NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Winter 2021/2022 Solar Industry Update

David Feldman
Krysta Dummit, ORISE[a] Fellow
Jarett Zuboy
Jenny Heeter
Kaifeng Xu
Robert Margolis

January 11, 2022

[a] Oak Ridge Institute for Science and Education

Executive Summary

Global Solar Deployment

- In the first 9 months of 2021, PV installations increased significantly, y/y, for many leading markets, including the United States.
- An estimated 171 GW of PV were installed globally in 2021, and analysts project 209 GW_{DC} of PV will be installed in 2022 and 231 GW_{DC} will be installed in 2023.

U.S. PV Deployment

- California, the largest distributed PV market in the United States, is proposing revisions to its net metering that would reduce compensation for distributed PV and incentivize electrification and energy storage.
- An estimated 21 GW_{AC} (27 GW_{DC}) of PV were installed in the United States in 2021.
- The United States installed a record 11.8 GW_{AC} (16.3 GW_{DC}) of PV in the first 9 months of 2021.
- The United States installed approximately 5.7 GWh/1.9 GW_{AC} of energy storage onto the electric grid in the first 9 months of 2021, up 419% y/y, as a result of record levels of residential and front-of-the-meter deployment (mostly in California).

PV System and Component Pricing

- Despite supply chain shortages and component price increases, reported PV system prices from select states were relatively flat between H2 2020 and H2 2021.

Global Manufacturing

- In H1 2021, the top 10 companies in module and cell shipments remained the same from H1 2020.
- Many Chinese companies are shifting to producing larger cell sizes.
- PV manufacturers, mostly Chinese companies, have generally been profitable since 2019.

U.S. PV Imports

- 18.8 GW of PV modules were imported into the United States in the first nine months of 2021, down 9% y/y.
  - Imports fell likely due to the U.S. Customs and Border Protection (CBP's) decision in June to stop imports that might contain material made from forced labor, as well as a trade case filed in June accusing Chinese manufacturers of circumventing AD/CVD duties.
- 2.5 GW_{DC} of cells were also imported in the first nine months of 2021, up 26%.
  - The increase in demand for cells to supply domestically assembly modules may be driven by supply chain issues, causing installers difficulty in procuring module supply.

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

Agenda

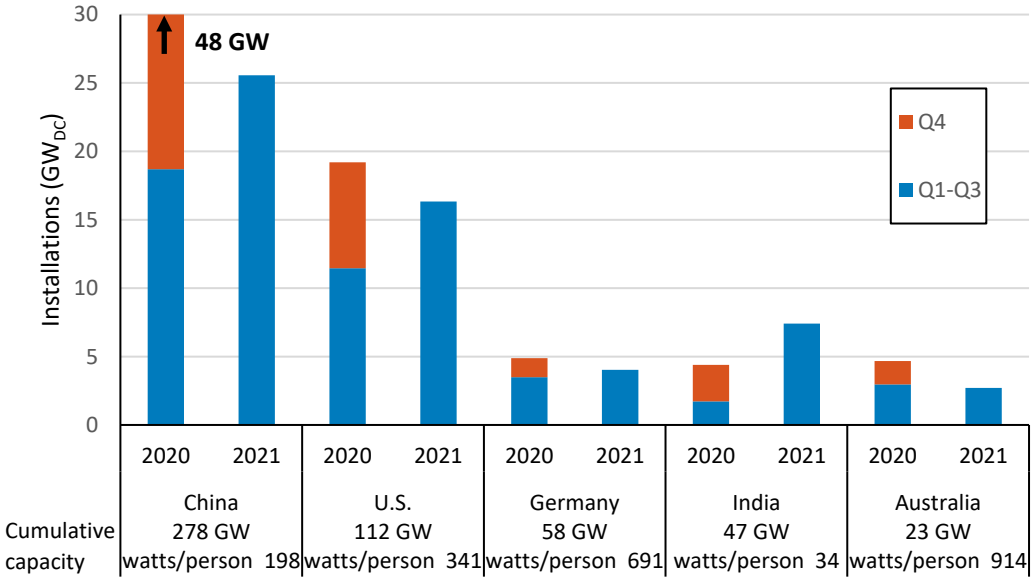
1. Global Solar Deployment
2. U.S. PV Deployment
3. PV System Pricing
4. Global Manufacturing
5. Component Pricing
6. Market Activity
7. U.S. PV Imports

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

- **In the first 9 months of 2021, PV installations increased significantly, y/y, for many leading markets, including the United States.**
  - India installed 177% more in the first 9 months of 2021 than it did over the same period in 2020.
- **An estimated 171 GW of PV were installed globally in 2021, and analysts project 209 GW_{DC} of PV will be installed in 2022 and 231 GW_{DC} will be installed in 2023.**

