacted, boosting and lengthening federal incentives for domestic solar manufacturing and deployment.**
  - **Analysts estimate that IRA will be a large contributor to annual installations, more than doubling between 2022 and 2025.**
- **California's revised net metering (NEM 3.0) proposal might not be released until after the November elections.**
- **The United States installed 7.9 GWac of PV in H1 2022; half of that was in Texas, Florida, and California.**
- **29% of U.S. utility-scale PV and ~19% of all U.S. PV systems built in 2021 used CdTe panels.**
- **The United States installed ~5.9 GWh (2.3 GWac) of energy storage onto the electric grid in H1 2022.**

What is in the Inflation Reduction Act (IRA) for solar?

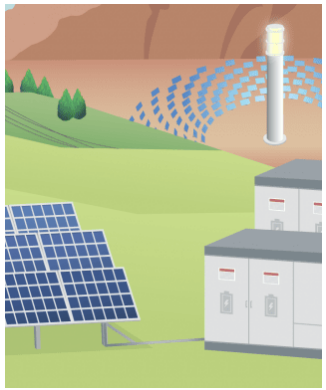
The bulk of the funding for clean energy in IRA comes in the form of tax credits.

New items are underlined.

Deployment-Related Tax Credits

The **residential clean energy credit (25D)** can be taken on the costs of a residential solar PV system installed during the tax year.

- This includes PV panels, balance-of-system equipment (such as racking or inverters), installation costs (including permitting fees and inspection costs), sales tax on eligible expenses, and (standalone) energy storage (≥ 3 kWh).



The **investment tax credit (ITC, 48/48E)** can be taken on the cost of a commercial/utility-scale solar system installed during the tax year.

- This includes PV panels or CSP equipment, balance-of-system equipment, sales and use taxes, installation costs, circuit breakers, step-up transformers, (standalone) energy storage (≥ 5 kWh), surge arrestors, and interconnection costs for projects ≤ 5 MW_{ac}.

OR

The **production tax credit (PTC, 45(d)/45Y)** can be taken on the electricity generated by a commercial/utility-scale solar system for the first 10 years of operation.

What is in the IRA for solar?

The bulk of the funding for clean energy in IRA comes in the form of tax credits.

New items are underlined.

Manufacturing-related Tax Credits

The **advanced energy project credit (48C)** can be taken on the cost of building, expanding, or re-equipping a manufacturing or recycling plant for solar equipment during the tax year. It may also be taken on the cost of re-equipping an industrial or manufacturing facility with equipment to reduce greenhouse gas emissions by at least 20% (e.g., the installation of CSP system for industrial process heat).

OR

The **advanced manufacturing production credit (MPTC, 45X)** can be taken per unit of clean energy component (for select components) produced in the United States and sold in a given year.

There is also $500 million for the Defense Production Act, some of which could be used for solar manufacturing (e.g., industries farther afield in the supply chain such as MGS or solar glass).

What is in the IRA for solar?

	Applicable Facilities	Credit Value
MPTC	All	Varies by component
48C	Facility construction meets labor rules	30%
	Facility construction *does not* meet labor rules	6%
PTC*	Facilities < 1 MW_{ac} and/or meet labor rules	2.6 ¢/kWh†
	Facilities ≥ 1 MW_{ac} that *do not* meet labor rules	0.3¢/kWh†
ITC*	Facilities < 1 MW_{ac} and/or meet labor rules	30%
	Facilities ≥ 1 MW_{ac} that *do not* meet labor rules	6%
25D	All	30%

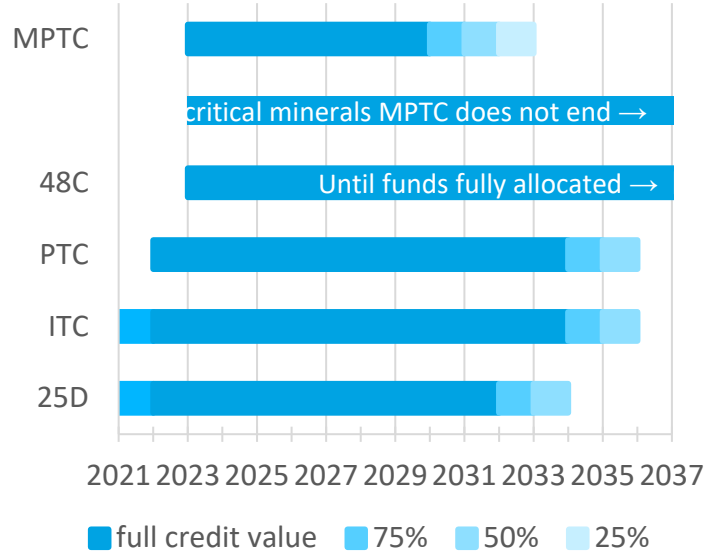
Domestic content bonus for ITC (+10 percentage points) or PTC (+10%)

Energy community bonus for ITC (+10 percentage points) or PTC (+10%)

+10%–20% low-income bonus for ITC *only*

† Adjusted for inflation
*Could be extended based on GHG levels

Length of IRA Tax Credits



What is in the IRA for solar?

Funding is also made available in IRA that could impact solar deployment.

Grants

- $3 billion for *environmental and climate justice block grants* through the EPA
- $760 million in grants to study *high-voltage interstate transmission* through DOE
- $145 million for *tribal electrification* through the Bureau of Indian Affairs
- $1.7 billion for the *Rural Energy for America Program (REAP)* through the USDA

  +$304 million in grants or loans for underutilized technologies and technical assistance for REAP applicants

Loans

- $40 billion for the DOE Loan Program Office

  + $250 billion to repurpose, retool, repower, or replace defunct energy infrastructure as well as remediate or reduce emissions of operating infrastructure
- $1 billion in electric loans for *rural renewable energy* under the Rural Electrification Act through USDA
- $9.7 billion for *rural electric co-ops* for the purchase of renewable energy or renewable energy systems through the USDA
- $4 billion in loans for *affordable housing energy efficiency* (which could include solar) through HUD
- $2 billion in loans for electric transmission facilities through DOE
- $18 billion (increased from $2 billion to $20 billion allowed outstanding total) for the Tribal Energy Loan Guarantee Program through DOE

The IRA also requires that for 10 years, in order to place solar on federal lands, certain oil and gas leasing requirements must be met.

Treasury Request for Comment on IRA

The Treasury Department—not DOE—will release the requisite guidelines and clarifications on the IRA to answer questions related to the IRA.

The Internal Revenue Service issued six notices on October 5 asking for comments on different aspects of extensions and enhancements of energy tax benefits in the Inflation Reduction Act:

- Notice 2022-46 requests comments on credits for clean vehicles.
- Notice 2022-47 requests comments on energy security tax credits for manufacturing (i.e., the MPTC, 48C).
- Notice 2022-48 requests comments on incentive provisions for improving the energy efficiency of residential and commercial buildings.
- Notice 2022-49 requests comments on certain energy generation incentives (i.e., the ITC/PTC and low-income bonus).
- Notice 2022-50 requests comments on *elective payment* of applicable credits and *transfer of certain credits*.
- Notice 2022-51 requests comments on *prevailing wage*, *apprenticeship*, domestic content, and *energy communities'* requirements.

The IRS requested that those interested in providing feedback to the questions in the notices follow the instructions in the notices to reply by November 4, 2022. Comments were to be submitted *electronically* or in writing and should reference the notice number (e.g., IRS-2022-47).

Recent Solar News

- On September 16, the U.S. Department of Commerce published its final rule on the President's Declaration of Emergency in June 2022. The final rule will go into effect November 15. It waives the AD/CVD deposits on cells and modules so long as they entered or were withdrawn from a warehouse for consumption either before June 6, 2024, or before the date the emergency was terminated.
  - Commerce also included a requirement that the cells and modules that benefit from the AD/CVD waiver must be utilized (i.e., used or installed) in the United States within 180 days following the date of termination of the emergency in order to prevent stockpiling.
- In September, the Federal Emergency Management Agency (FEMA) proposed changing the classifications for ground-mounted solar installations from Type 1 to Type 4. Type 4 buildings are considered essential in that their continuous use is needed, particularly in response to disasters (e.g., hospitals, air traffic control centers, and fire stations).
  - This change would significantly increase the requirements for snow, wind, and seismic tolerance for solar facilities.
  - SEIA, which has obtained more than 300 signatures from clean energy companies, has strongly opposed these changes and has encouraged the International Code Council's voting members to reject the proposal and approve a set of compromise solutions, which include a carveout for solar facilities to be designated Type 2.
  - Though anecdotal evidence from recent events in Florida and Ukraine suggests solar facilities are relatively robust to various disasters, analysis by renewable energy project underwriter GCube Insurance cites frequent incidence of solar losses across a range of extreme weather events to suggest PV technologies "are behind the curve" when it comes to improving weather resistance.

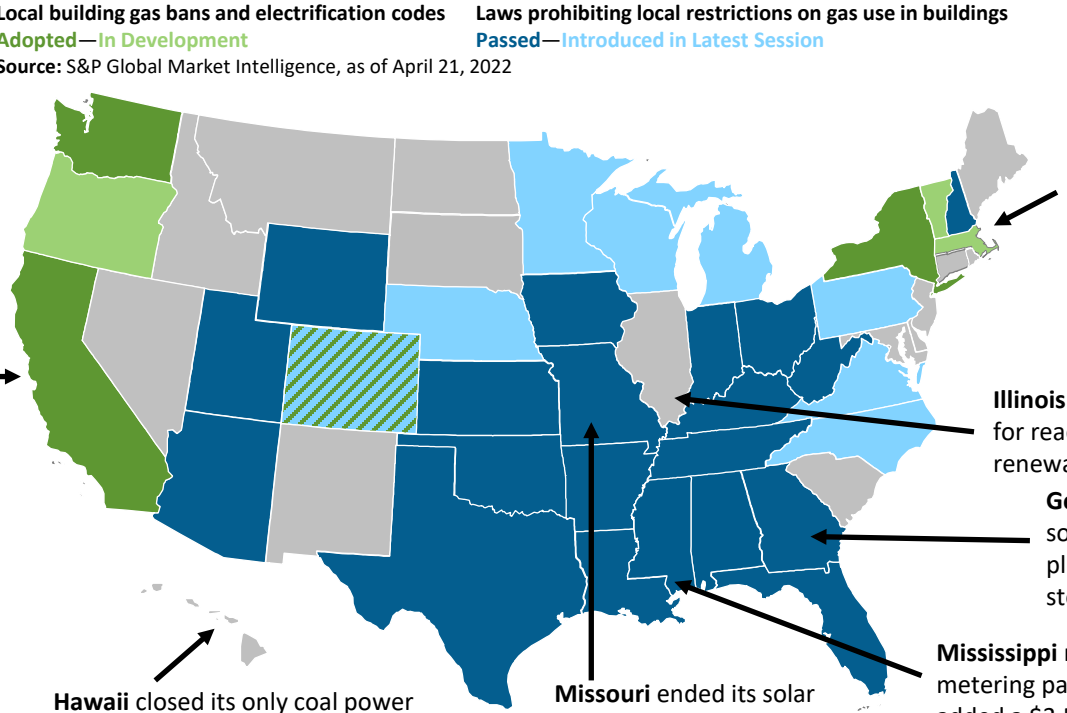
Sources: Federal Register, Morgan Lewis, FEMA Proposal Factsheet Oct. 2022 (seia.org), SEIA press release, Froehling & Robertson, pv tech on GCube Insurance.

Q3 2022 State Updates

Solar leaders California and Massachusetts enacted major policies promoting PV deployment and decarbonization, while relative latecomers Illinois, Georgia, and Mississippi took more modest steps in the same direction.

California enacted several solar-relevant policies: (1) targeting carbon neutrality by 2045 and 90% clean energy by 2035, (2) creating a community renewable energy program aimed at increasing PV access among renters and low-incomes residents, (3) eliminating ratepayer subsidies for the extension of new gas lines, (4) extending the exclusion of new solar systems from property taxes through 2026, (5) requiring instant online permitting for residential PV and PV-plus-storage systems via programs such as NREL's SolarAPP+, and (6) establishing a streamlined certification process for large solar, wind, and storage plants.

California's revised net metering (NEM 3.0) proposal might not be released until after the November elections.



Massachusetts enacted a major climate bill with provisions to increase deployment of solar and offshore wind, EVs, energy storage, and grid improvements and to demonstrate the prohibition of fossil fuel connections in new buildings. Additional solar-specific provisions aim to promote pollinator-friendly PV and agrivoltaics.

Illinois approved a plan for reaching 40% renewables by 2030.

Georgia approved a statewide solar expansion of 200 MW plus increased solar energy storage.

Mississippi raised its net-metering participation cap and added a $3,500 solar rebate for homes and businesses.

Hawaii closed its only coal power plant as part of the state's transition to wind, solar, and battery power.

Missouri ended its solar energy property tax exemption.

Source: California Governor's Office (9/16/22); Canary Media (9/1/22); Commonwealth of Massachusetts (Bill H.5060); NASEO (8/19/22); PV Magazine (8/24/22, 9/27/22); PV Tech (8/12/22); Sacramento Business Journal (9/21/22); Solar Power World (8/1/22, 9/16/22, 10/4/22); Utility Dive (7/1/22, 8/12/22, 9/16/22); S&P Global Market Intelligence (6/9/22).

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

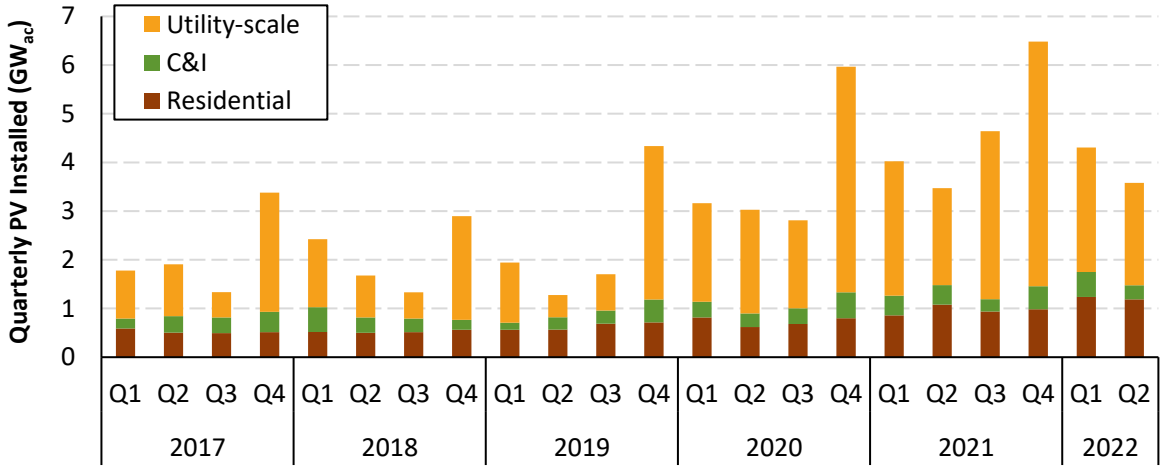
According to EIA data, the United States installed 7.9 GW_{ac} of PV in H1 2022—its largest H1 ever—up 5% y/y.

- Residential (2.4 GW_{ac}) remained up significantly in H1 2022: 25% y/y.
- However, utility-scale PV was down 2% y/y (only 4.7 GW_{ac} were installed) while C&I (0.8 GW_{ac}) held steady in H1 2022 (0% y/y).

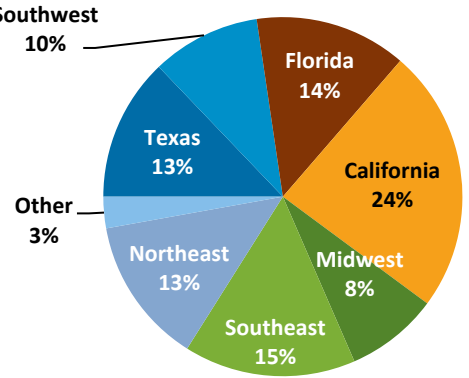
Half of U.S. PV capacity installed in H1 2022 was in Texas, Florida, and California.

- After a slow start in Q1 2022, Texas installed 800 MW_{ac} in Q2 alone, totaling over 1 GW_{ac} in H1 2022.

U.S. PV Installations by Market Segment



H1 2022 U.S. PV Installations by Region (7.9 GW_{ac})



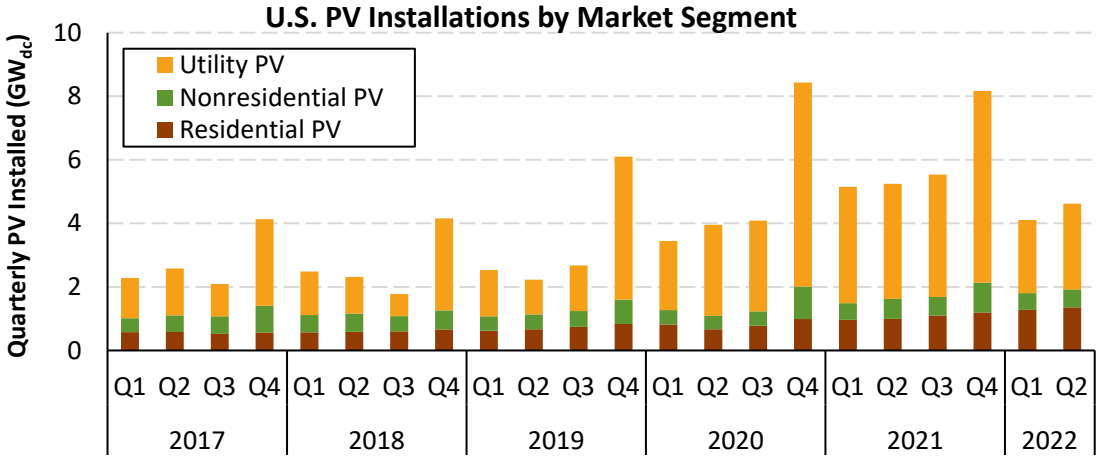
Note: EIA reports values in W_{ac} which is standard for utilities. The solar industry has traditionally reported in W_{dc}. See the next slide for values reported in W_{dc}.
Sources: EIA, "Electric Power Monthly," forms EIA-023, EIA-826, and EIA-861 (July 2022, February 2021, February 2019).

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

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

Wood Mackenzie/SEIA reports that the United States installed 8.7 GW_{dc} of PV in H1 2022—a decrease of 16% y/y.

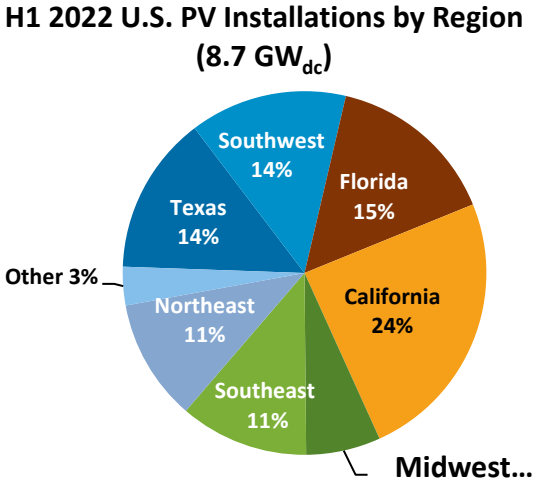
- The utility-scale market accounts for most of this loss, with only 5.0 GW_{dc} (-31% y/y) installed in H1 2022.
- Nonresidential PV held fairly steady at 1.1 GW_{dc} (-5% y/y), and residential PV continued the gains it saw in Q1, with 2.6 GW_{dc} (+35% y/y) installed in H1 2022, setting a quarterly record for the fifth consecutive quarter.



California and Florida continue to lead installations, accounting for 40% of H1 2022 installations on their own.

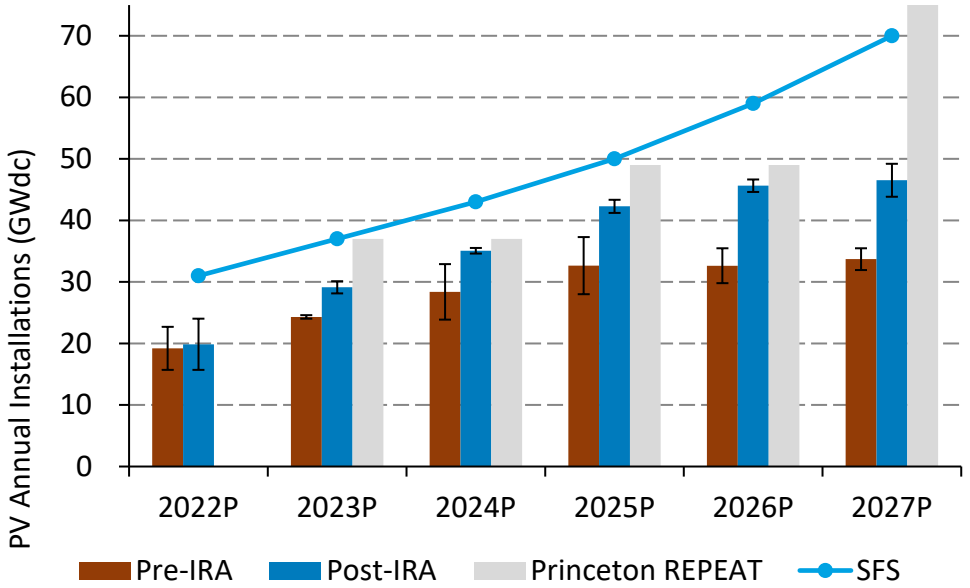
- After a slow start in Q1 2022, Texas has had a robust Q2 2022, installing 1.1 GW_{dc} in Q2 alone.

In the community solar market, Maine and New York accounted for 72% of the installations in H1 2022.



Sources: Wood Mackenzie/SEIA: U.S. Solar Market Insight: Q3 2022.

Projected Annual U.S. PV Deployment



Notes: P = projection. Colored bars represent average projections, and error bars represent high and low projections, line is the decarbonization with electrification scenario from the Solar Futures Study.
Sources: BNEF, 2Q 2022 Global PV Market Outlook, 5/27/22; BNEF, 3Q 2022 Global PV Market Outlook, 8/26/22; Wood Mackenzie and SEIA, Q2 2022 US Solar Market Insight, 6/22; Wood Mackenzie and SEIA, Q3 2022 US Solar Market Insight, 9/22. Princeton REPEAT, Preliminary Report: The Climate and Energy Impacts of the Inflation Reduction Act of 2022, 8/22. U.S. Department of Energy, Solar Futures Study, 9/21.

Based on projections provided both before and after passage of the IRA, about 20 GW_{dc} of PV are expected to be installed in the United States in 2022.

Before IRA, according to projections by BNEF and Wood Mackenzie/SEIA, annual PV installations were expected to increase to 33 GW_{dc} in 2025 (~19% annual growth over three years) and then level off, reaching only 34 GW in 2027.

After IRA, projections from those two sources increased by ~30% per year, reaching 47 GW_{dc} in 2027. The Princeton REPEAT projections are even more optimistic.

While these projections are still below the installations necessary to meet the decarbonization with electrification model from the Solar Futures Study, it still represents a massive shift in future solar deployment.

The difference between these pre- and post-IRA projections is also affected by the executive order issued in June 2022 that preemptively delayed implementation of potential tariffs on modules from Southeast Asia, in relation to the ongoing investigation.

U.S. Energy Storage Installations by Market Segment

The United States installed approximately 5.9 GWh (2.3 GW_{ac}) of energy storage onto the electric grid in H1 2022, +183% (+153%) y/y, as a result of record levels of residential deployment and high grid-scale deployment.

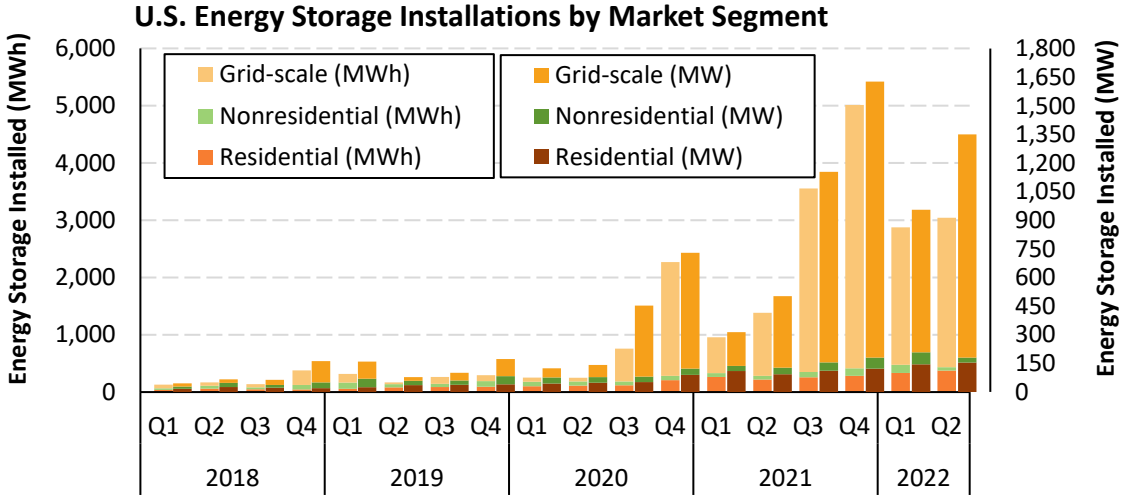
- Grid-scale and residential storage installations were up 137% (212%) and 71% (66%) in Q2 2022 y/y respectively.
- Nonresidential storage had a lackluster Q2 2022, installing only 26.3 MW_{ac}.

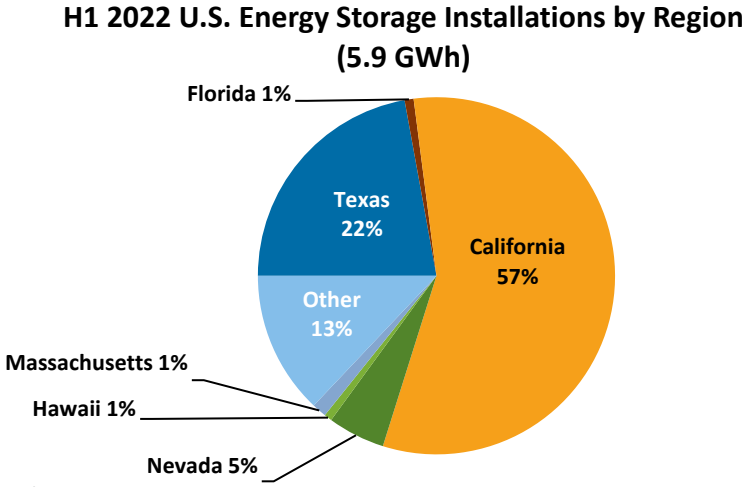
Over 1.1 GW of grid-scale projects originally scheduled to come online in Q2 were delayed or canceled but 61% are still expected before the end of the year.

- Supply chain issues, transportation delays, and interconnection queue challenges were the main reasons.

The standalone storage ITC is also expected to boost storage retrofits on homes with existing solar.

California took the lead in all three categories in Q2 2022. However, Texas also had a remarkable quarter, contributing 60% of installed grid-scale capacity in Q2 2022.



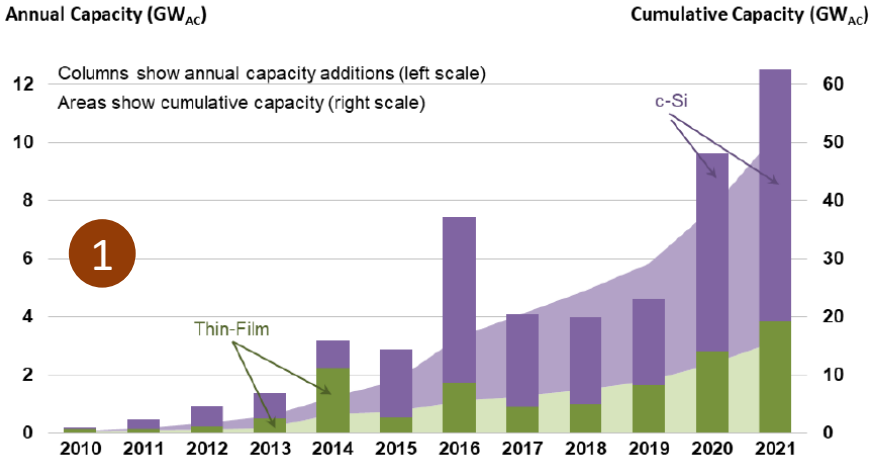


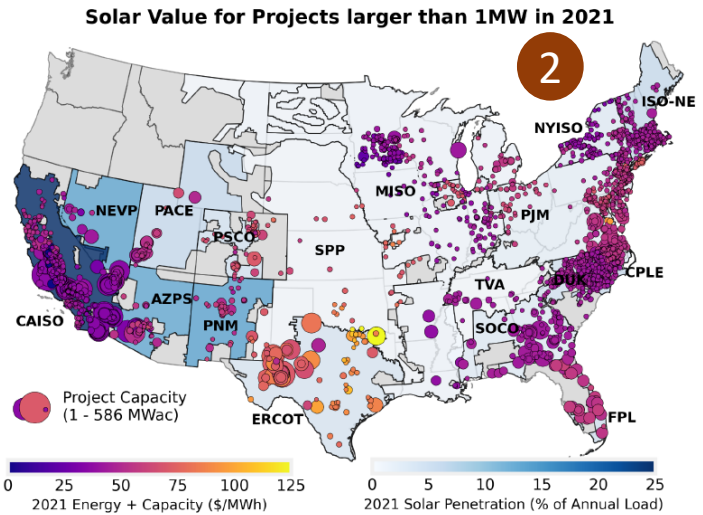
Note: "Front-of-the-meter" refers to all projects deployed on the utility side of the meter, regardless of size or ownership.

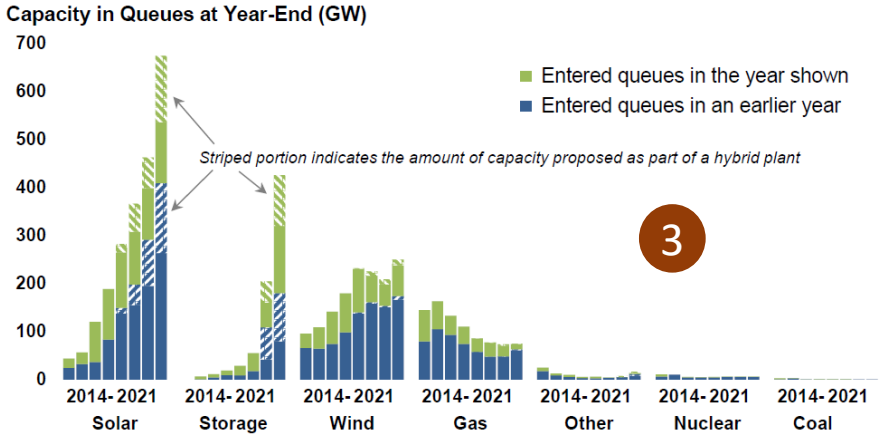
Source: Wood Mackenzie Power & Renewables and Energy Storage Association, U.S. Energy Storage Monitor: Q2 2022.

Five New Things to Know from Utility-Scale Solar: *2022 Edition*

1. Thin film modules, which are exempt from Section 201 tariffs, have gained market share since 2018 and constituted almost a third of U.S. utility-scale modules in 2021.
2. Solar market value varied within and across markets, but nationally, it increased 50% above 2020 levels owing to rising energy prices in 2021.
3. Across areas representing ~85% of U.S. electricity demand, 674 GW of solar was in interconnection queues at the end of 2021; 42% was paired with battery storage.
4. Single-axis tracking systems constituted 90% of new utility-scale capacity in 2021; tracking added ~4 percentage points to capacity factor in the sunniest regions.
5. Operation and maintenance cost decreased by 58% between 2011 and 2021.



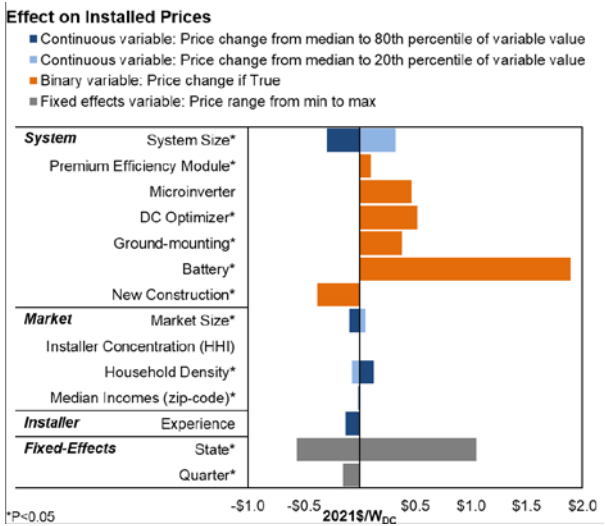




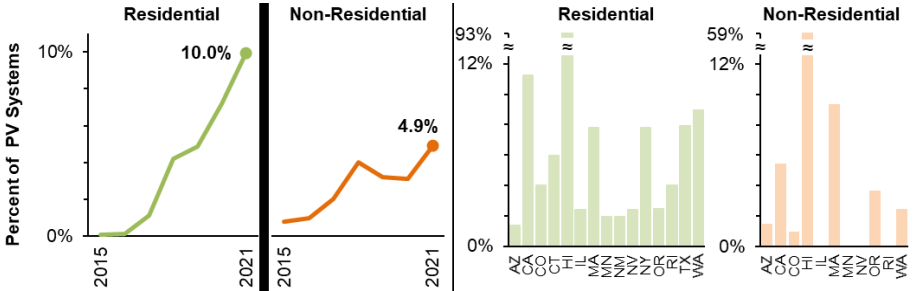
Source: Bolinger et al. 2022. *Utility-Scale Solar, 2022 Edition*. Lawrence Berkeley National Laboratory.

Five New Things to Know from *Tracking the Sun: 2022 Edition*

Sensitivity of Installed Prices to Modeled Drivers



Storage Attachment Rates by State (2021)



1. The median module efficiency of U.S. residential PV systems was 20.1%, up 0.3 percentage points y/y. Almost all module efficiencies ranged from 19% to 21%.

2. Third-party ownership has declined over time from its historical high of 59% of residential installations in 2012 to 28% in 2021. Market share varies a lot by state.

3. Residential attachment rates have steadily risen over time, reaching 10% of the sample in 2021. Virtually all systems had storage durations ranging from 1.5 to 3.0 hours.

4. Direct comparison of PV+storage and standalone PV can be misleading. LBNL performed a regression analysis that estimates a $1.9/Wdc storage premium for residential PV.

5. Based on LBNL sensitivity analysis, there is a wide range across the state fixed effects variables ($1.6/W), suggesting the presence of strong state-level pricing drivers beyond those explicitly captured in the model (e.g., cost of living, retail rates, incentives, solar insolation, and permitting processes). Conversely, effects associated with the various market and installer related drivers are all small (less than $0.2/W), but in general they are directionally intuitive.

Source: Barbose, G., N. Darghouth, E. O'Shaughnessy, and S. Forrester. 2022. *Tracking the Sun: Pricing and Design Trends for Distributed Photovoltaic Systems in the United States 2022 Edition*. Berkeley, CA: Lawrence Berkeley National Laboratory. September 2022.

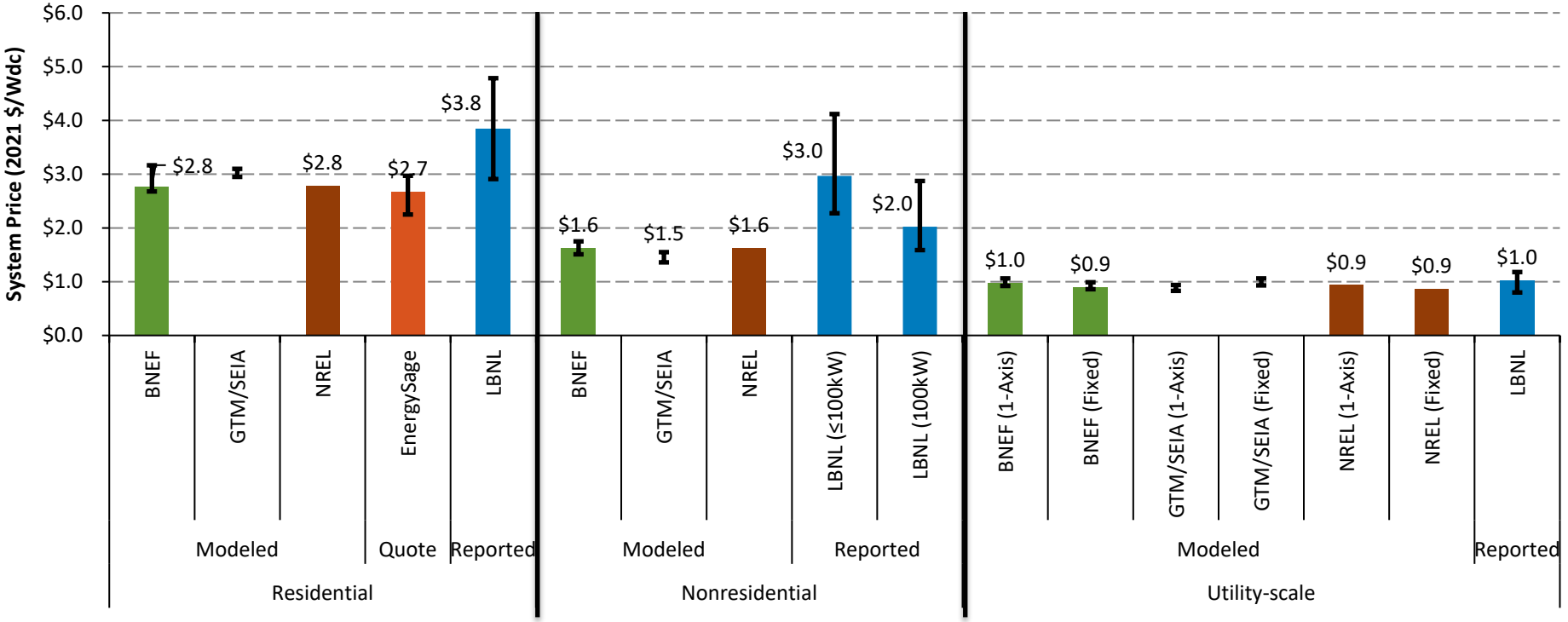
Agenda

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

- **Most data suggest PV system pricing across market segments continues its downward trajectory.**
- **U.S. PV system pricing, or costs, 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 2021, the ranges in average U.S. PV system pricing across methods were reported to be:**
  - **$2.8/W–$3.8/W for residential solar**
  - **$1.5/W–$3.0/W for nonresidential solar**
  - **$0.9/W–$1.0/W for utility-scale solar.**
- **In the first half of 2022, 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**
  - **$1.8/W–$3.6/W for nonresidential solar**
  - **$1.0/W for utility-scale solar.**

2021 Modeled, Reported, and Quoted System Price from Various Sources

- NREL and LBNL PV system pricing figures are consistent with other sources.
- Across various sources, reported system pricing is generally higher than modeled system pricing, and quotes are in the middle.