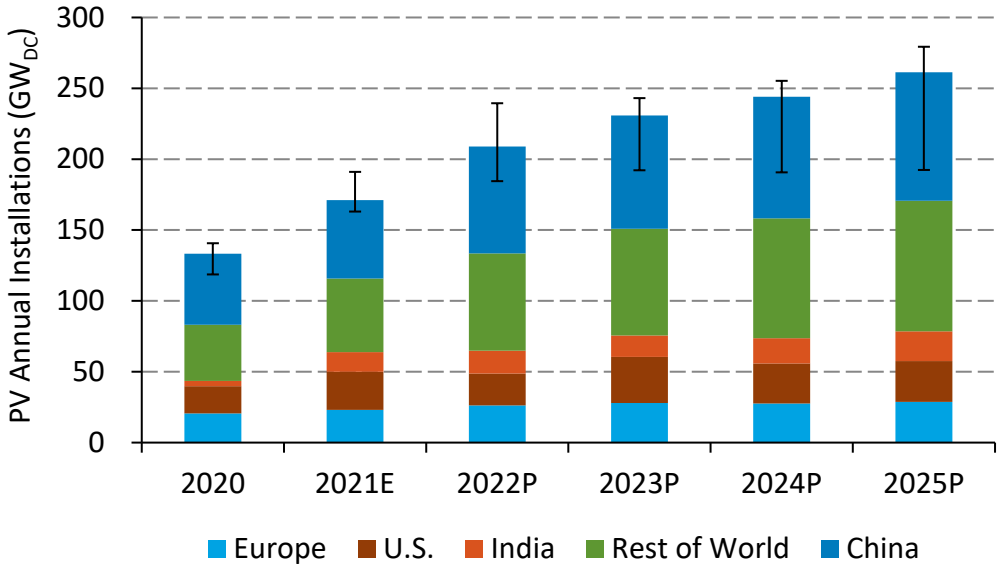
International Q1–Q3 2021 Installations



- In the first 9 months of 2021, PV installations increased significantly, y/y, for many leading markets, including the United States.
- India installed 177% more in the first 9 months of 2021 than it did over the same period in 2020.
  - Analysts attributed India's large increase to targeted lockdowns that better enabled developers to manage contingencies.
- Australia's installations are slightly down, y/y, due to reductions in large-scale PV capacity additions, which are more likely to occur in Q4.
- At the end of June 2021, these countries had cumulatively installed 518 GW$_{DC}$ of PV.
  - Though China represents over half of this capacity, it has significantly fewer watts of solar per person than Germany and Australia.

Sources: Australian Photovoltaic Institute. IEA, Snapshot of Global PV Markets: 2021. Mercom (11/01/21, 12/13/21). Wood Mackenzie/SEIA: U.S. Solar Market Insight: Q4 2021.

Annual Global PV Demand



- An estimated 171 GW of PV were installed globally in 2021.
- Analysts project continued increases in annual global PV installations, with a median estimate of 209 GW_{DC} in 2022 (22% y/y growth) and 231 GW_{DC} in 2023 (11% y/y growth).
- China, Europe, the United States, and India are projected to account for about two-thirds of global PV installations over this period.
- Analysts note that these projections come despite many projects in 2022 risking delay or cancelation due to increasing material and shipping costs.

Notes: E = estimate, P = projection. Bars represents median projections for analyses with country-level estimates. Error bars represent high and low projections. Not all sources have data for all categories.
Sources: BNEF, 4Q 2021 Global PV Market Outlook, 11/25/21; Goldman Sachs Equity Research, Americas Clean Technology: Solar 2021 Outlook, 01/09/22; Solar Power Europe, Global Market Outlook For Solar Power 2021-2025, 7/20/21; InfoLink, 12/27/21; IEA, Renewables 2021, 12/21; Rystad Energy, 10/26/21, Wood Mackenzie and SEIA's US Solar Market Insight, Q4 2021.

CSP Updates

- **Technological developments and demonstrations announced last quarter aim to expand the scope and value of CSP applications.**
  - **Thermal Storage:** (1) patent filing for higher-reliability molten salt tanks by a consortium including Australian CSP company Vast Solar, (2) R&D by the German Aerospace Center on sulfur as an energy storage medium (with additional chemical manufacturing and agricultural applications)
  - **Industrial Process Heat:** solar steam generation system pilot, using technology from Sweden's Absolicon, in the Canary Islands
  - **Green Hydrogen and Solar Drop-In Fuels:** (1) demonstration of hydrogen production via concentrated solar heat and electricity plus solid-oxide, high-temperature electrolyzers by Bloom Energy and Heliogen, (2) demonstration by the French solar research facility at CNRS-PROMES of hydrogen production from biomass gasification aided by concentrated solar heat, (3) COP 26 award for R&D on concentrated sunlight to produce renewable transportation fuels from water and CO_2, developed by a consortium of European research institutions and companies
  - **Hybrid Plants for Continuous Power Supply:** (1) system by SENER combining CSP with molten salt storage and PV in Spain, (2) System by CrossBoundary Energy combining CSP with batteries and diesel generators for mining operations in Madagascar
  - **Modular, Fixed-Mirror Design:** demonstration by CENER (the National Renewable Energies Centre) in Spain of a 300-kWt fixed-mirror system, the first prototype without solar field tracking on such a scale, designed for modularity and capital cost reductions
- **Africa, Southwest Asia, and China lead in current CSP project development. Namibia and Iran have announced their first CSP projects.**

Sources: Helioscsp (12/7/21, 11/26/21, 11/25/21, 11/24/21a, 11/24/21b, 11/22/21, 11/19/21, 11/18/21, 11/17/21, 11/9/21, 10/28/21)

U.S. CSP Company Heliogen Becomes Publicly Traded

- At the end of 2021, U.S.-headquartered CSP developer Heliogen became a public company, traded on the New York Stock Exchange, after merging with Athena Technology Acquisition Corporation and raising $188 million in the process.
- The news is counter to recent trends for CSP companies in the United States.
  - The United States led the world in CSP technology with the first large-scale plants in the 1980s and then another resurgence from 2007 to 2015 in large part thanks to DOE loan guarantees for 1.2 GW in projects.
  - However, many of the companies involved have either filed for bankruptcy (SolarReserve and Abengoa in 2021), are not actively involved in CSP development (Nextera), or, in the case of Brightsource, have not publicized activity (Brightsource's last press release was in 2017).
- Additionally, Heliogen's public trading of stock comes shortly after the company began generating revenues (starting in early 2021).
  - Heliogen had net losses of ~$7 million in 2019 ($2020).
  - Heliogen announced its first customer in March 2021—Rio Tinto, the world's second-largest mining company—and it began steps to go public in April.
  - The company had been privately funded before by, among others, Bill Gates.

Sources: PV Magazine (1/3/22); Heliogen Public Filings (S-4); CNN (11/19/19)

Heliogen Technological Focus

- Heliogen develops and installs modular CSP plants using artificial intelligence to precisely direct heliostats to collection towers. It also uses an autonomous system to install and maintain the heliostat field.
  - The innovation is mostly centered on the lower cost and the added precision of the heliostats.
  - Because of the precision gained, Heliogen claims to be able to generate heat above 1,000 degrees Celsius (tower plants operate at a peak of 550 degrees); however, they still face the same challenges as other developers in designing a system that can manage that high temperature.
- Heliogen's success also comes at a time when the world is trying to find ways to decarbonize industrial processes, on top of its focus on transportation and electricity.
- In addition to providing process heat for mining, Heliogen has collaborated with Bloom Energy to produce green hydrogen.
  - The companies claim that when Heliogen's technology is paired with Bloom Energy's high-temperature electrolyzer, hydrogen can be made 45% more efficiently. The CSP reduces the need for electricity, which represents almost 80% of the cost to produce hydrogen.

Sources: PV Magazine (11/16/21); Scientific American (07/14/16); Brightsource (April 2014)

World's Largest Green Hydrogen Project Begins Construction

- Sinopec started construction on a $470 million demonstration green hydrogen project in Xinjiang, China. When built, it will have:
  - 300 MW of captive PV to supply half of the electricity
    - The other half will come from local wind farms.
  - 260 MW of alkaline electrolyzers to produce 20,000 tons of hydrogen (with a 49% capacity utilization rate), or 0.5% of Sinopec's current annual yield
    - The hydrogen will be used at a local oil refinery, but it could be used to power around 86,000 hydrogen cars.
  - Hydrogen pipeline and hydrogen storage tanks (able to store 1/3 of daily production volumes).
- The project is expected to begin operation in 2023.

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

- **California, the largest distributed PV market in the United States, is proposing revisions to its net metering that would reduce compensation for Distributed PV, and incentivize electrification and energy storage**
- **An estimated 21 GW_{AC} (27 GW_{DC}) of PV were installed in the United States in 2021.**
- **The United States installed a record 11.8 GW_{AC} (16.3 GW_{DC}) of PV in the first 9 months of 2021.**
- **The United States installed approximately 5.7 GWh/1.9 GW_{AC} of energy storage onto the electric grid in the first 9 months of 2021, up 419% y/y, as a result of record levels of residential and front-of-the-meter deployment (mostly in California).**

Bipartisan Infrastructure Law

(aka Infrastructure Investment and Jobs Act or Public Law No. : 117-58)

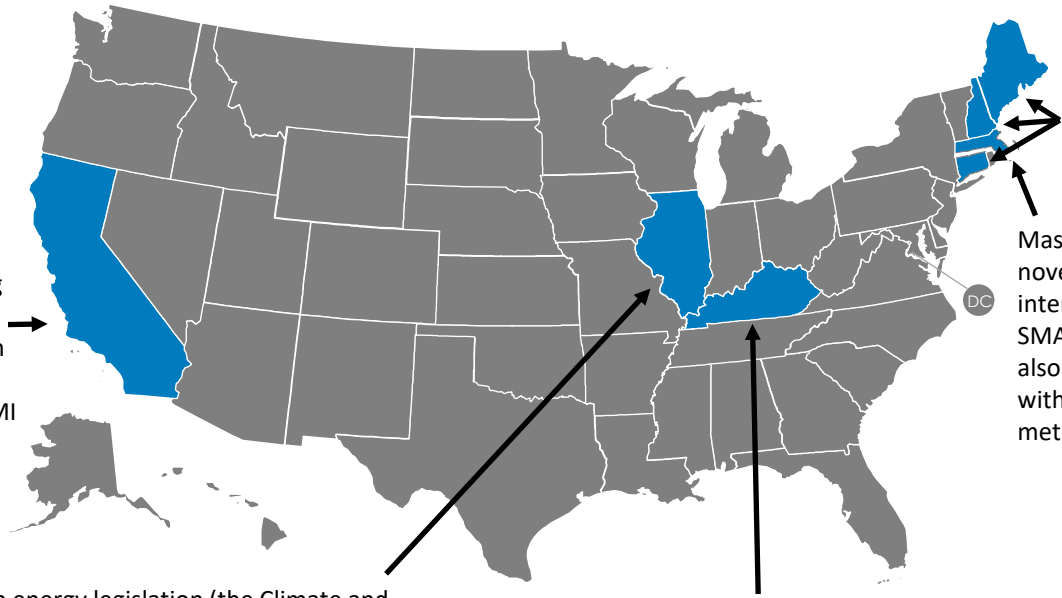
- $62 billion to DOE, $16.2 billion to EERE (for comparison, the ARRA was $31 billion to DOE) which will impact solar energy in a variety of ways including directly through funding to SETO for fiscal year FY 2022–FY 2025:
  - $40 million for *SETO research, development, demonstration, and commercialization*
  - $20 million for *advanced solar energy manufacturing initiative*
  - $20 million for *solar energy technology recycling RD&D program*
  - Adding the viability of siting solar energy on current and former mine land to the Solar Energy Technology strategic vision report*
- And by
  - Increasing access to electricity ($17 billion)
  - Increasing demand for (clean) electricity (~$26 billion)
  - Emphasizing energy efficiency (~$4 billion)
  - Investing in the critical minerals/materials supply chain (~$1.4 billion)
  - Investing in cybersecurity for the energy sector ($550 million)
  - Investing in the workforce and an equitable transition (one council, one board, $750 million)
  - Establishing the Office of Clean Energy Demonstration (OCED) with ~$21 billion in funding.
- The Infrastructure Law is separate, and sometimes additive, from what Congress annually appropriates DOE. Because Congress has not yet passed a full-year appropriations bill, some funds awarded in the Infrastructure Law may be held up.

*$500 million (FY 2022–FY 2026) for clean energy demonstration projects (2/5 must be solar) on current and former mine lands, but that funding goes to the OCED.

Public Law No. :117-18

H2 2021 State Updates

Many states took actions related to distributed generation compensation policies, including considering changes to credit rates or the creation of net metering successor tariffs. Of special interest was the consideration of cost shifts either to or away from distributed generation customers.



Maine expanded its size limit for net metering; New Hampshire called for any net metering rules to avoid cost shifts; and Connecticut approved multiple compensation tariff options.

Massachusetts DPU provisionally approved a novel cost-sharing structure for interconnection projects and expanded the SMART program after 18 months. Lawmakers also enacted an expansive clean energy bill with emission reduction targets and net metering caps.

SMUD approved a net metering successor tariff. CPUC has proposed cutting compensation for distributed PV on the basis that it shifts costs and harms LMI customers disproportionately.