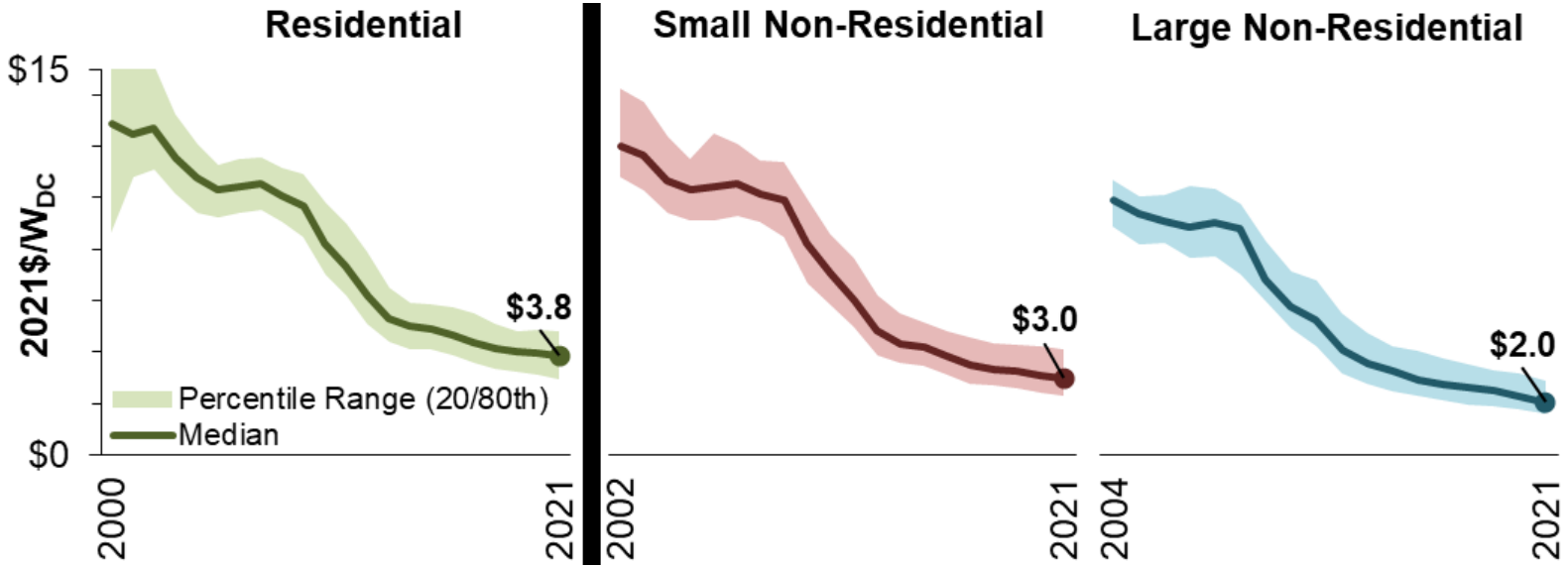


Note: Some sources only report a range, which is represented by the error bars.

Sources: Barbose et al. 2022; Bolinger et al. 2022; Ramasamy et al. 2022; BNEF, "H1 2022 U.S. PV Market Outlook," April 2022; **:** Wood Mackenzie/SEIA: U.S. Solar Market Insight: 2021 Year-in-Review, March 2022; EnergySage, Solar Market place Intel Report H1 2021 – H2 2022.

Tracking the Sun: National Price, 2000–2021

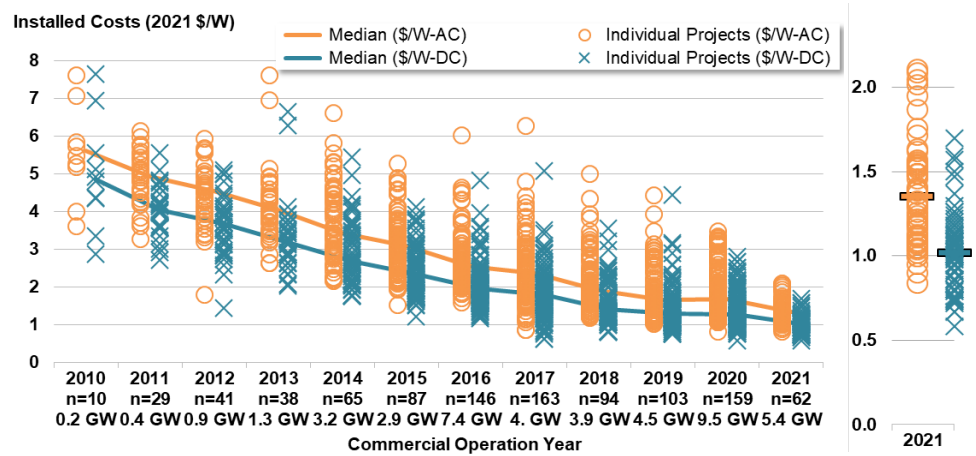
- Over the long term, median installed prices have fallen by roughly $0.4/W per year, on average, but price declines have tapered off since 2013, after which price declines averaged $0.1–$0.2/W across segments.
- That tapering off is mostly a function of the underlying module cost trajectory, but also reflects growing customer acquisition costs, loan fees, and other costs embedded outside the inverter and modules.



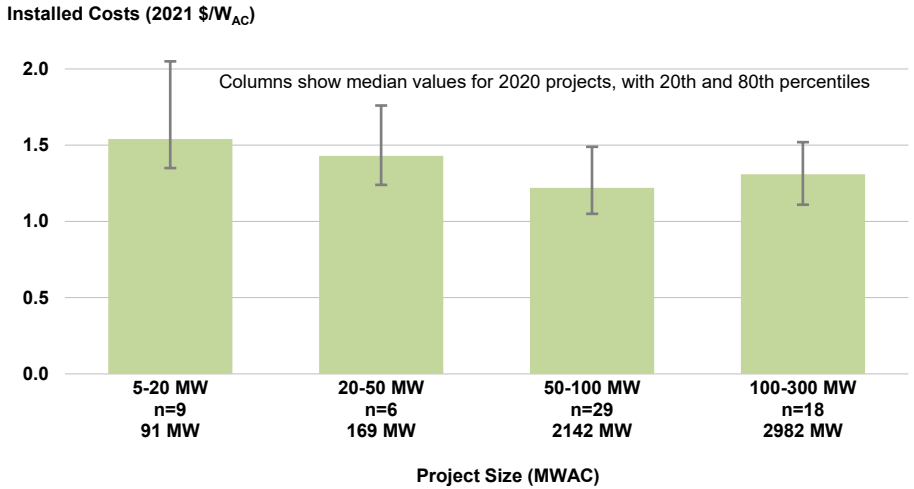
Source: Barbose, G., N. Darghouth, E. O'Shaughnessy, and S. Forrester. 2022. *Tracking the Sun: Pricing and Design Trends for Distributed Photovoltaic Systems in the United States 2022 Edition*. Berkeley, CA: Lawrence Berkeley National Laboratory. September 2022.

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

- The median installed price of PV has fallen by 76% since 2010 to $1.35/Wac ($1.02/Wdc) in 2021.
- The lowest 20th percentile of project prices fell below $1.1/Wac ($0.8/Wdc) in 2021.

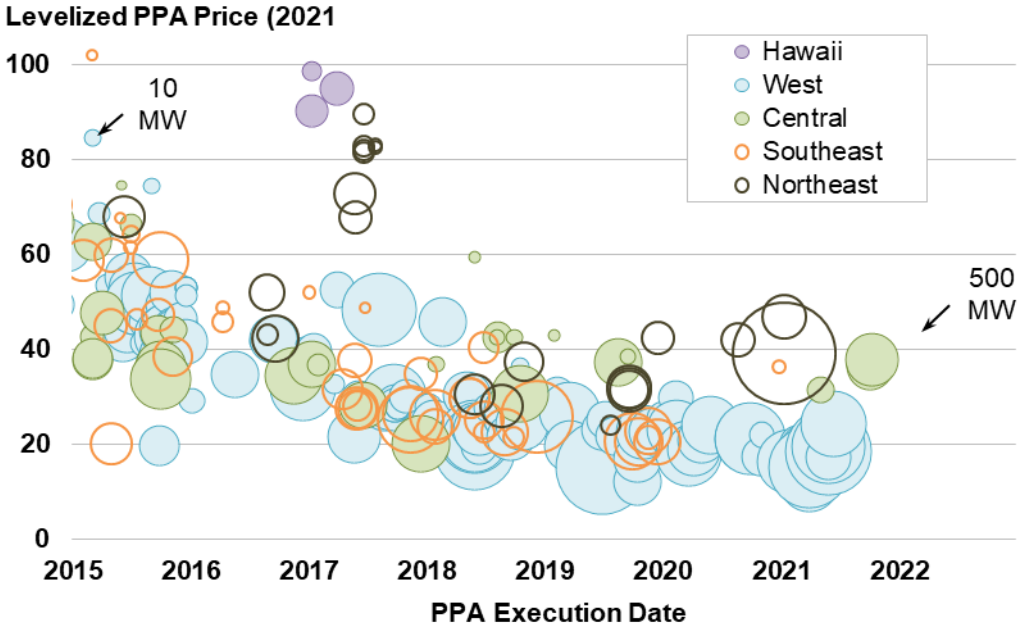


- Larger utility-scale solar projects (50–100 MW) cost 21% less than smaller projects (5–20 MW) per megawatt of installed capacity in 2021.
- This sample is backward-looking and may not reflect the price of projects built in 2022 and 2023.



Source: Bolinger, M., J. Seel, C. Warner and D. Robson. 2022. *Solar Empirical Trends in Project Technology, Cost, Performance, and PPA Pricing in the United States: 2022 Edition*. Berkeley, CA: Lawrence Berkeley National Laboratory.

U.S. Utility-Scale PV PPA Pricing



- Average PPA prices in the Lower 48 fell by ~87% (or ~19%/year) from 2009 to 2019, but they have been stagnant (or slightly higher) ever since.
- The most recent PPAs in the LBNL sample are priced around $20/MWh for projects in CAISO and the non-ISO West and at $30-$40/MWh for projects elsewhere in the continental United States.
- Solar PPA prices are now often competitive with wind PPA prices, as well as the cost of burning fuel in *existing* gas-fired generators.

Source: Bolinger, M., J. Seel, C. Warner and D. Robson. 2022. *Solar Empirical Trends in Project Technology, Cost, Performance, and PPA Pricing in the United States: 2022 Edition*. Berkeley, CA: Lawrence Berkeley National Laboratory

Q1 2022 NREL Bottom-Up Cost Modeling

- Coming over a decade after its first publication, NREL has released its annual cost breakdown of installed PV and battery storage systems, detailing installed costs for PV and storage systems as of the Q1 2022.
- Between Q1 2021 and the Q1 2022, prices soared throughout the U.S. economy and the PV and energy storage markets in particular.
  - The ongoing COVID-19 pandemic caused or complicated supply chain constraints, and industry-specific events and trade policies drove up PV and battery prices.
- Such volatility poses a challenge for capturing representative PV and storage costs, which are used to help track long-term technology and soft cost trends so R&D can be focused on the highest-impact activities.
- For this reason, the Q1 2022 report uses two types of benchmarks to help distinguish the impacts of short-term market distortions from the impacts of longer-term technology trends.

Source: Ramasamy et al. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2022.

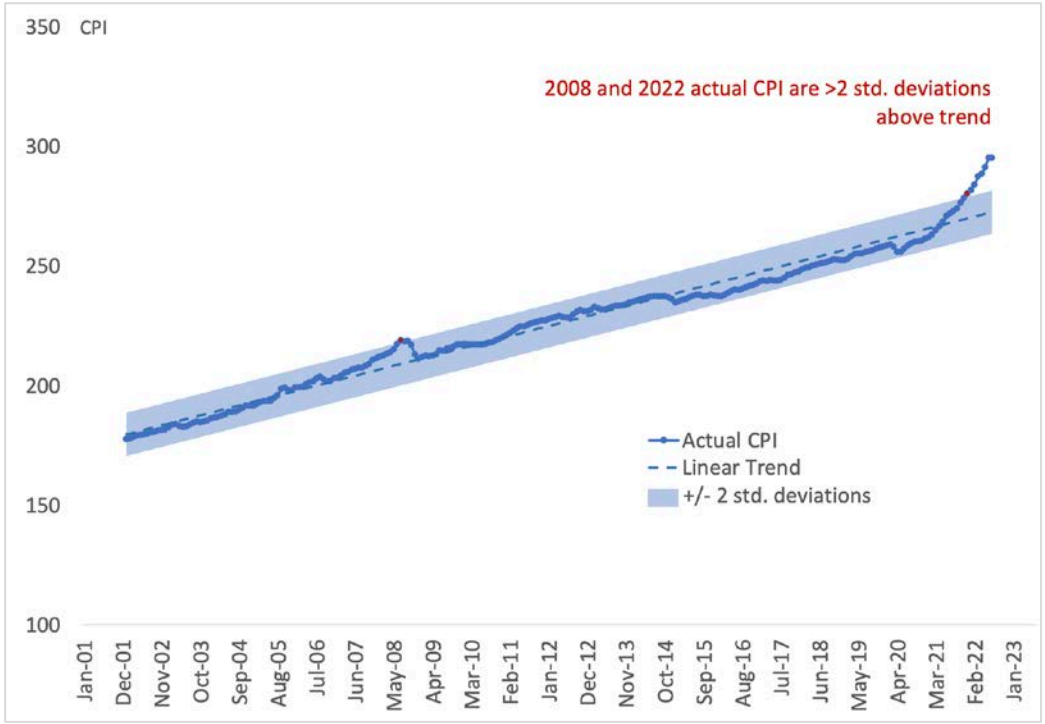
Q1 2022 NREL Bottom-Up Cost Modeling: Two Benchmark Metrics

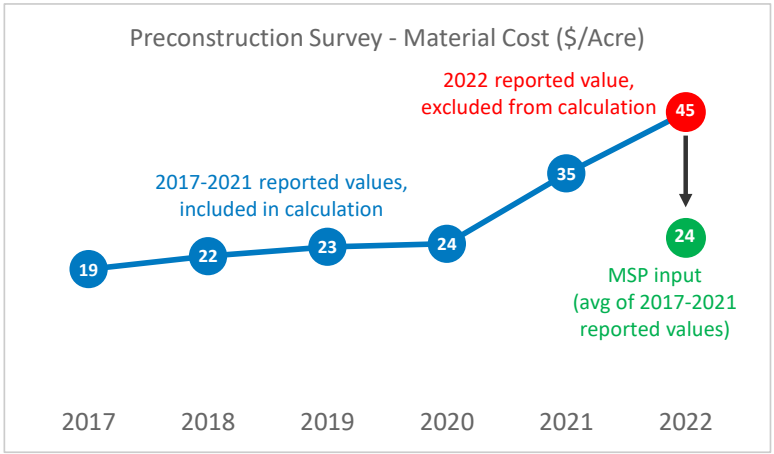
	Minimum Sustainable Price (MSP) Benchmark	Modeled Market Price (MMP) Benchmark
Description	Estimated cash costs of representative PV and storage components: modeled at the lowest prices at which product suppliers can remain financially solvent in the long term, based on input costs that represent the lowest prices each input supplier can charge to remain financially solvent in the long term	Estimated cash costs of representative PV and storage components under market conditions experienced during the analysis period
Approach	Distorted input costs removed from model calculations Most common technology configuration modeled	Based on reported market costs and prices of different subcost components for representative systems Same technology configuration as for MSP
Purpose	Long-term analysis and projections, informing R&D investment decisions	Near-term policy and market analysis based on disaggregated system costs

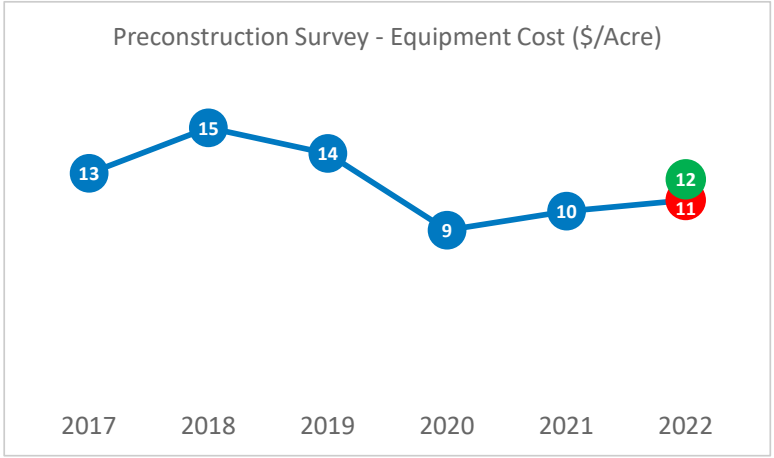
- Two general approaches are used to infer MSP for PV and storage system components:
  - Detailed bottom-up cost modeling (modules)
  - Mitigation of market- and policy-distorted input values (inverters, BOS, transmission).
- For all soft costs, the same values are used for MSP and MMP.
- These are initial efforts to characterize MSP, which will be refined in future benchmark reports.

Source: Ramasamy et al. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2022.

Q1 2022 NREL Bottom-Up Cost Modeling: Example MSP Methods







The Consumer Price Index (CPI) in Q1 2022 was more than two standard deviations above a linear fit to 20 years of CPI data (left), so 2022 data are excluded from MSP input calculations, and the remaining data are averaged to arrive at the MSP input value (right). Data are averaged because the available time series is inadequate to discern consistent time trends; this method could be modified to make MSP adjustments based on a linear fit once sufficient time-series data are available.

Source: Ramasamy et al. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2022.