Illinois enacted expansive clean energy legislation (the Climate and Equitable Jobs Act) which increased its RPS to 40% by 2030, 50% by 2050, and effectively gets rid of coal plants by 2030. It also set a date for a net metering transition.

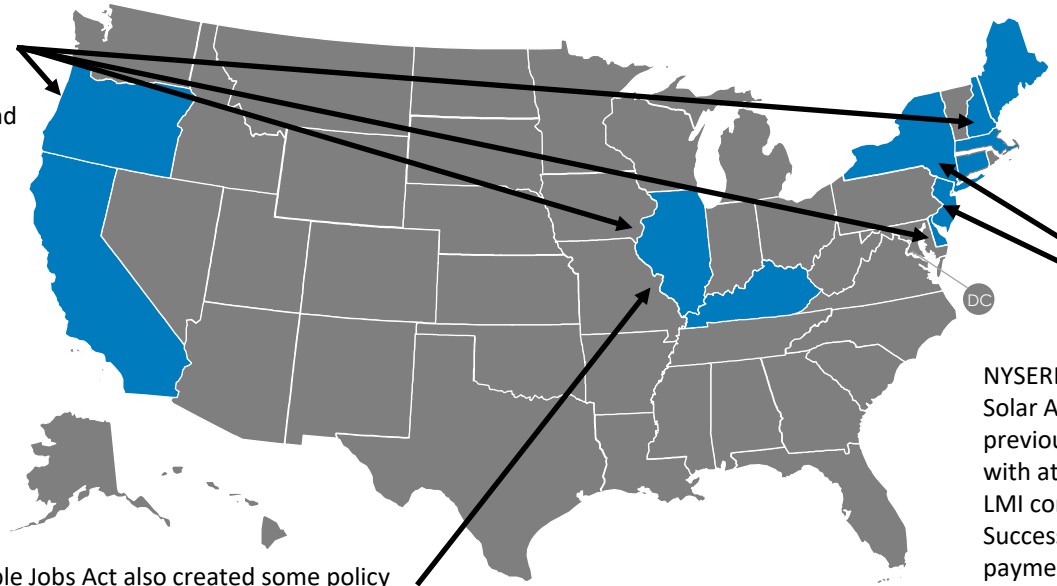
Kentucky Public Service Commission decided to continue offering traditional retail rate net metering.

Source: Meister Consultants Group, *50 States of Solar: Net Metering Quarterly Update* (Q3 2021), pv magazine: MA DPU interconnection, SMART expansion, and CPUC NEM articles.

H2 2021 State Updates

Community solar continues to expand, with many states requiring LMI participation goals and/or greater incentives for LMI participants and projects.

Illinois, Delaware, and New Hampshire increased their maximum community solar system size limits. Delaware and Oregon both loosened their requirements for community solar with the aim to increase LMI participation.

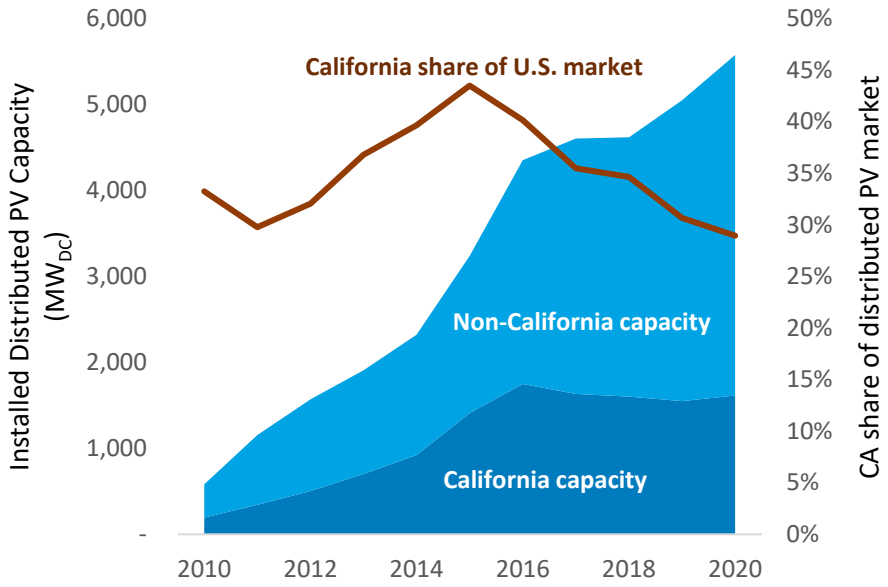


NYSERDA introduced the Inclusive Community Solar Adder, which adds $52.5 million to previous New York community solar incentives, with at least 20% capacity being earmarked for LMI communities. New Jersey opened the Successor Solar Incentive, which will provide payments for renewable energy certificates from community solar, with a bonus for LMI participants.

Illinois's Climate and Equitable Jobs Act also created some policy certainty for distributed PV (including community solar) by increasing the Solar for All program by $30 million and opening more capacity in the Adjustable Block Programs' community solar subprogram for projects waitlisted when funding lapsed.

Source: Meister Consultants Group, *50 States of Solar: Net Metering Quarterly Update* (Q3 2021), pv magazine: MA DPU interconnection, SMART expansion, and CPUC NEM articles.

California Proposal Would Reduce Compensation for Distributed PV, Incentivize Electrification and Energy Storage



Annual installed U.S. distributed PV capacity, showing California's ~30% share of the national distributed PV market

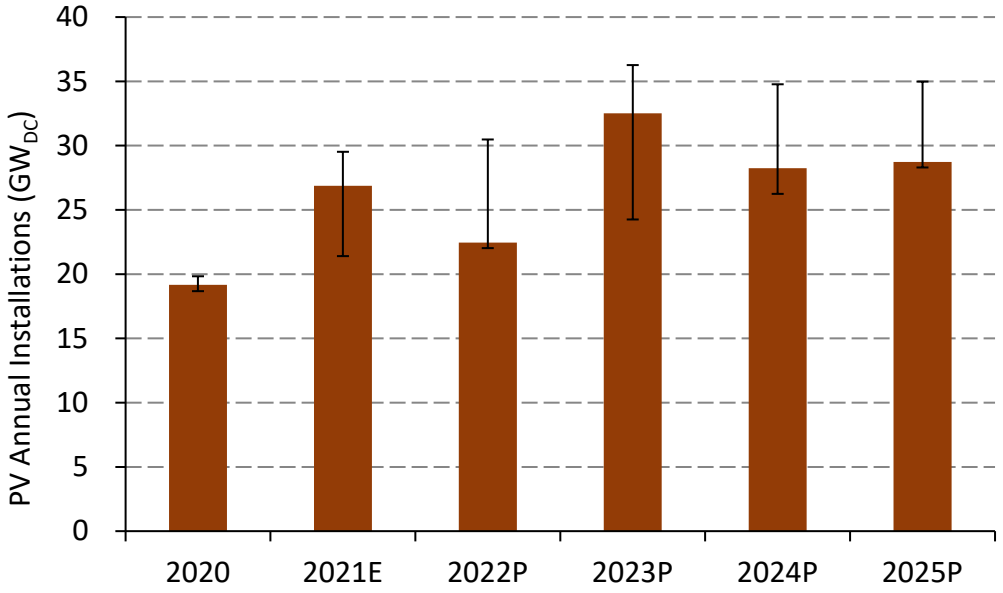
- The 12/13 CPUC proposal cuts compensation for behind-the-meter PV.
  - California's existing net energy metering policy credits PV customers at the retail rate for energy exported to the grid.
  - The proposal says this current policy shifts electric system costs from PV to non-PV customers, is not cost-effective, and harms low-income customers disproportionately.
  - The proposed avoided-cost rate-calculation method, with instantaneous netting of energy consumption/production, likely will cut PV energy export rates by ~75%–80%.
- A proposed $8/kW monthly residential PV charge (not applied to low-income customers) is meant to mitigate cost-shifting to non-PV customers and increase utility revenue.
  - The monthly charge is partially offset by a Market Transition Credit paid for 10 years, starting at $1.62/kW (PG&E) and $3.59/kW (Southern California Edison) for non-low-income residential systems connected in 2022 and then declining 25% each year for systems connected from 2023 through 2025.
  - The Market Transition Credit was designed to create a glide path from the old to the new compensation scheme and to offset the $8/kW monthly charge to the extent that adopters of PV + storage systems could achieve a 10-year payback period (as modeled by CPUC).

Sources: Wood Mackenzie and SEIA, US Solar Market Insight (Q4 2021); Utility Dive (12/14/21); PV Tech (12/14/21); CPUC, Rulemaking 20-08-020 (12/13/21); Cowen, CPUC Proposal On NEM 3.0 Promotes Storage (12/13/21), Watts Happening: Proposed NEM 3.0 Promotes Storage (12/17/21); Goldman Sachs, NEM Proposed Decision - Potential Fixed Charges, Lower Rates (12/14/21).

California Proposal Would Reduce Compensation for Distributed PV, Incentivize Electrification and Energy Storage

- The proposed policy could slow California's deployment of distributed PV, which generated the equivalent of 7% of state electricity sales and 38% of total state PV production in 2020.
- The policy is meant to incentivize electrification and PV+storage.
  - Electrification and storage enable increased PV self-consumption, which offsets the full retail electricity rate and is more valuable than exports under the proposed rates.
  - Storage also enables shifting of PV energy exports to peak periods with higher time-of-use rates.
- The policy would have different effects on residential and nonresidential PV systems.
  - Export compensation rate structures are the same for residential and nonresidential PV systems, but only residential systems are subject to the $8/kW monthly charge.
  - Nonresidential loads generally may align better than residential loads with times of solar energy generation, which can reduce the importance of exports to nonresidential system economics.
- The policy requires existing (NEM 1.0 and 2.0) solar customers to transition to the new tariff no later than 15 years after the date of interconnection, with an energy storage rebate available to customers who switch to the new tariff earlier.
- Proponents of the proposal argue that the current NEM structure causes non-solar customers – including a disproportionate share of LMI customers – to subsidize solar adopters. Critics of the proposal argue that distributed solar is not being properly valued and that it will make rooftop solar no longer economically viable, significantly decreasing demand and putting thousands of solar installers out of work.
- After a 25-day comment period, a decision on the proposal will come within 30 days, with a vote on the decision delayed until after January 27, 2022.