Q1 2022 NREL Bottom-Up Cost Modeling: Example MSP/MMP Methods

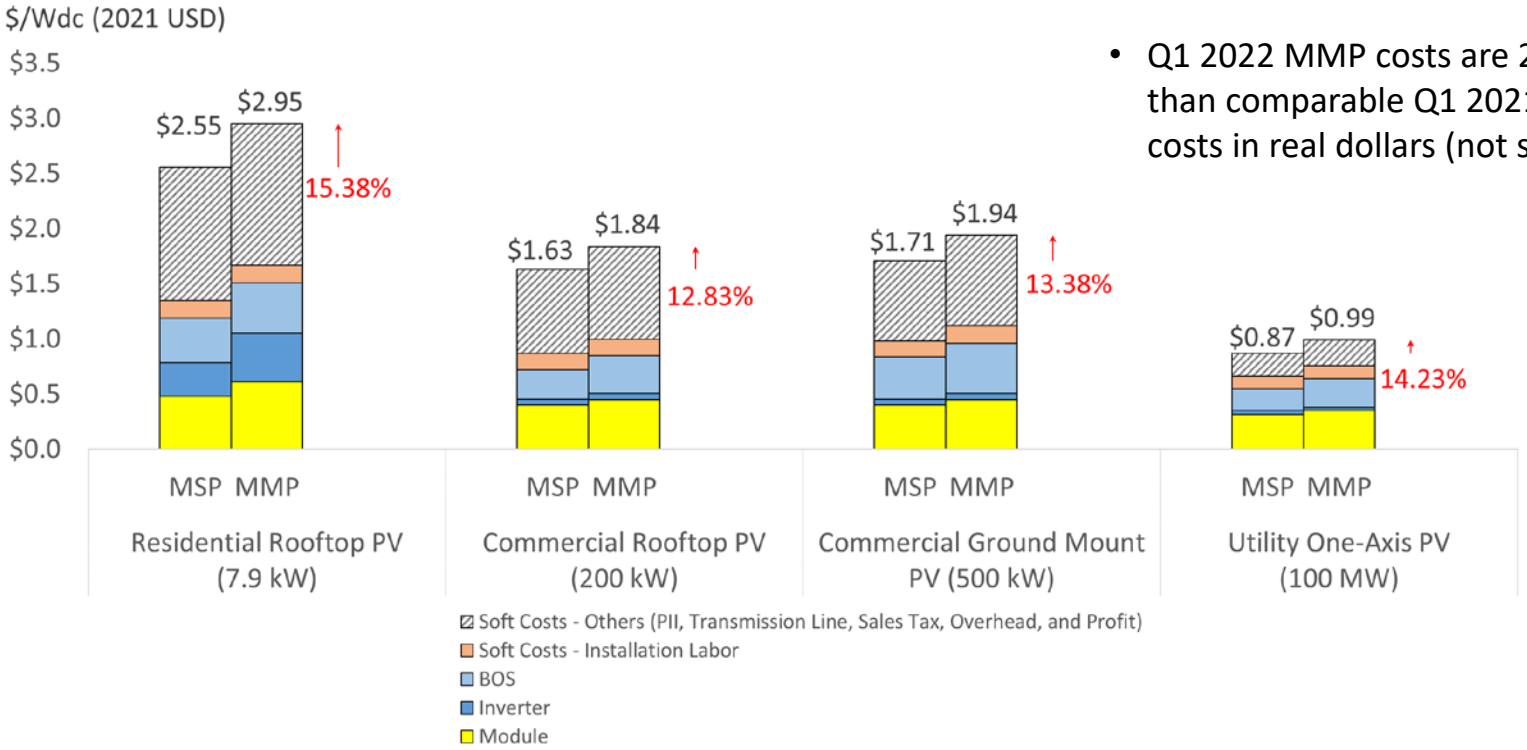
Category	MSP Value (2021 Real USD)	MMP Value (2021 Real USD)	Sources
Module price	**$0.48/$W_{dc}$** Value derived from bottom-up cost modeling Assumes modules from Southeast Asia, excludes U.S. tariffs in PV supply chain, includes supply chain premium for small installers[a]	**$0.54/$W_{dc}$** Ex-factory gate (first buyer) price, Tier 1 monocrystalline modules Assumes modules from Southeast Asia, influenced by U.S. tariffs in PV supply chain, includes supply chain premium for small installers[a]	MSP from NREL modeling, MMP from Woodmac and SEIA (2022)
Microinverter price	**$0.36/$W_{ac}$** (inverter loading ratio [ILR] = 1.21) Avg of 2017–2021 costs (distorted 2022 costs removed)/(1+25%) Excludes 25% Section 301 tariff Includes supply chain premium for small installers[a]	**$0.53/$W_{ac}$** (ILR = 1.21) Ex-factory gate (first buyer) price, Tier 1 inverters Includes supply chain premium for small installers[a]	Barbose et al. (2021a), Woodmac and SEIA (2022), USITR (2018)
Structural BOS (racking)	**$19.1/$m^2$** Includes flashing for roof penetrations and all rails and clamps Avg of 2019–2021 costs (distorted 2022 costs removed) Includes supply chain premium for small installers[a]	**$31.5/$m^2$** Includes flashing for roof penetrations and all rails and clamps 2022 online racking material cost Includes supply chain premium for small installers[a]	Online Material Cost: RENVU (2022), EcoDirect (2022), altE Store (2022)

- Shown is a sample of modeled cost parameters for residential PV.
- Methods for distinguishing MSP from MMP vary by cost category.
  - **Modules:** using bottom-up model with no tariffs (MSP) versus using analyst data influenced by tariffs (MMP)
  - **Inverters:** averaging 2017–2021 costs and removing Section 301 tariff (MSP) versus using 2022 analyst data influenced by tariff (MMP)
  - **Structural Balance of Systems:** averaging 2019–2021 costs (MSP) versus using 2022 costs.

Source: Ramasamy et al. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2022.

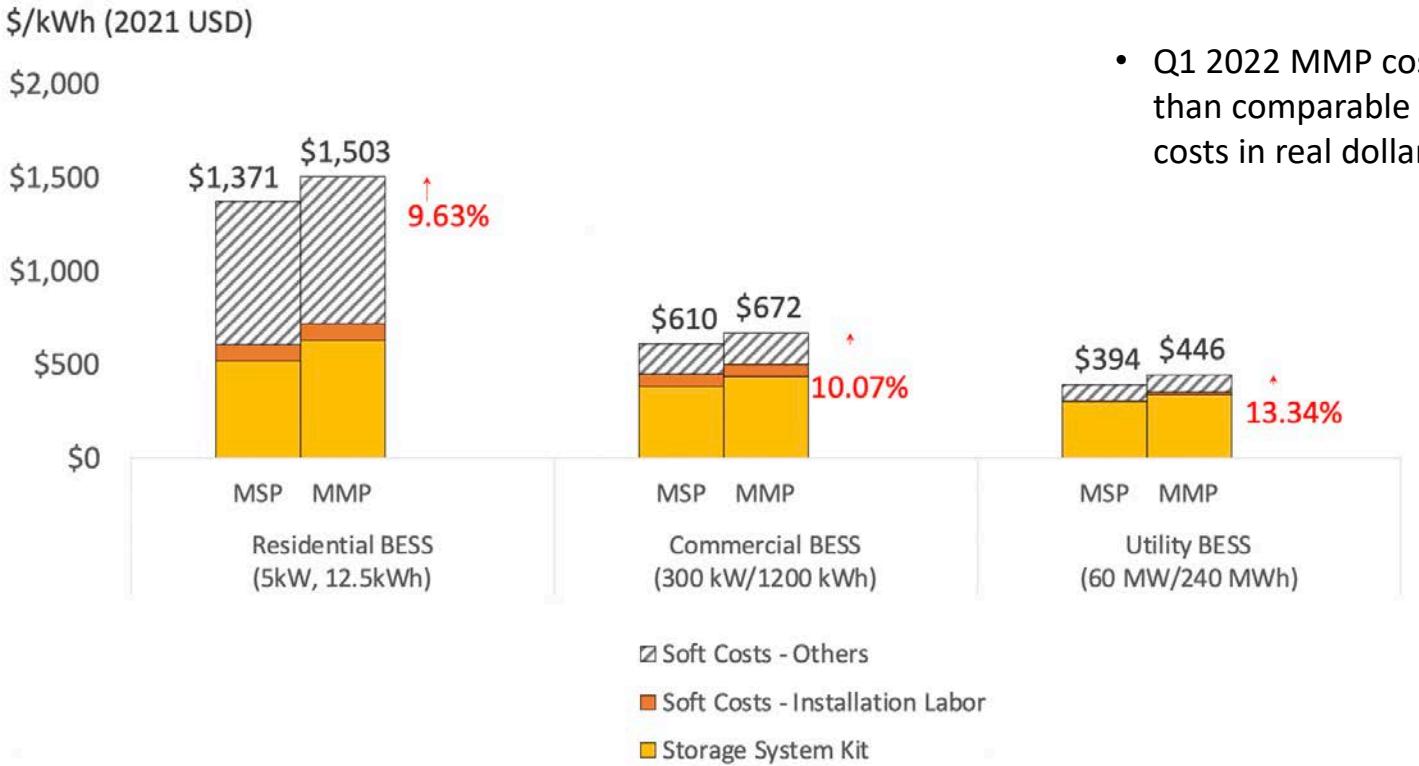
Q1 2022 NREL Bottom-Up Cost Modeling: Standalone PV Benchmarks

- For standalone PV, MMP costs are 13%–15% higher than MSP costs in Q1 2022.
- Q1 2022 MMP costs are 2%–8% higher than comparable Q1 2021 benchmark costs in real dollars (not shown).



Source: Ramasamy et al. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2022.

Q1 2022 NREL Bottom-Up Cost Modeling: Standalone Storage Benchmarks

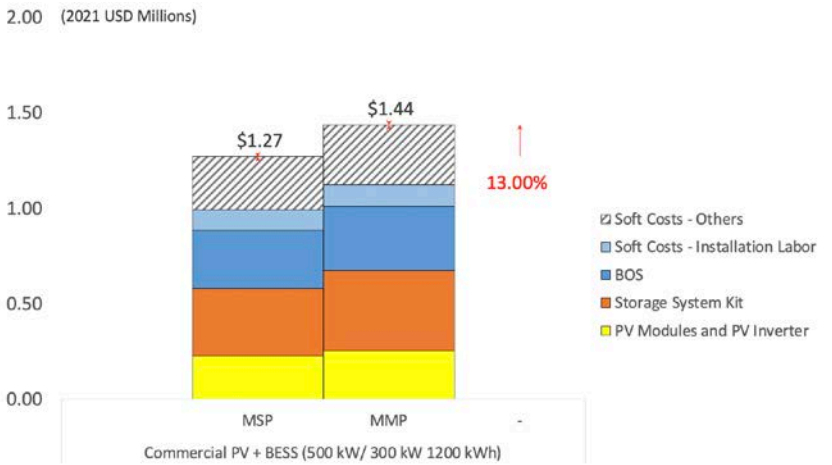


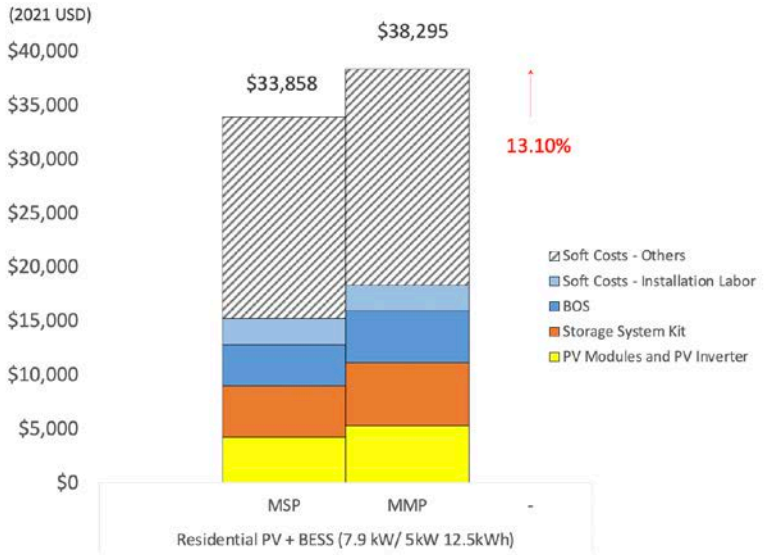
- For standalone storage, MMP costs are 10%–13% higher than MSP costs in Q1 2022.
- Q1 2022 MMP costs are 2%–12% higher than comparable Q1 2021 benchmark costs in real dollars (not shown).

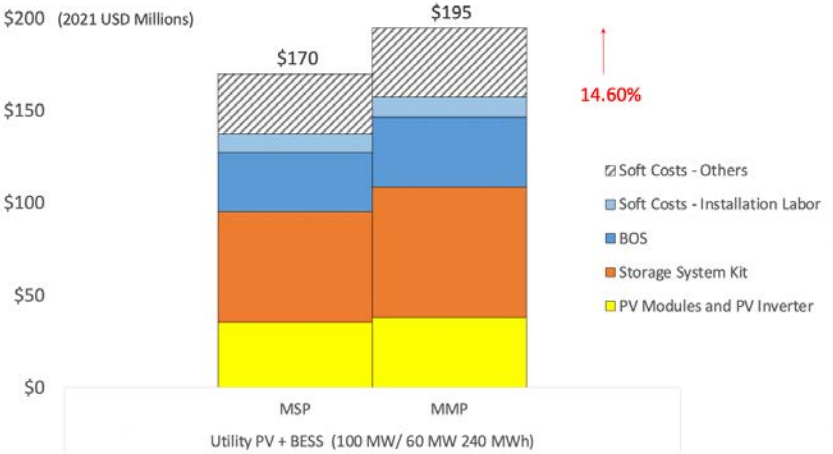
Source: Ramasamy et al. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2022.

Q1 2022 NREL Bottom-Up Cost Modeling: PV-Plus-Storage Benchmarks

- For PV + storage, MMP costs are 13%–15% higher than MSP costs in Q1 2022.
- Q1 2022 MMP costs are 6%–11% higher than comparable Q1 2021 benchmark costs in real dollars (not shown).

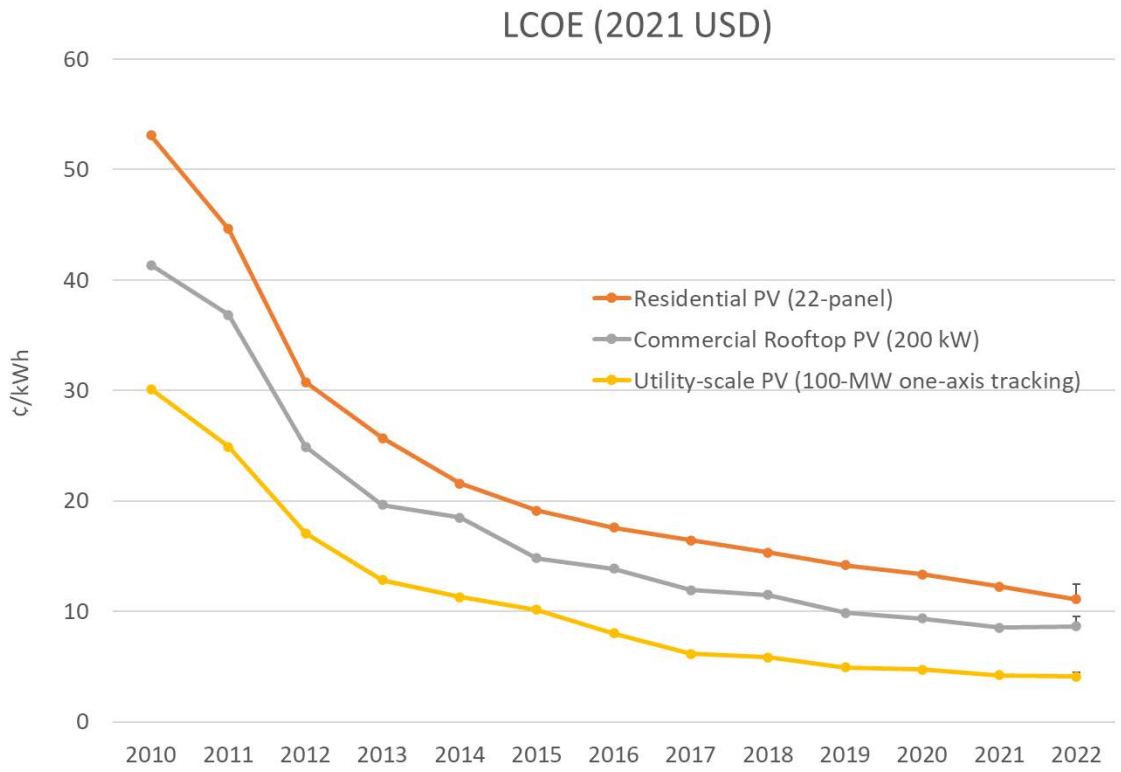






Source: Ramasamy et al. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2022.

Q1 2022 NREL Bottom-Up Cost Modeling: Standalone PV LCOE Over Time

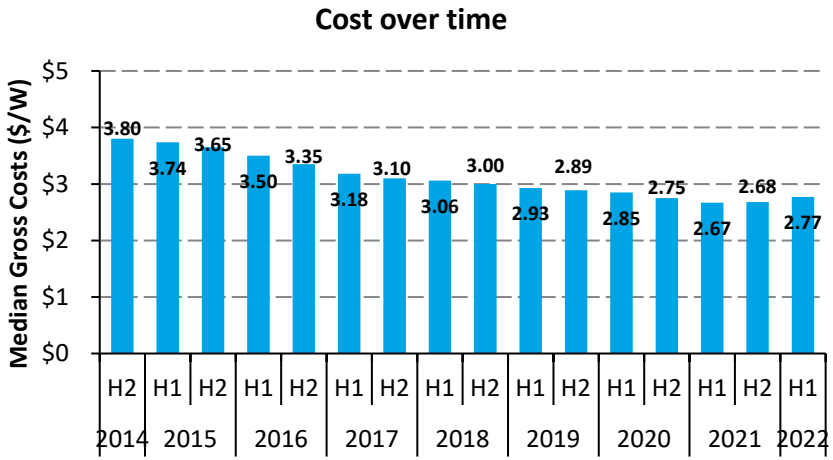


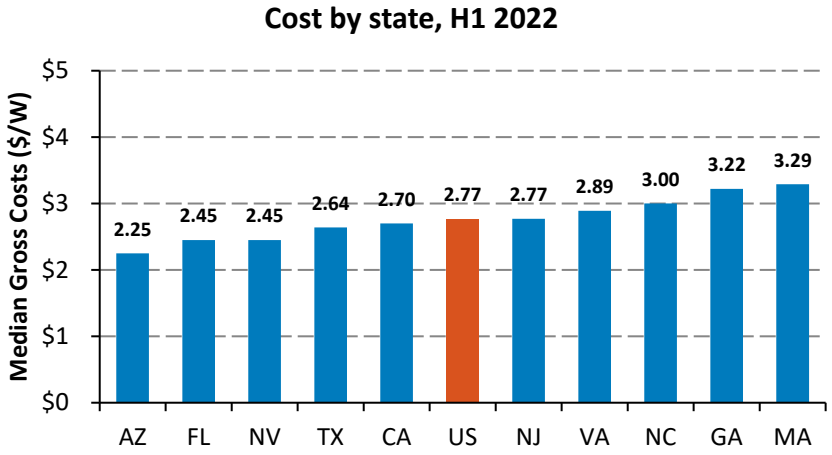
- In 2022, the dots represent LCOEs calculated using MSP, and the tops of the error bars represent LCOEs calculated using MMP.
- Methods vary for calculating the LCOE values before 2022, but those methods are most similar to the MMP method used in the Q1 2022 report.
- In previous years, there was less market distortion that would have affected the difference between MSP and MMP.
- Based on plotted values, LCOE fell 79%–86% between 2010 and 2022.