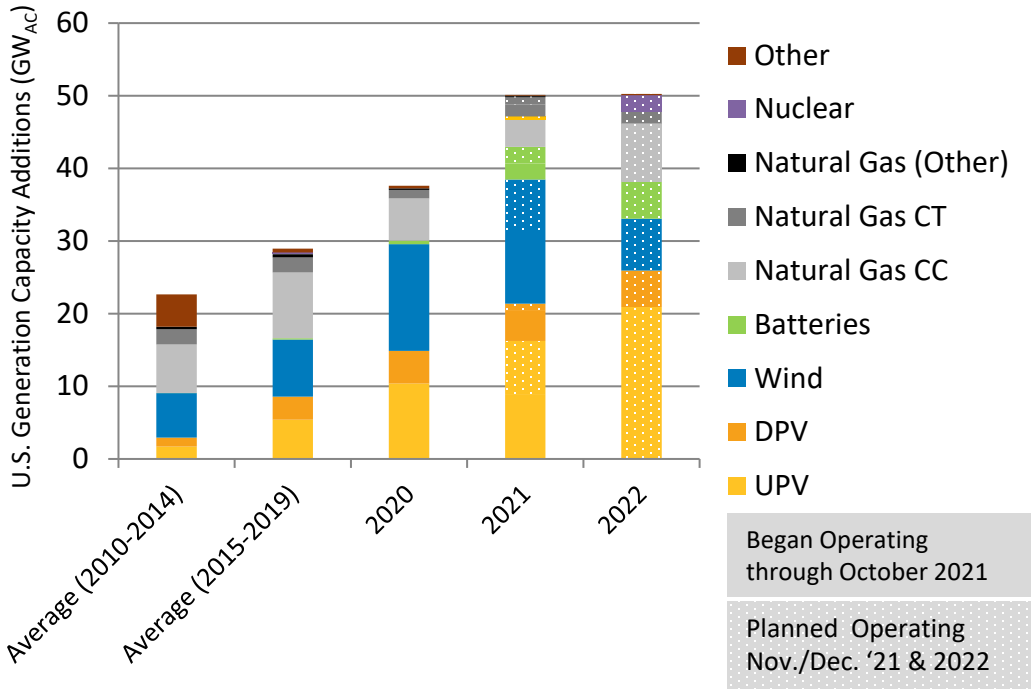
Annual U.S. PV Demand



Notes: E = estimate, P = projection. Bars represents median projections, and error bars represent high and low projections. Not all sources have data for all categories.
Sources: BNEF, 4Q 2021 Global PV Market Outlook, 11/25/21; Goldman Sachs Equity Research, Americas Clean Technology: Solar 2021 Outlook, 01/09/22; Wood Mackenzie and SEIA's US Solar Market Insight, Q4 2021.

- An estimated 27 GW_{DC} of PV were installed in the United States in 2021.
- The median projection is for a decrease to 22 GW_{DC} in 2022 (16% y/y) before installations grow to 33 GW_{DC} in 2023 (45% y/y) and then decline again in 2024 (13% y/y).
- Analysts recently cut 2022 U.S. projections due to rising costs and logistical challenges.
- Analysts project a significant increase in PV demand should the federal investment tax credit be extended, as proposed by the Build Back Better legislation passed in the House.

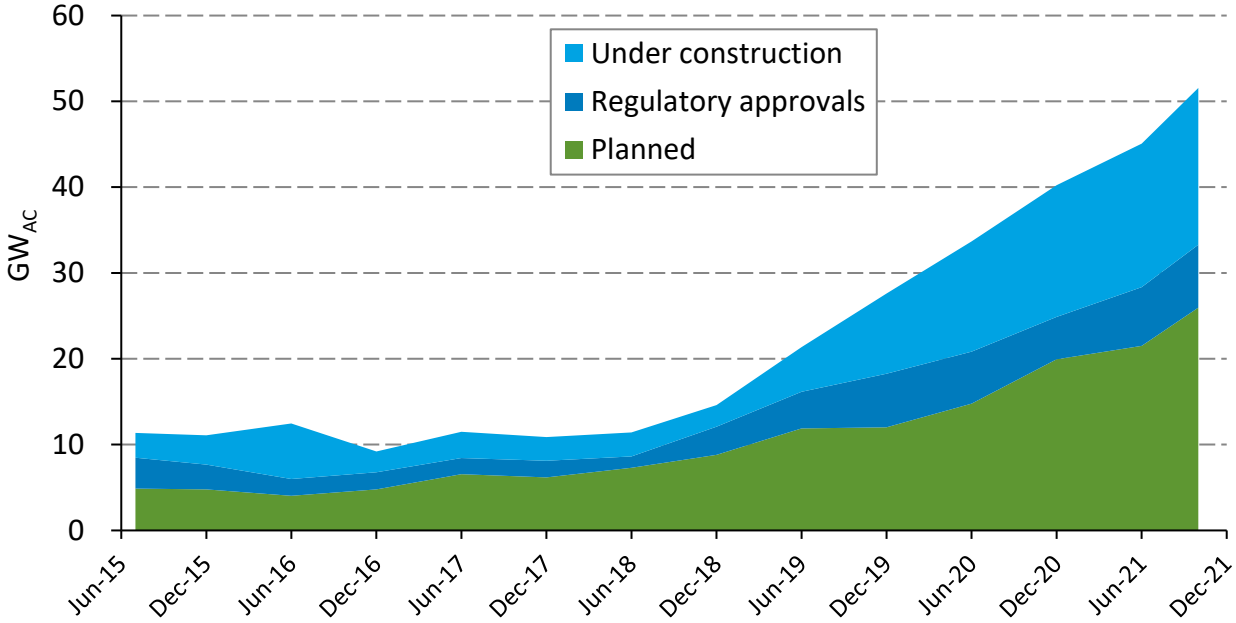
U.S. Generation Capacity Additions by Source: 2010–2022



- EIA estimates the percentage of U.S. electric capacity additions from solar will grow from 40% in 2020 (14.9 GW) to 43% in 2021 (21.4 GW) and over 50% in 2022 (25.9 GW).
  - Solar averaged 13% of capacity additions from 2010 to 2014 and 30% from 2015 to 2019.
  - Wind and batteries are estimated to represent another 34% and 9% in 2021, respectively, and 14% and 10% in 2022, respectively.
- It is estimated that significantly more electric generation capacity will be coming online than in the previous decade.
- Despite robust projections from EIA, in December SEIA revised their 2022 solar projections downwards and is expecting the market to shrink y/y (though remain above 2020 levels) due to supply chain constraints and price increases. **Source**: Wood Mackenzie/SEIA: U.S. Solar Market Insight: Q4 2021.

Sources: EIA Form 860M/Preliminary Monthly Electric Generator Inventory ("Planned" and "Operating" Dec 2021) EIA Short-term Energy Outlook Table 8b, Dec 2021; Solar power will account for nearly half of new U.S. electric generating capacity in 2022 - Today in Energy - U.S. Energy Information Administration (EIA)