Source: Ramasamy et al. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2022.

Residential System Price Reported by EnergySage

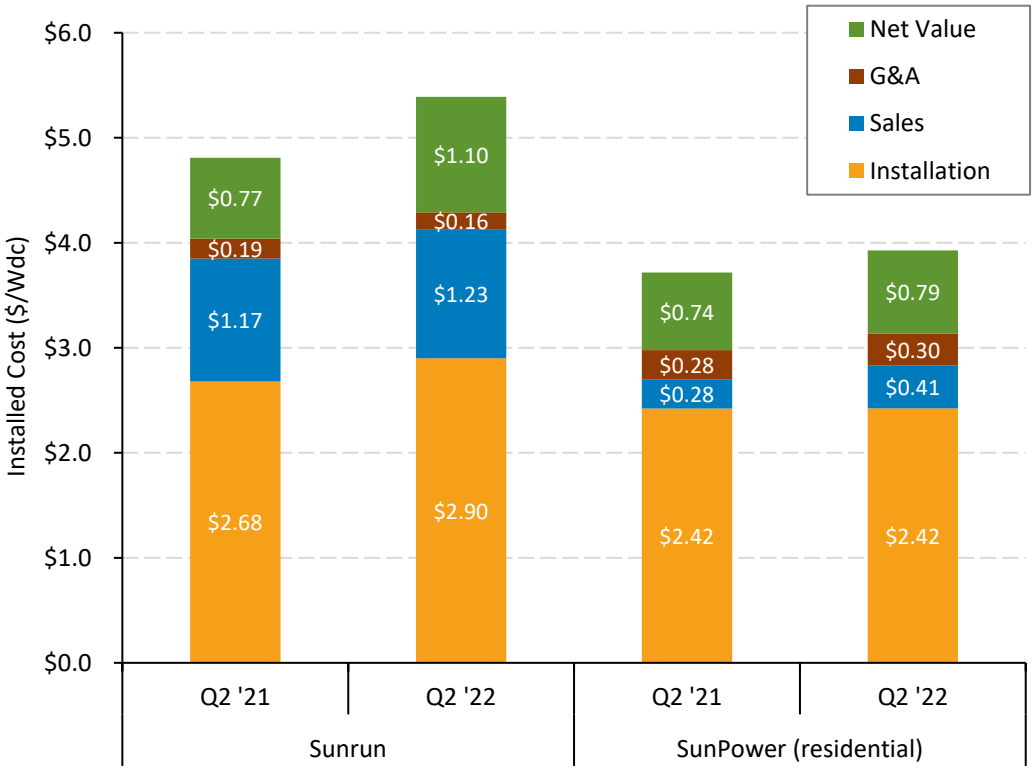
- The median reported price by EnergySage for residential PV systems increased 3.7% y/y, for the second straight period, after never having done so before.
  - EnergySage attributed the price increase to supply chain disruptions.
- Residential system price varied by state. In H1 2022, the median price of a residential system in Massachusetts was 46% higher than the median price of a residential system in Arizona.
  - Part of the price disparity between states is due to differences in average system size, though other factors, such as cost of living (e.g., Massachusetts), also play a role.





Note: Price based on winning quoted price.
Source: EnergySage, Solar Market place Intel Report H2 2021 – H1 2022.

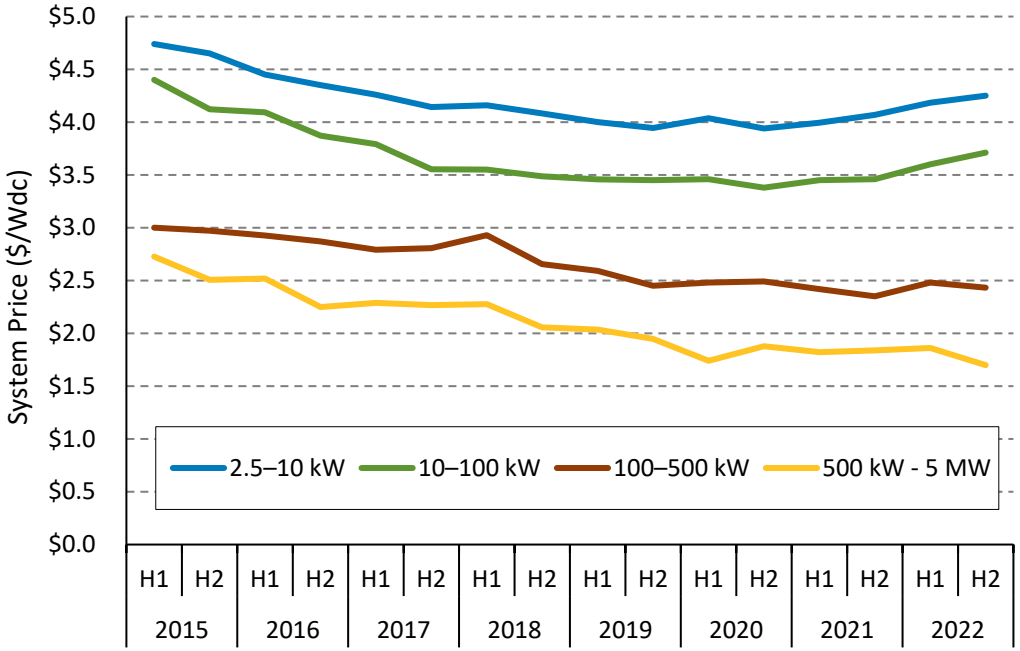
Sunrun and SunPower Cost and Value, Q2 2022



- Large residential installers reported strong demand for PV in Q2 2022, and they put less emphasis on costs and delays related to supply-chain constraints than they did in recent quarters.
  - Demand was enhanced by rising utility costs, inflation, "overall economic distress," and customer desire for energy reliability.
  - Large customer backlogs were reported (e.g., 53,000 customers for SunPower).
  - Delays and cost increases were experienced owing to the U.S. Customs and Border Protection's detainment of module imports under the Uyghur Forced Labor Prevention Act (UFLPA), which came into force on June 21, 2022.
  - Large installers have increased module inventories to mitigate supply risk.
- Costs include PV systems paired with batteries, which are increasing in popularity.
  - Sunrun's total PV + battery installations increased to 42,000 in Q2 2022.
  - The battery attachment rate was 19% for SunPower and 31% for Sunnova in Q2 2022.
  - Battery supply constraints continued to cause project delays and reduce attachment rates.

Sources: Corporate filings.

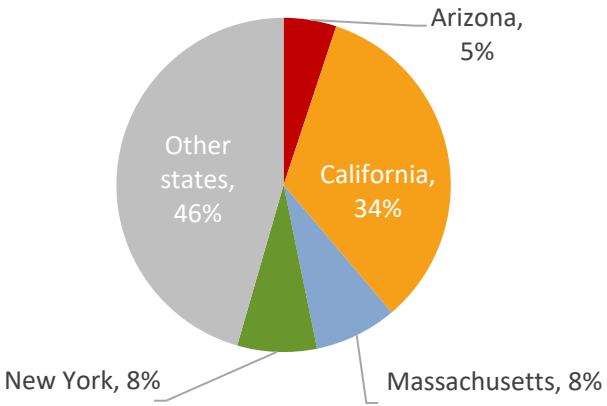
Distributed PV System Pricing from Select States



2022 MW reported YTD: Arizona (139), California (844), Massachusetts (104), New York (545)
Note: System prices above $10/W and below $0.75/W were removed from the data set. There were not enough reported prices for systems above 5 MW in the data set to show a trend over time.
Sources: Arizona Goes Solar (10/22); California Distributed Generation (8/30/22); Massachusetts Lists of Qualified Generation Units (9/22); Solar Electric Programs Reported by NYSERDA (10/22); Wood Mackenzie & SEIA, US Solar Market Insight: Q3 2022 (9/22).

- From H2 2021 to H2 2022 (partial), the median reported distributed PV system price in Arizona, California, Massachusetts, and New York:
  - Increased 4% to $4.25/Wdc for systems 2.5 to 10 kW
  - Increased 7% to $3.71/Wdc for systems 10 to 100 kW
  - Increased 3% to $2.43/Wdc for systems 100 to 500 kW
  - Decreased 8% to $1.70/Wdc for systems 500 kW to 5 MW.
- These states constituted 54% of U.S. distributed PV deployment over the past 10 years.

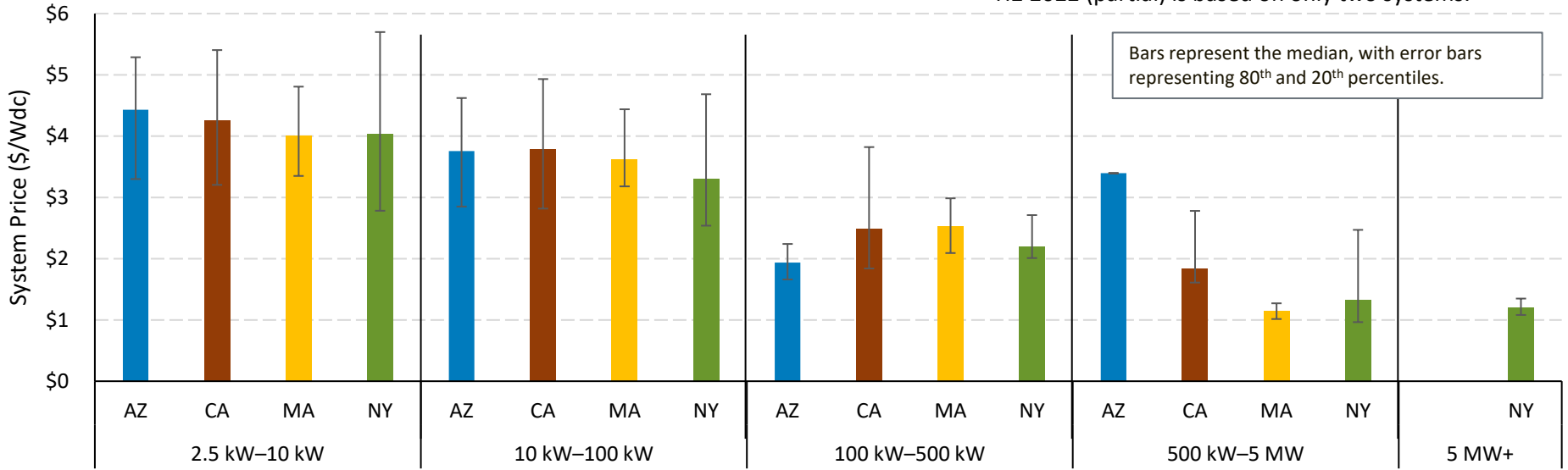
U.S. Distributed PV Deployment Over 10 y



Distributed System Pricing from Select States, H2 2022 (partial)

- In addition to price differences based on system size, there is variation between states and within individual markets.
- Dollar-per-watt prices generally decrease as system size increases.

- For systems of less than 100 kW, price increases varied between H2 2021 and H2 2022 (partial):
  - 5% in Arizona, 3%–8% in California, 5%–12% in Massachusetts, 4% in New York.
- Price changes in systems greater than 100 kW varied dramatically in some states during this period because of small sample sizes.
  - For example, the 500 kW – 5 MW price in Arizona in H2 2022 (partial) is based on only two systems.



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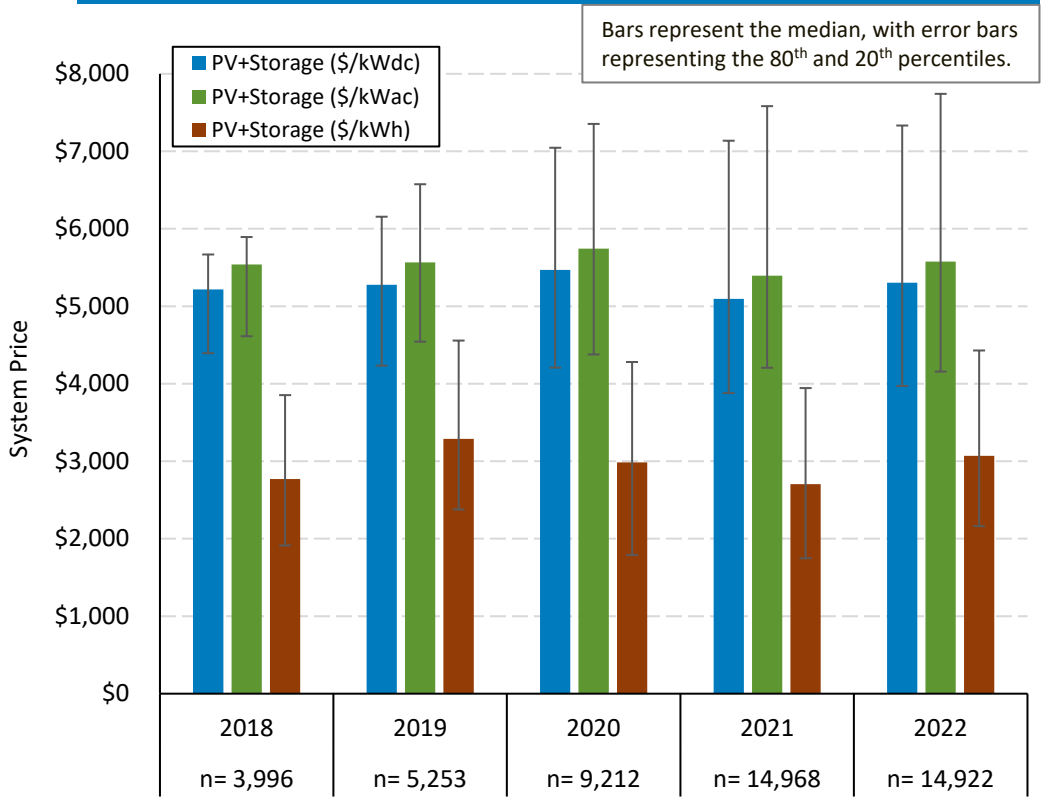
Sources: Arizona Goes Solar (10/22); California Distributed Generation (8/30/22); Massachusetts Lists of Qualified Generation Units (9/22); Solar Electric Programs Reported by NYSERDA (10/22).

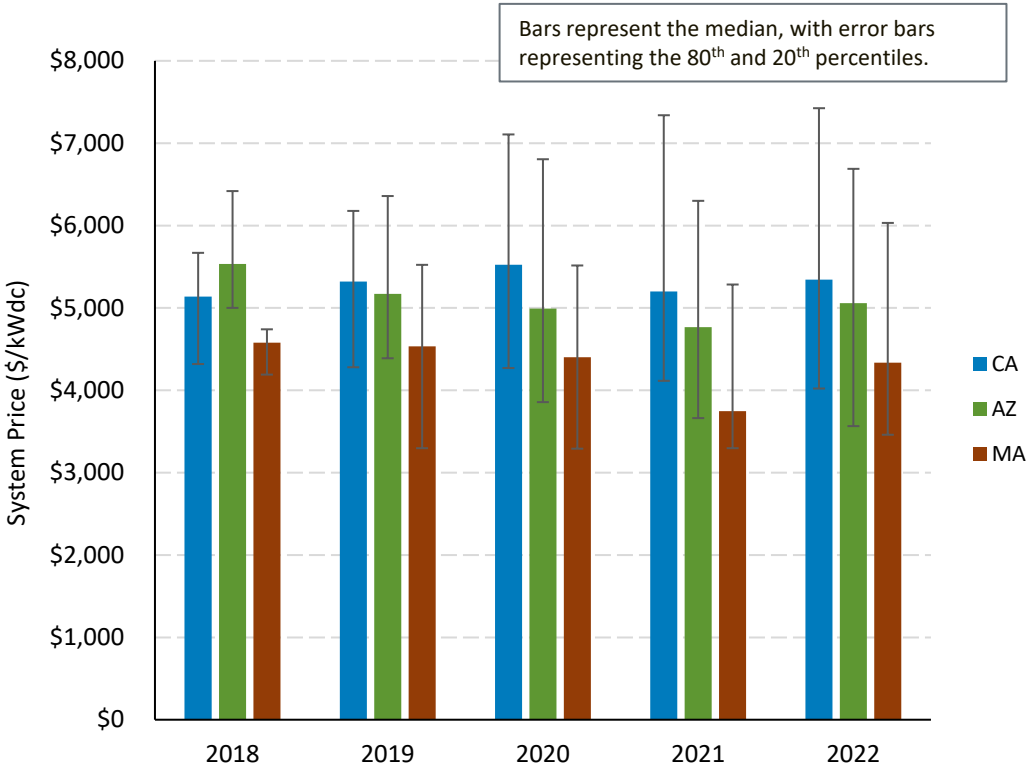
Residential U.S. PV+Storage Pricing



- In 2022 YTD, residential PV+storage systems in Arizona, California, and Massachusetts had a median system price of $3,100/kWh, or $5,600/kWac ($5,300/kWdc)—an increase of 3%–14% compared with full 2021 median values.
  - 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).

2022 YTD residential PV+storage sample, after data cleaning (MW): Arizona (9), California (110), Massachusetts (6)
Sources: Arizona Goes Solar (10/22); California Distributed Generation (8/30/22); Massachusetts Lists of Qualified Generation Units (9/22).

Residential U.S. PV+Storage Pricing

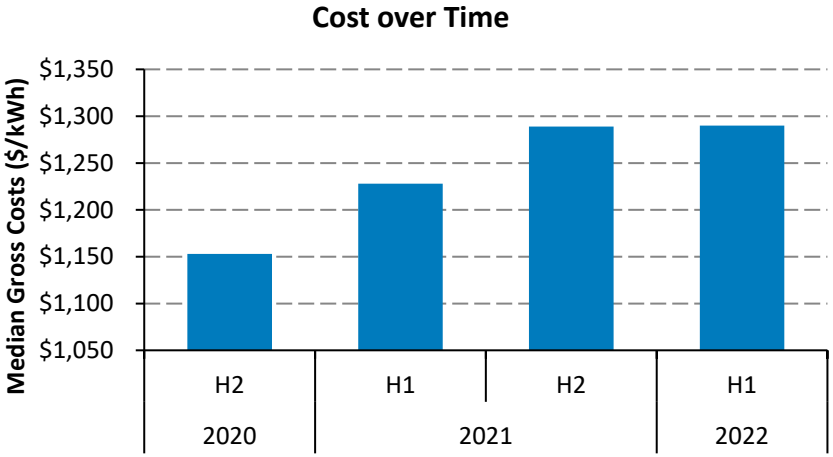


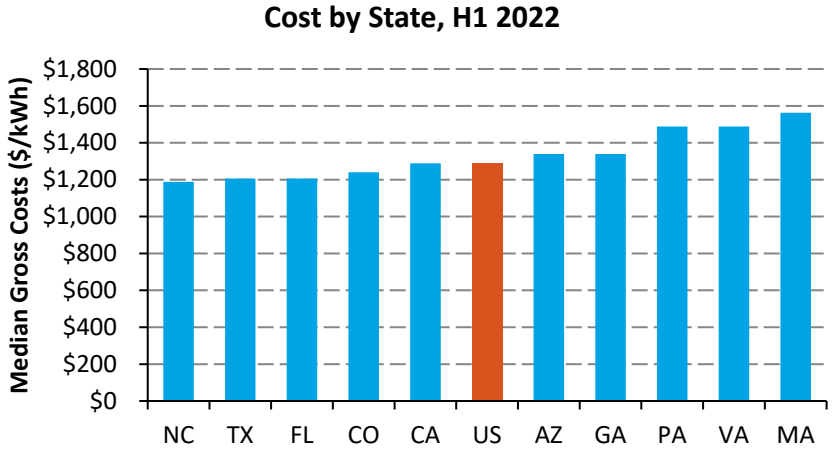
- In 2022 YTD, residential PV+storage system prices in Arizona, California, and Massachusetts varied between states and internally.
  - Prices may vary due to differences in storage power and capacity, permitting and interconnection differences, local competitive factors, and installer experience.
- Compared with full median 2021 values, prices (in dollars per kWdc of PV capacity) increased in 2022 YTD in Arizona (6%), California (3%), and Massachusetts (16%).

2022 YTD residential PV+storage sample, after data cleaning (MW): Arizona (9), California (110), Massachusetts (6)
Sources: Arizona Goes Solar (10/22); California Distributed Generation (8/30/22); Massachusetts Lists of Qualified Generation Units (9/22).

Residential Storage Price Reported by EnergySage

- EnergySage reports an increase in storage costs—unlike solar costs—over time.
  - Many of the increases in state price medians are correlated to a decrease in median system size.
- Residential storage system price varied by state. In H1 2022, the median price of a residential storage system in Massachusetts was 28% higher than the median price of a residential storage system in North Carolina.
  - In the EnergySage data set, the median cost of a battery in the top ten states ranged from $12,000 to $16,000.



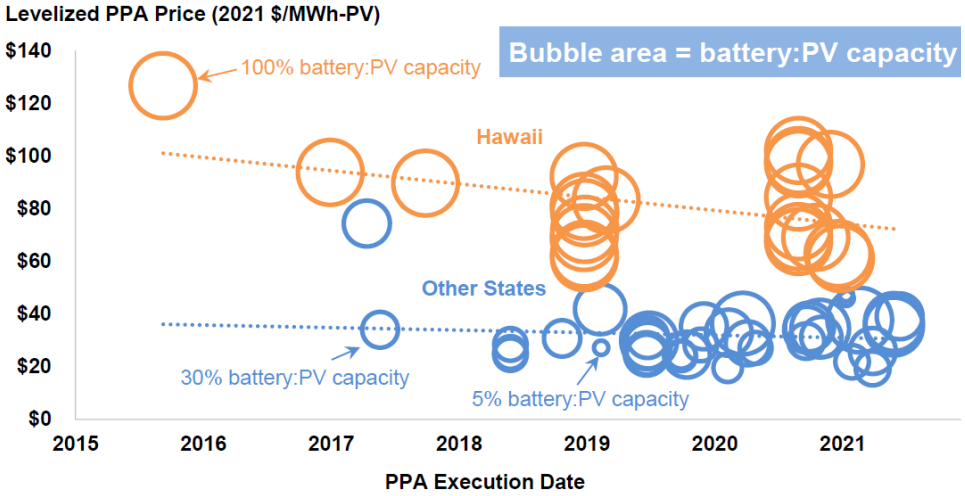


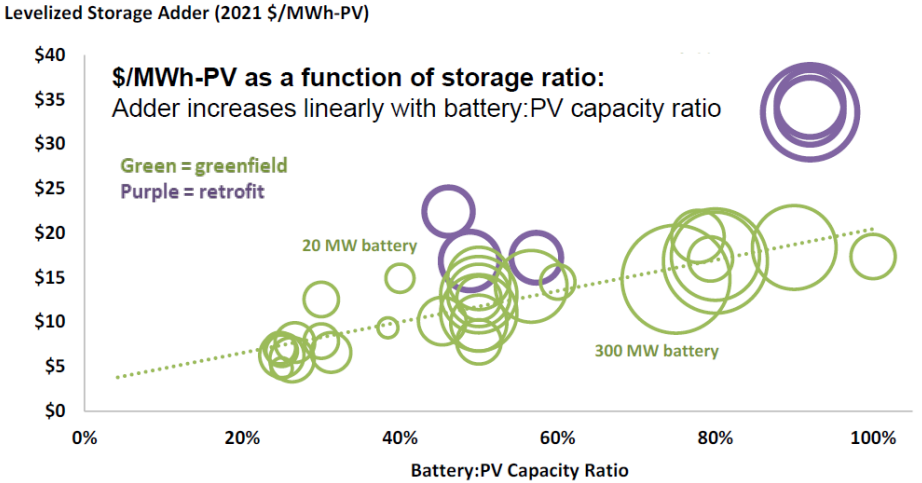
Note: Price based on winning quoted price.
Source: EnergySage, Solar Market place Intel Report H2 2021 – H1 2022.

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

- Deployment of PV+battery hybrids surged in 2021.
- Larger batteries relative to PV capacity (median 73%) and longer battery duration (median 2.2 hours) increased hybrid system costs 15% in 2021, to $3.5/Wac-PV.
- Sampled hybrid PPA prices have declined over time, especially in Hawaii, where the battery-to-PV capacity ratio is always 100%.

- The "levelized storage adder" (premium for PV+storage relative to a standalone PV PPA) increased in 2021 as the battery-to-PV capacity ratio increased.
- The storage adder increases linearly with increasing battery-to-PV capacity ratio.
  - ~$11/MWh-PV at 50%, $17/MWh-PV at 80%
  - Below, green circles are greenfield systems, purple are circles are battery retrofits, and the trend is based on greenfield systems only.





Source: Bolinger et al. 2022. *Utility-Scale Solar, 2022 Edition*. Lawrence Berkeley National Laboratory.

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- **According to Infolink (formerly PV Infolink), the top 10 module manufacturers were responsible for 101.7 GW (+45% y/y) in H1 2022 and the top 5 cell manufacturers together shipped 59 GW of cells (+60% y/y).**
- **Since IRA legislation was introduced and subsequently passed, numerous announcements of planned domestic manufacturing capacity additions have been made across the solar PV supply chain. The number of announcements is weighted toward module manufacturing facilities (~42 GW, 32.5 GW c-Si and 9.5 GW CdTe, versus 10–15 GW for the other steps).**
- **Several leading global PV companies announced expansion corporate production capacity to 50 GW or greater by 2023.**

PV Shipment Rankings

Rank	H1 2022 Shipments	
	Cells	**Modules**
1	Tongwei (20-30 GW*)	↑↑ Jinko Solar (18.2 GW)
2	Aiko (16.5 GW)	Trina Solar (18.1 GW)
3	Runergy	↓↓ LONGi (18.0 GW)
4	↑ Solar Space	↓ JA Solar (15.7 GW)
5	↑ Jietai	Canadian Solar (8.7 GW)
6		↑ Risen Energy (7.0)
7		↑↑ Astronergy
8		First Solar (4.3 GW produced)
9		↓↓ Hanwha Q Cells
10		↓ Suntech

** Estimate based on projected 2021/2022 manufacturing capacity*

According to Infolink (formerly PV Infolink), the top 10 module manufacturers were responsible for 101.7 GW (+45% y/y) in H1 2022.

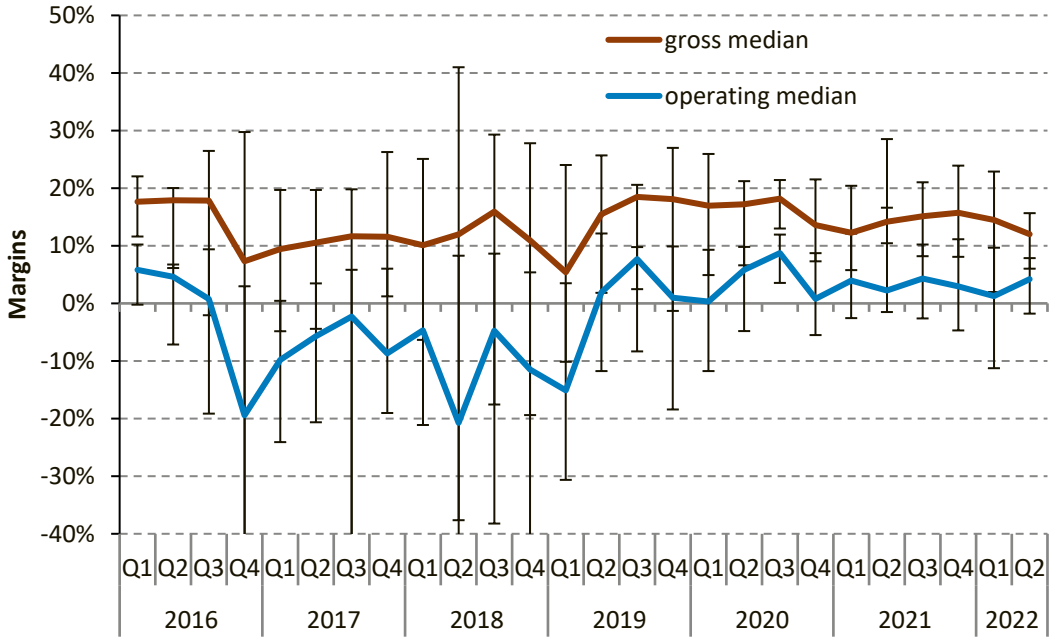
- Much of this growth was the result of accelerated energy transitions overseas, with shipment volumes growing as high as 36% in Q2 2022.
- Large modules (i.e., M10/182mm and G12/210 mm) accounted for 80% of the shipments.
- Though there was some reshuffling, the top 10 and top 4 module manufacturers remain the same.
- The top four module manufacturers aim to ship >40 GW each in 2022.

The top 5 cell manufacturers together shipped 59 GW of cells in the H1 2022 (+60% y/y).

- Cell prices rose during Q2 2022 as a result of both a supply shortage due to maintenance and high overseas demand.
- Like modules, large cells (i.e., M10/182mm and G12/210 mm) took up a large fraction (76%) of shipments.

Sources: InfoLink: 2022H1 cell shipment rankings, 2022H1 Module shipment ranking; 2021H1 cell shipment rankings, 2021H1 Module shipment ranking, PVTech (08/30/22), and Taiyang News (07/29/22, 09/02/22).

PV Manufacturers' Margins



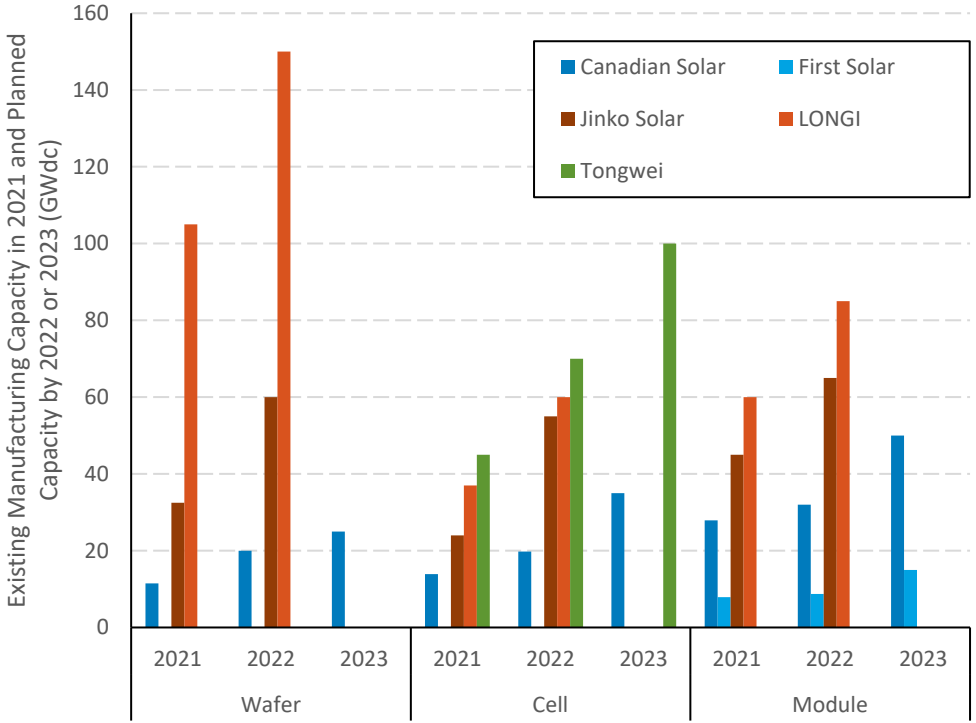
- PV manufacturers, mostly Chinese companies, have generally been profitable since 2019.
- The median gross margin of the publicly traded PV companies represented to the left was down 18% q/q but the median operating margin is up 3× q/q.
- There continues to be significant variation by individual companies as individual factors come into play, although variation has been substantially less since 2019.
  - For example, Tongwei (a leading polysilicon and PV cell manufacturer) announced in October that its net profits in the first three quarters of the year increased 2.5X (y/y) to $3 billion, as high polysilicon prices and strong demand drive growth.

Lines represent the median, with error bars representing 80th and 20th percentiles for the following companies in Q1 2022: Canadian Solar, First Solar, JA Solar, Jinko Solar, LONGi, Maxeon, Motech Industries, REC Silicon, Renesola, Risen, Shanghai Aiko, Shanghai Aerospace, Tongwei, Trina Solar, and United Renewable Energy. Margin data from Hanwha Q Cells, Sunpower, and Yingli are also included from Q1 2010 to Q1 2022 where available.

Note: Gross margin = revenue – 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; PVTech (10/11/22).

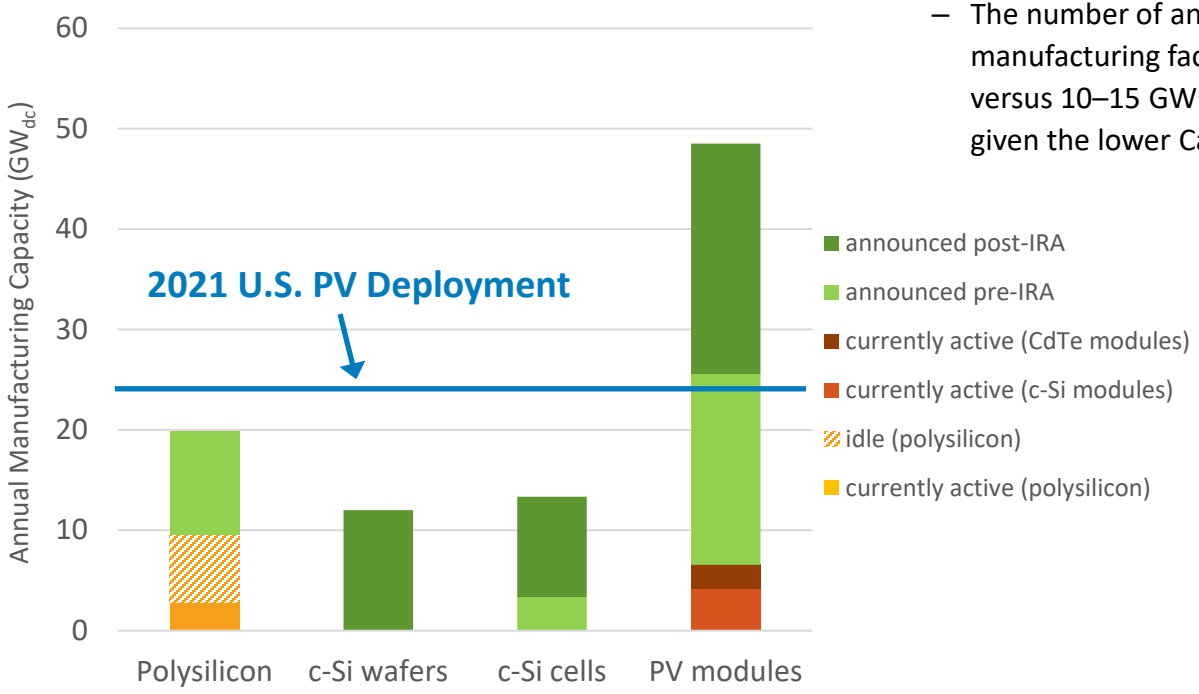
Selected Top-Tier PV Manufacturing Expansion



- Several leading PV companies have announced expansions of corporate production capacity to 50 GW or greater by 2023.
- Based on facility ramp-up and projects under construction, Clean Energy Associates also recently announced expectations that polysilicon production capacity would reach the equivalent of 295 GW by the end of 2022 and 536 GW by the end of 2023—significantly alleviating global supply/demand imbalance.
  - Non-Chinese ingot and wafer capacity also continues to increase, with Jinko Solar ramping up its 7-GW Vietnamese ingot facility, and JA Solar (Vietnam) and LONGi (Malaysia) beginning construction of their ingot and wafer facilities.

Sources: Company figures based on public filings; The China Project (07/19/22); PVTech (04/27/22, 10/11/22); Taiyang News (05/06/22, 07/26/22); Clean Energy Associates, PV Supplier Market Intelligence Program: Q2 2022.

Domestic Manufacturing Announcements



There have been numerous announcements across the solar PV supply chain of planned domestic manufacturing capacity additions since the initial introduction of the Solar Energy Manufacturing for America Act (SEMA) and the subsequent passage of IRA.

- The number of announcements is weighted toward module manufacturing facilities (~42 GW, 32.5 GW c-Si and 9.5 GW CdTe, versus 10–15 GW for the other steps), as would be expected given the lower CapEx than other steps in the supply chain.
- Currently, only *announced* module capacity comes close to meeting even 2021 deployment needs.
- Though not included in the figure, there have also been announcements for EVA, backsheet, tracker components, and battery manufacturing.

In addition to materials explicitly covered by the tax credits in IRA, there have also been announcements for solar glass, frames, and metallurgical grade silicon production.

Sources: the U.S. International Trade Commission DataWeb, Wood Mackenzie/SEIA: U.S. Solar Market Insight: Q2 2022, and compilation of public announcements (see Appendix).