EIA PV Project Planned Pipeline

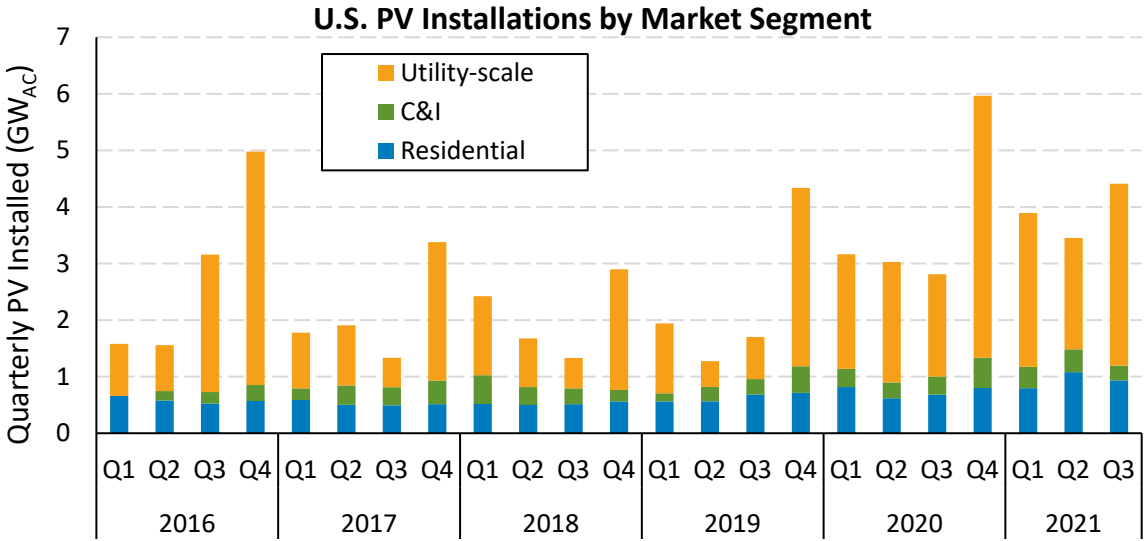


According to EIA data, the U.S. PV project pipeline of utility-scale PV projects continues to hit record highs, with 18 GW_{AC} of projects being under construction, 7 GW_{AC} having received regulatory approval, and 25 GW_{AC} planned as of October 2021.

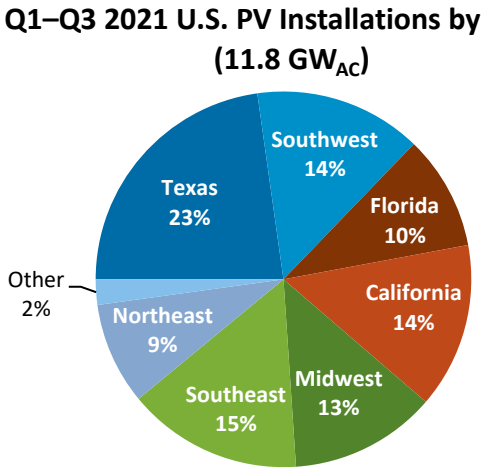
Note: Pipeline is defined as all planned PV projects that have been submitted in EIA's Form 860M. All projects have a scheduled placed-in-service date between 2021 and 2030.
Source: EIA Form 860M/Preliminary Monthly Electric Generator Inventory ("Planned" June and October 2021).

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

- The United States installed 11.8 GW_{AC} of PV in Q1–Q3 2021, its largest Q1–Q3 total ever, up 31% y/y.
  - Residential PV was up 33%, C&I PV was up 13%, and utility-scale PV was up 33% in Q1–Q3 2021.



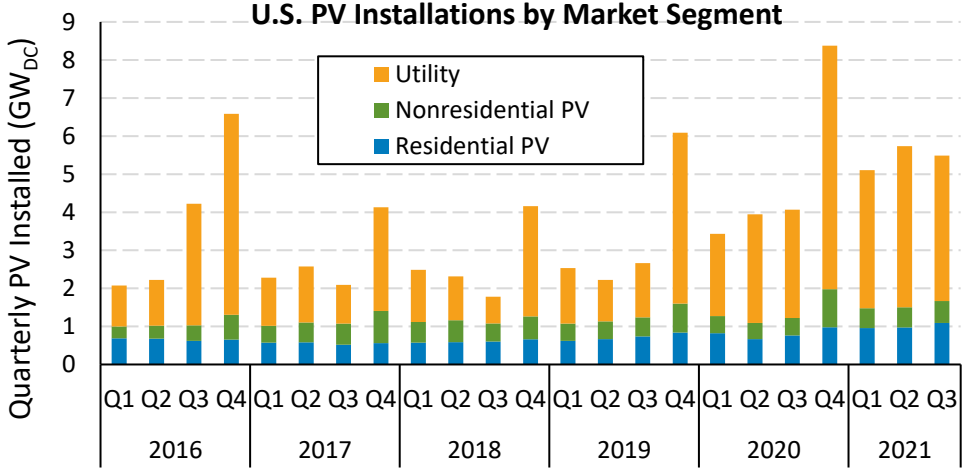
- Texas, Florida, and California installed over 1 GW each, and Virginia added over 780 MW_{AC} in Q1–Q3 2021—over half of total installations.
  - Texas installed nearly 2.7 GW_{AC}.
- Despite a concentration of PV installations in the top markets, diversification of growth continues across the United States.
  - Thirty-eight states installed >10 MW_{AC} of PV in Q1–Q3 2021, and 21 states installed >100 MW_{AC}.



Note: EIA defines "utility-scale" as projects having a capacity greater than 1 MW. EIA reports values in W_{AC} which is standard for utilities. The Solar industry has traditionally reported in W_{DC}. See next slide for values reported in W_{DC}.
Sources: EIA, "Electric Power Monthly," forms EIA-023, EIA-826, and EIA-861 (August 2021, February 2021, February 2019).

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

- SEIA reports the United States installed 16.3 GW_{DC} of PV in Q1–Q3 2021, up 43% y/y.
  - The first three quarters of 2021 each achieved record PV installs, with quarterly residential installations surpassing 1 GW_{DC} for the first time in any quarter.
- At the end of Q1–Q3 2021, there were over 112 GW_{DC} of cumulative PV installations.

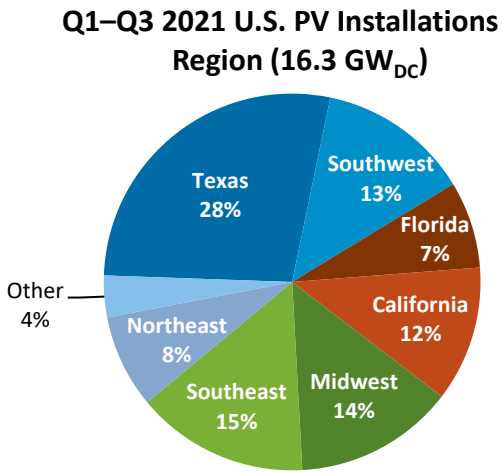


Source: Wood Mackenzie/SEIA: U.S. Solar Market Insight: Q4 2021.