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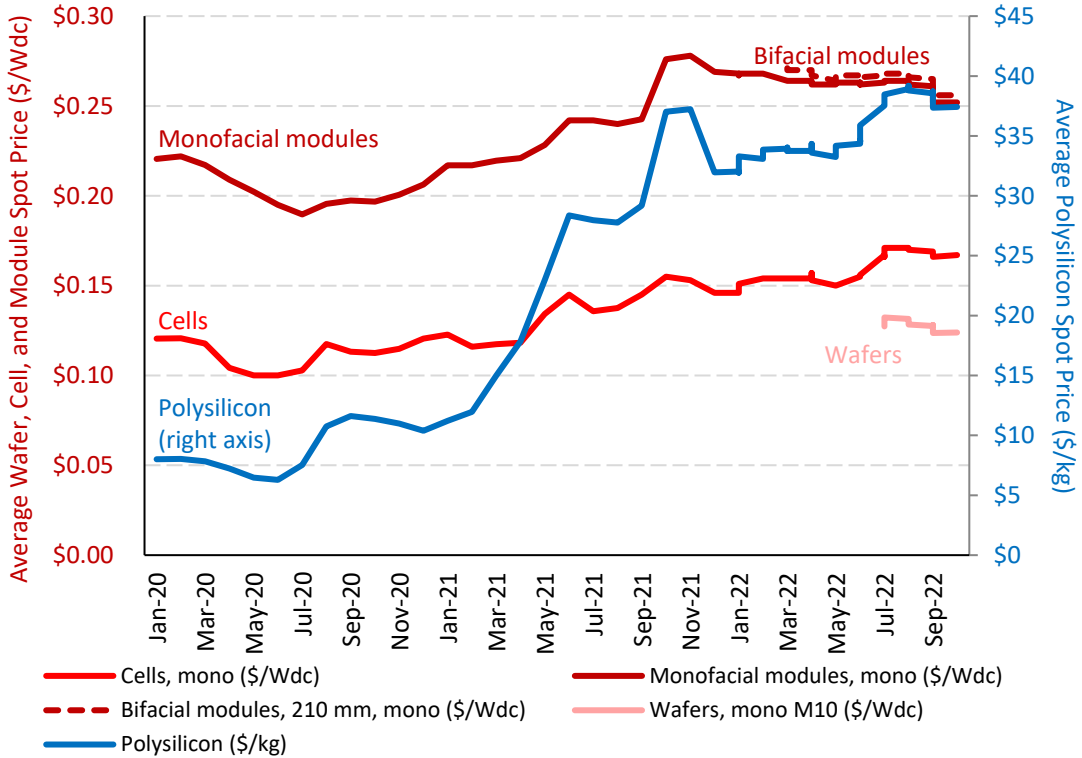
- **Global polysilicon spot prices were high in Q3 2022 at around $38–$39/kg, up 20% since January 2022 and 270% since January 2021.**
- **Module spot prices ended down 4% in Q3 2022, at $0.25/W, which may be due in part to increasing module inventories in Europe.**
- **In Q2 2022, the average U.S. module value ($0.37/Wdc) was about the same q/q and was up 13% y/y, trading at a 41% premium over the global spot price for monofacial monocrystalline silicon modules.**

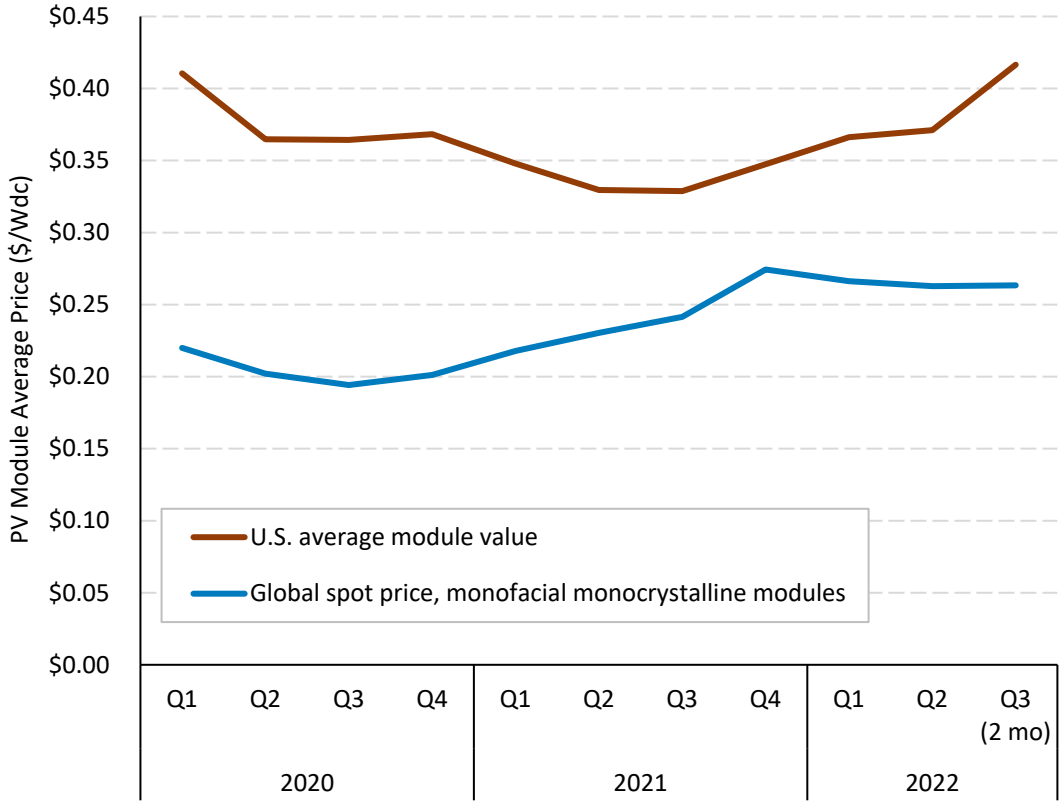
PV Value Chain Spot Pricing



- Polysilicon spot prices were high in Q3 2022 at around $38–$39/kg, up 20% since January 2022 and 270% since January 2021.
  - The spike was driven by continued high demand and supply disruptions due to an industrial accident and power rationing related to a heat wave and drought in China.
  - Price increases in yuan were partially offset by yuan depreciation against the U.S. dollar.
  - Analysts expect substantial price reductions by 2023 as production capacity ramps up.
- Cell spot prices rose 6% in Q3 2022 owing in part to the power rationing in China.
- Module spot prices ended down 4% in Q3 2022, which may be due in part to increasing module inventories in Europe.

Source: BloombergNEF Solar Spot Price Index (10/18/22); BloombergNEF Bimonthly PV Index (9/27/22); PV Magazine (8/31/22, 10/17/22); PV Tech (8/18/22)

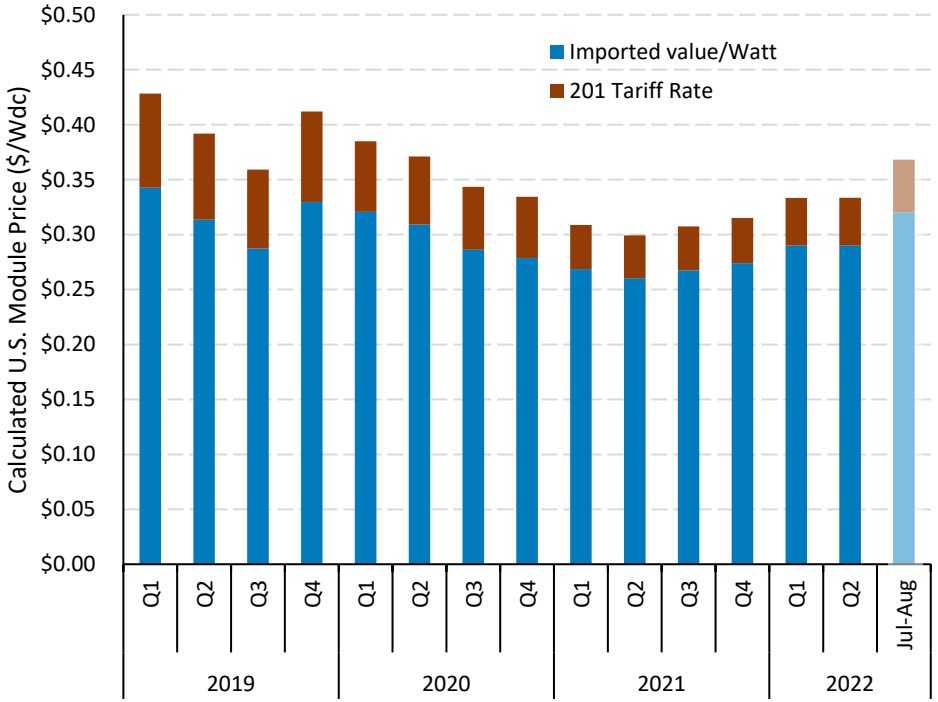
Module Prices: Global versus United States



- In Q2 2022, the average U.S. module value ($0.37/Wdc) was about the same q/q and was up 13% y/y, trading at a 41% premium over the global spot price for monofacial monocrystalline silicon modules.
- The average U.S. module value rose 12% in the first 2 months of Q3 2022 to $0.42/Wdc, 58% above the global price, which stayed constant during this period.
- The disparity between U.S. and global module prices to date in 2022 reflects the tumultuous U.S. policy and supply and demand context.
  - The U.S. Department of Commerce anti-circumvention investigation stalled module shipments from Southeast Asia early in Q2 2022.
  - An executive order in early June exempting those Southeast Asian modules from tariffs for 2 years caused a spike in demand and prices from that region.
  - The UFLPA came into force on June 21, causing renewed supply constraints and price increases for modules from Southeast Asia.

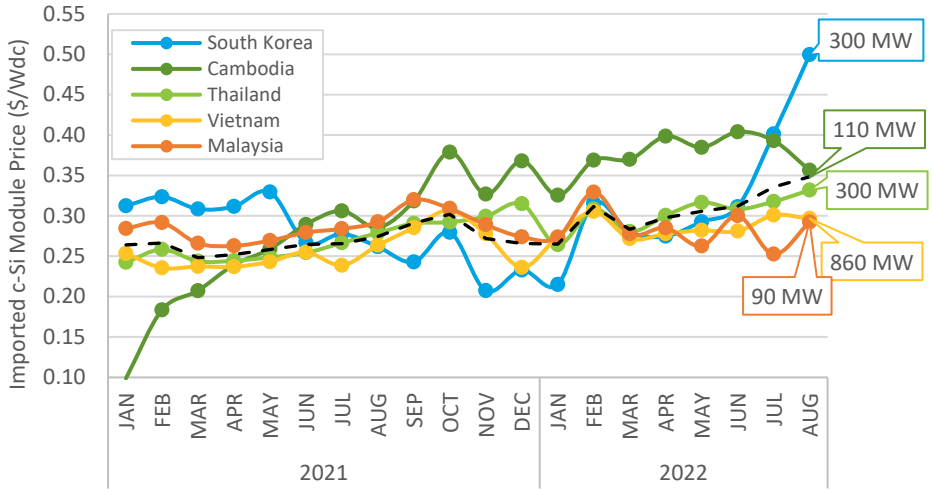
Source: BloombergNEF Solar Spot Price Index (10/18/22); BloombergNEF Bimonthly PV Index (9/27/22); U.S. Energy Information Administration, Monthly Solar Photovoltaic Module Shipments Report (10/17/22); Wood Mackenzie & SEIA, US Solar Market Insight: Q3 2022 (September 2022).

Calculated U.S. Module Pricing



Based on the reported value and capacity of imported PV modules, the average price of a PV module in the United States held steady q/q in Q2 2022, although it looks likely to rise sharply in Q3.

– These price increases have been nonuniform across countries, with prices rising mostly steeply for imports from Thailand and South Korea.



Note: Manual corrections were made to three values due to suspected data entry errors for HTS code 8541430010: Cambodia (February 2022), Malaysia (June 2020), and Vietnam (July 2019).

Sources: Imports by HTS code: 8541460015(2018-2021)/8541430010(2022-), Customs Value and Second Quantity (watts) from the U.S. International Trade Commission DataWeb, the U.S. Census Bureau USA Trade Online tool and corrections page.

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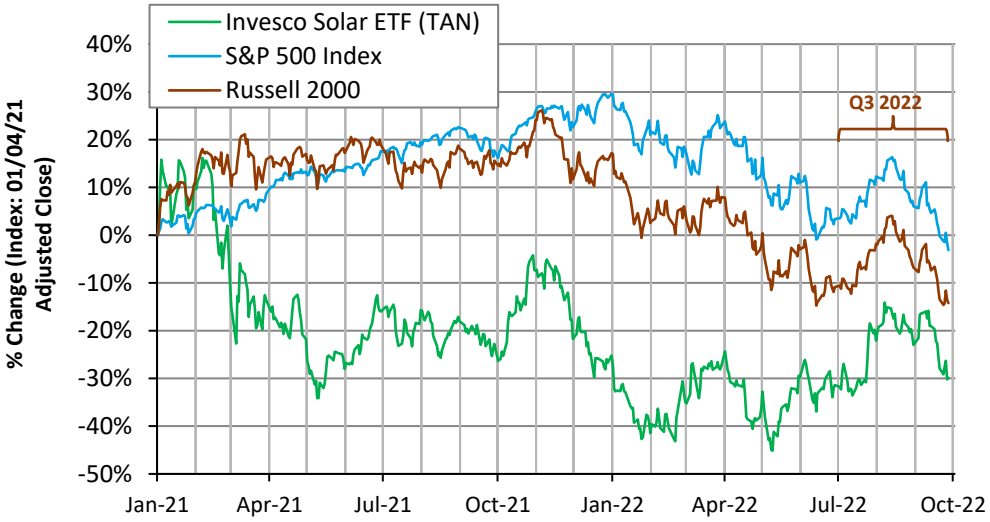
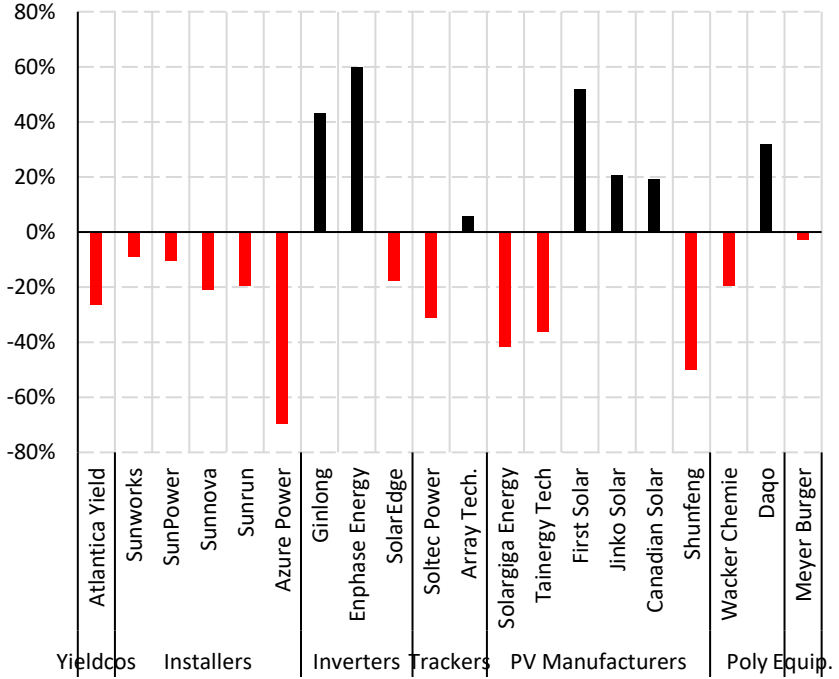
- **Solar stocks represented by the Invesco Solar ETF rose 25% in the first month of Q3 2022 before losing most of those gains by the end of the quarter. The pattern was similar in the broader market—in the context of rising interest rates and recession concerns**
- **SREC bid prices in Washington, D.C. dipped $100 in mid-2022 but then quickly rebounded.**

Stock Market Activity

- Solar stocks represented by the Invesco Solar ETF rose 25% in the first month of Q3 2022 before losing most of those gains by the end of the quarter. The pattern was similar in the broader market—in the context of rising interest rates and recession concerns—but solar stocks ended up 2% for the quarter while the broader market lost 4%–6%.
- Solar stocks received a boost from passage of the IRA in mid-August.



Individual Stock Performance (Q1–Q3 2022)

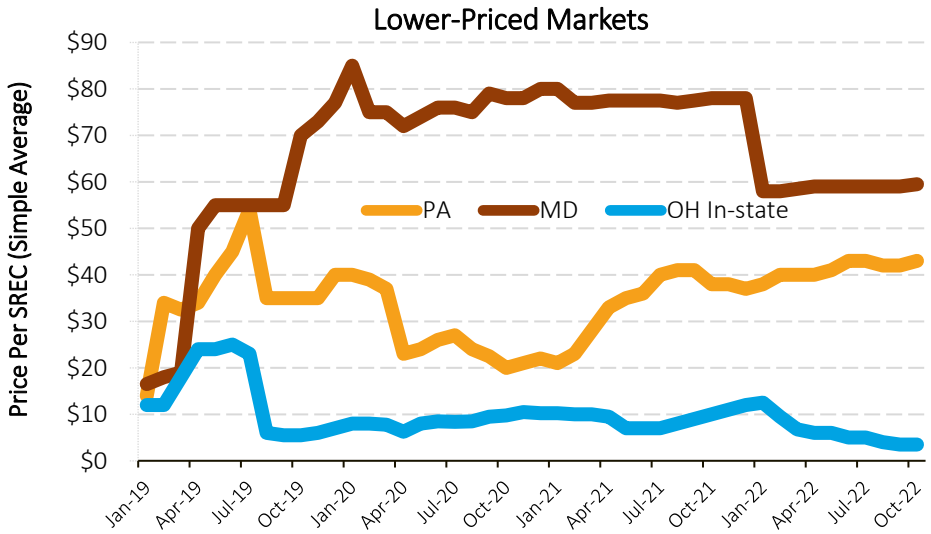


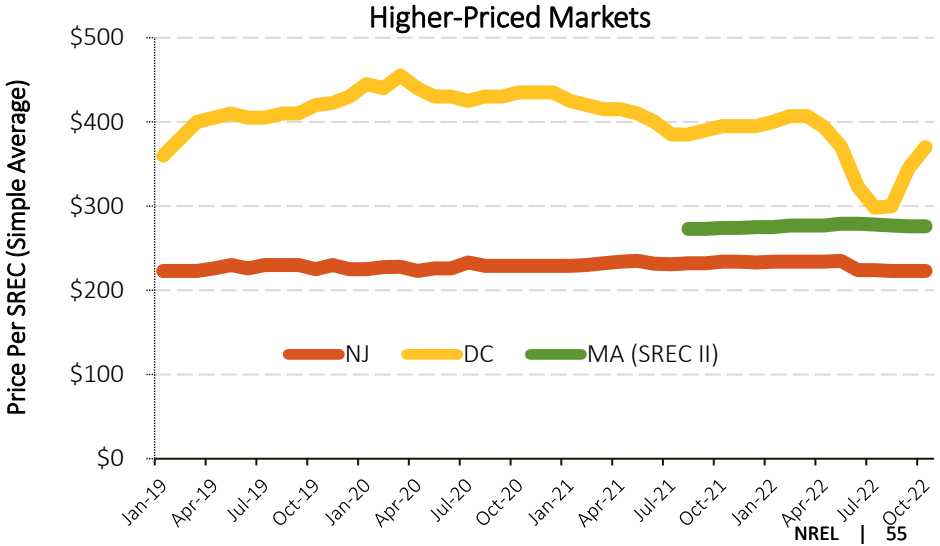
Note: The TAN index is weighted toward particular countries and sectors. As of 10/14/22, 47% of its funds were in U.S. companies and 22% were in Chinese companies. Its top 10 holdings, representing 55% of its value, were Enphase, First Solar, SolarEdge, GCL, Xinyi, Sunrun, Daqo, Shoals, Array Technologies, and Encavis.

Sources: Invesco (10/14/22), Morningstar (10/3/22), Yahoo Finance (10/11/22).

SREC Pricing

- SREC bid prices in Washington, D.C. dipped $100 in mid-2022 but then quickly rebounded.
  - The price decline and increase may indicate uncertainty of an oversupply of SRECs, as more than half of D.C.'s solar capacity has been installed in the past 2 years.
- Other SREC prices stayed relatively flat during this period.
- Active SREC programs have closed in New Jersey, Massachusetts, and Ohio.





Source: SRECTrade, https://www.srectrade.com/, accessed 8/3/22.

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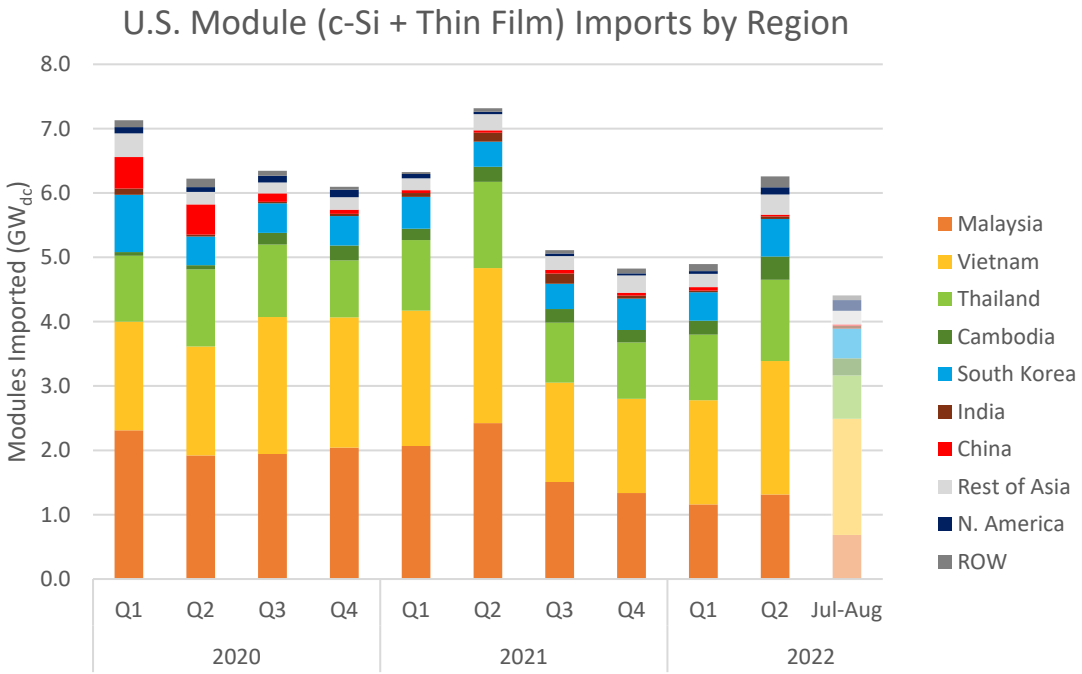
- **11.2 GWdc of PV modules were imported into the United States in H1 2022, down 18% y/y.**
  - Most panels imported were exempt from Section 201 duties and were therefore likely bifacial. A significant number of thin-film modules were also imported.
- **However, In Q2 2022, U.S. module imports grew substantially (+28%, or 1.4 GW q/q) for the first quarter in a year.**
- **1.2 GWdc of cells were imported in H1 2022, down 6% y/y.**
  - Despite the renewal of the Section 201 tariffs in February, which raised the quota exemption from 2.5 GW_{dc} to 5.0 GW_{dc}, there has not been a significant uptick in the import of solar cells. Imports are on track to match those of 2021.

Module Imports and Calculated Prices by Region



In Q2 2022, U.S. module imports grew substantially (+28%, or 1.4 GW q/q) for the first quarter in a year, totaling 11.2 GW_{dc} in H1 2022.

- Import levels decreased after the withhold release order (WRO) on PV cells and modules was announced in late Q2 2021. Additionally, many manufacturers in Southeast Asia had reduced production levels earlier in the year with the announcement of a U.S. anti-circumvention investigation and when the 2-year waiver was announced in June, manufacturers said it would take time to ramp production back up.
- The Q2 increase was mainly the result of increased imports from Vietnam (+28% q/q, 455 MW) and Thailand (+24% q/q, 244 MW).
- Both Q2 2022 (-14%,-1 GW) and H1 2022 (-18%, -2.5 GW) imports are still down significantly y/y.

While Q3 is not yet complete, it has already nearly matched Q1 imports.

- This has been mainly the result of imports from Vietnam, which totaled nearly 1.8 GW (1.2 GW c-Si + 0.6 GW thin film) over July and August.

Sources: Imports by HTS code: 8541460015(2018-2021)/8541430010(2022-) and 8541460035(2018-2021)/8541430080(2022-), Second Quantity (watts) from the U.S. International Trade Commission DataWeb as well as the U.S. Census Bureau USA Trade Online tool and corrections page as of 10/20/22.

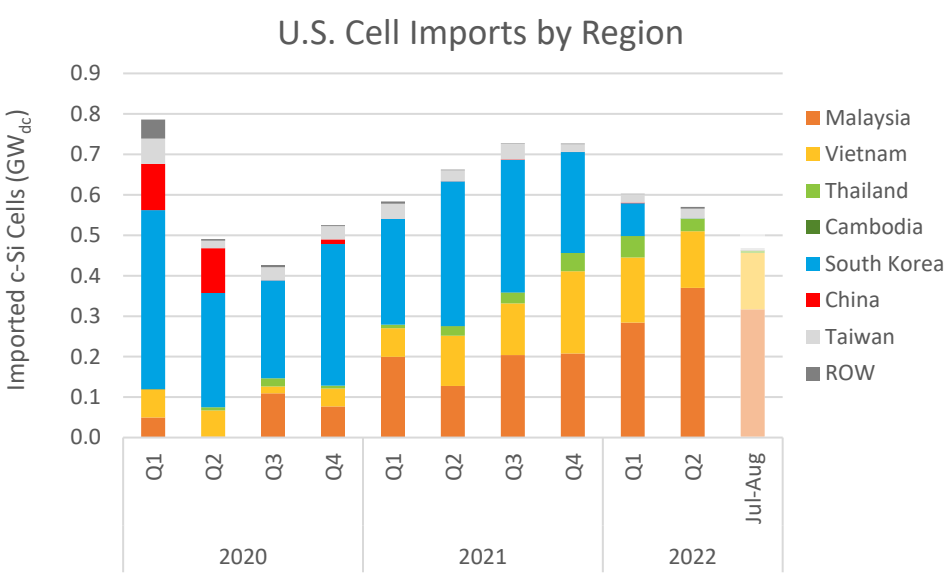
c-Si Cell Import Data

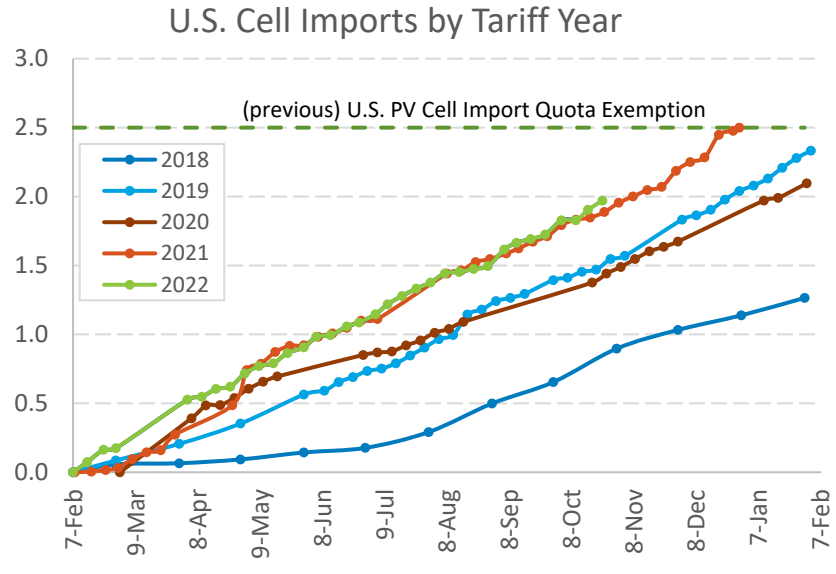
According U.S. Census data, cell imports saw a significant shift in region of origin during H1 2022.

– From Q4 2021 to Q2 2022, South Korea dropped from 34% of cell imports to 0%, while Malaysia grew from 28% to 65%.

1.2 GW_{dc} of cells were imported in H1 2022, a fall of 6% relative to H1 2021.

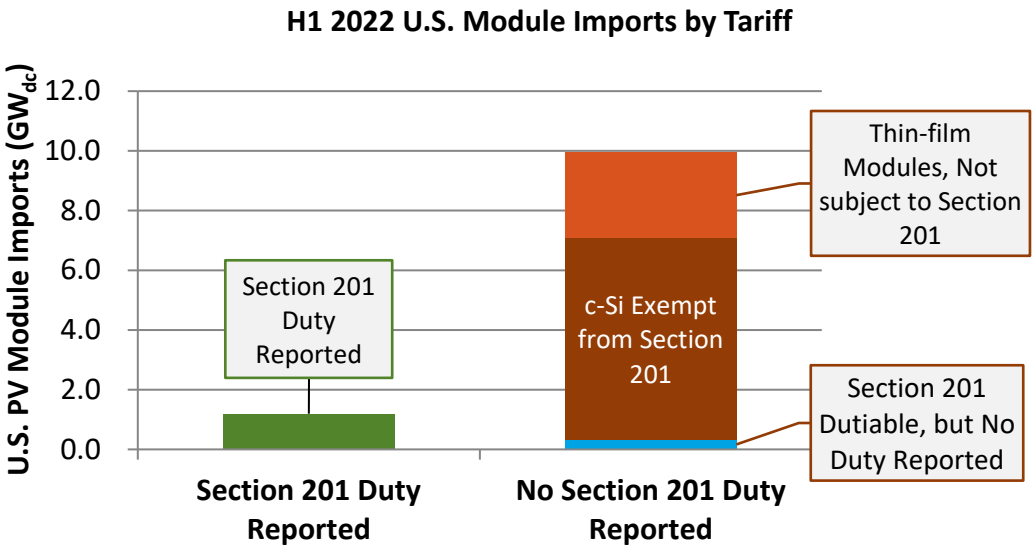
Despite this, and despite the increased quota exemption from 2.5 GW_{dc} to 5.0 GW_{dc}, for the Section 201 tariffs which were renewed in February, imports remain on track to match those of 2021, according to CBP Commodity Status Reports.





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 10/20/22; U.S. Customs and Border Protection Commodity Status Reports February 2019–October 2022.

H1 2022 U.S. Module Imports by Tariff



- In H1 2022, only 11% (1.2 GW_{dc}) reported a tariff, compared to 67% (9.2 GW_{dc}) in H1 2021.
  - Most of the modules that did not were c-Si technology panels exempt from Section 201 tariffs (6.7 GWdc, 60%) or thin-film and not subject to tariffs (2.9 GWdc, 26%).
  - H1 2022 imports of thin-film modules were up 40%, or 0.8 GW y/y.
- In Q2 2022, imports of c-Si panels exempt from Section 201 tariffs nearly doubled that of the previous quarter (+4.0 GW_{dc} versus +2.7 GW_{dc}), continuing a nearly exponential trend over the last three quarters.
  - The c-Si imports were likely bifacial panels, which the Biden administration exempted from Section 201 duties in February 2022.
  - CdTe panels are not subject to the various duties c-Si modules are, and they do not have a supply chain in locations currently scrutinized over the use of forced labor.

Notes: We assumed all modules not subject to Section 201 tariffs are reported under "Free under HS Chapters 1-98" or "Entered into U.S. Virgin Islands," with exemptions coming from HTS code 8541406015/8541430010, and technologies not applicable reported under HTS code 854140603. We assumed all panels subject to Section 201 duties are reported under "Dutiable- HS chapter 99." Manual corrections were made to the following value due to suspected data entry errors for HTS code 8541430010: Cambodia February 2022.

Sources: Imports by HTS code: 8541460015(2018-2021)/8541430010(2022-) and 8541460035(2018-2021)/8541430080(2022-), Second Quantity (watts), and Rate Provision Code from the U.S. International Trade Commission DataWeb as well as the U.S. Census Bureau USA Trade Online tool and corrections page as of 10/20/22.

Thank You

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List of Acronyms and Abbreviations

AD: antidumping
ac: alternating current
ASP: average selling price
BESS: battery energy storage system
BOS: balance of system
BNEF: Bloomberg New Energy Finance
CAISO: California Independent System Operator
CapEx: capital expenditures
C&I: commercial and industrial
CBP: U.S. Customs and Border Protection
CdTe: cadmium telluride
CPI: consumer price index
c-Si: crystalline silicon
CSP: concentrating solar power
CVD: countervailing
dc: direct current
DLR: Deutsches Zentrum für Luft- und Raumfahrt
DNI: direct normal irradiance
DOE: U.S. Department of Energy
EIA: U.S. Energy Information Administration
EPA: U.S. Environmental Protection Agency
ETF: exchange traded fund
EVA: ethylene vinyl acetate
GHG: greenhouse gas
GW: gigawatt
GWh: gigawatt-hour
H1: first half of year
H2: second half of year
HTS: harmonized tariff schedule
HUD: U.S. Department of Housing and Urban Development
IEA: International Energy Agency
IEEFA: Institute for Energy Economics and Financial Analysis
IRA: Inflation Reduction Act
IRS: Internal Revenue Service
ISO: independent system operator
ITC: investment tax credit
kW: kilowatt
kWh: kilowatt-hour
LBNL: Lawrence Berkeley National Laboratory
LCOE: levelized cost of energy
MGS: metallurgical-grade silicon
mono c-Si: monocrystalline
MMP: modeled market price
MPTC: manufacturing production tax credit
MSP: minimum sustainable price
MW: megawatt
MWh: megawatt-hour
NASEO: National Association of State Energy Officials
NEM: net energy metering
NREL: National Renewable Energy Laboratory
ORAU: Oak Ridge Associated Universities
ORISE: Oak Ridge Institute for Science and Education
PLI: production-linked incentive
PPA: power purchase agreement
PTC: production tax credit
PV: photovoltaics
Q: quarter
q/q: quarter 0ver quarter
R&D: research and development
REPEAT: Rapid Energy Policy Evaluation Analysis Toolkit
SEIA: Solar Energy Industries Association
SEMA: Solar Energy Manufacturing for America Act
SREC: solar renewable energy certificate
TAN: Invesco Solar ETF
UAE: United Arab Emirates
UFLPA: Uyghur Forced Labor Prevention Act
USD: U.S. dollars
USDA: U.S. Department of Agriculture
W: watt
WRO: withhold release order
y/y: year over year
YTD: year to date

List of Manufacturing Announcements

Nextracker & Atkore Commission Manufacturing Line In Arizona | TaiyangNews
Steel Fab Reopens In US For Nextracker | TaiyangNews
CHERP builds first nonprofit solar panel factory - The Claremont COURIER (claremont-courier.com)
Convalt sets ambitious production goals at Watertown site | Business | nny360.com
Convalt Energy receives bridge gap loan from JCIDA for Hounsfield project | Business | nny360.com
US Solar Backsheet Maker Expanding Capacity | TaiyangNews
Enphase Energy To Open Manufacturing Lines In US | TaiyangNews
First Solar to invest up to $1.2 billion in expanding U.S. solar manufacturing by 4.4 GW – pv magazine USA (pv-magazine-usa.com)
Expanding before opening: 2nd First Solar plant in Lake Twp. gets OK to be bigger | News | sent-trib.com
Fuyao Glass To Expand Production Capacity In The US | TaiyangNews
GAF Energy breaks ground on Texas solar roofing plant – pv magazine USA (pv-magazine-usa.com)
USA: 6 GW Solar Tracker Manufacturing Fab Planned | TaiyangNews
Hanwha To Produce Module Encapsulants in US | TaiyangNews
Nine gigawatt solar manufacturing facility being scouted for Qcell module manufacturing – pv magazine USA (pv-magazine-usa.com)
Hanwha Q Cells to build US solar module factory, expand cell capacity in South Korea – pv magazine International (pv-magazine.com)
https://www.pv-tech.org/heliene-president-opens-up-on-us-manufacturing-plans-post-ira/
https://www.pv-tech.org/heliene-president-opens-up-on-us-manufacturing-plans-post-ira/
Canada's Heliene opening its second U.S. solar panel factory | Reuters
Heliene boosts U.S. solar supply chain with expansion of Minnesota facility (renewableenergyworld.com)
Ice Industries Invests in new Ohio Facility to Serve America's Largest Solar Manufacturer :: Ice Industries
New JM Steel manufacturing plant will have a Nextracker tracker production line – pv magazine USA (pv-magazine-usa.com)
https://www.solarpowerworldonline.com/2022/03/maxeon-still-has-sights-set-on-u-s-solar-manufacturing-hub/
Meyer Burger aims to raise US$253 million to support manufacturing ramp-up - PV Tech (pv-tech.org)
OCI to invest $40 million to expand US solar module production facilities - KED Global
Mitrex to build N.Y. solar product manufacturing facility • SBIZ • Sustainable Biz Canada
Gov. Kemp: Solar Tech Company NanoPV to Open Manufacturing, Distribution Operations in Sumter County, Create Over 500 Jobs | Governor Brian P. Kemp Office of the Governor (georgia.gov)
Philadelphia Solar Announces 1 GW PV Panel Manufacturing Facility Investment Plan in U.S. (enfsolar.com)
PV Hardware plans 6GW solar tracker manufacturing factory in Texas - PV Tech (pv-tech.org)
REC Silicon signs second supply agreement for U.S. metal-grade silicon (solarpowerworldonline.com)
Reliance Industries acquires REC Group, plans 1 GW U.S. module facility – pv magazine USA (pv-magazine-usa.com)
New N-Type TOPCon Solar Module Fab In Texas, US | TaiyangNews
Silfab plans to start solar cell manufacturing in the United States, but Commerce investigation has halted progress (solarpowerworldonline.com)
Silfab Solar Doubles US solar panel manufacturing capacity - Press - SILFAB SOLAR
SPI Energy will start 1.5-GW silicon wafer manufacturing site stateside by 2023 (solarpowerworldonline.com)
SPI Energy Accelerates Growth of Solar Module Manufacturing Capacity to Meet Strong Demand (yahoo.com)
Sun Pacific to develop a U.S. solar panel manufacturing facility | ROI-NJ
Toledo Solar To Expand US Manufacturing Capacity | TaiyangNews
Governor Hochul Announces Plans for Ubiquity Solar to Establish U.S. Manufacturing Operations at Former IBM Huron Campus in Broome County | Governor Kathy Hochul (ny.gov)
Biden's Climate Push Lures Indian Firm to Make Panels in US (bloombergtax.com)