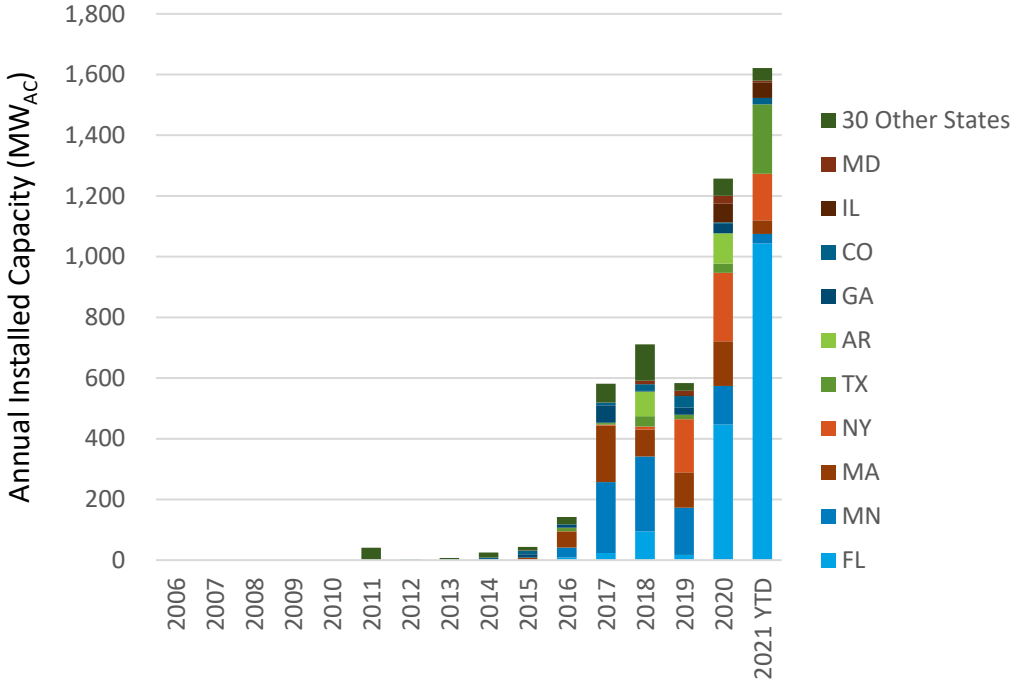
Unlike the values on the previous slide, the values on this slide are in GW_{DC} instead of GW_{AC}.

- These record installation levels are happening despite supply chain issues causing delays, higher prices, and permitting and labor constraints.
  - Domestic manufacturers have somewhat insulated the distributed market; however, limited supply can cause developers to procure equipment not in their original design, which can cause redesigns and push out online dates.

SEIA reports TPO market share at its lowest levels in over a decade—below 25% in each of the last four quarters.



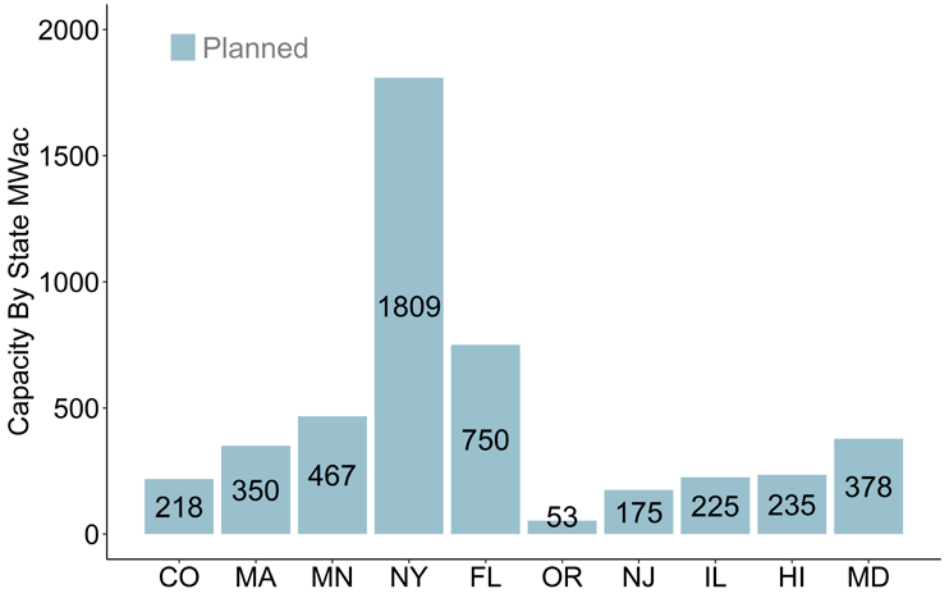
Annual Community Solar Installations, 2006–2021 YTD



- Cumulative community solar capacity topped 5 GW_{AC} as of mid-December 2021, across ~1,900 projects in 40 states and Washington, D.C.
- As of mid-December 2021, annual U.S. installations were 29% (1.6 GW_{AC}) above 2020 installations thanks largely to over 1 GW_{AC} of installations in Florida.
- The second-largest state in 2021, to-date, is Texas with over 200 MW_{AC} of projects.
  - Texas installed 95 GW_{AC} of community solar projects from 2016 to 2020.

Note: 2021 Data are as of mid-December 2021. Additional projects are likely to come online at the end of the year. The National Renewable Energy Laboratory's (NREL) definition of Community Solar: "*… a solar installation with multiple offtakers or owners, referred to as "subscribers." The subscribers enter into a contractual relationship with the owner or operator of the installation (or an intermediary) to receive some or all of the financial returns from a predefined share of the installation's output.*"
Data Source: NREL Sharing the Sun data set (2021) and publication (2021)

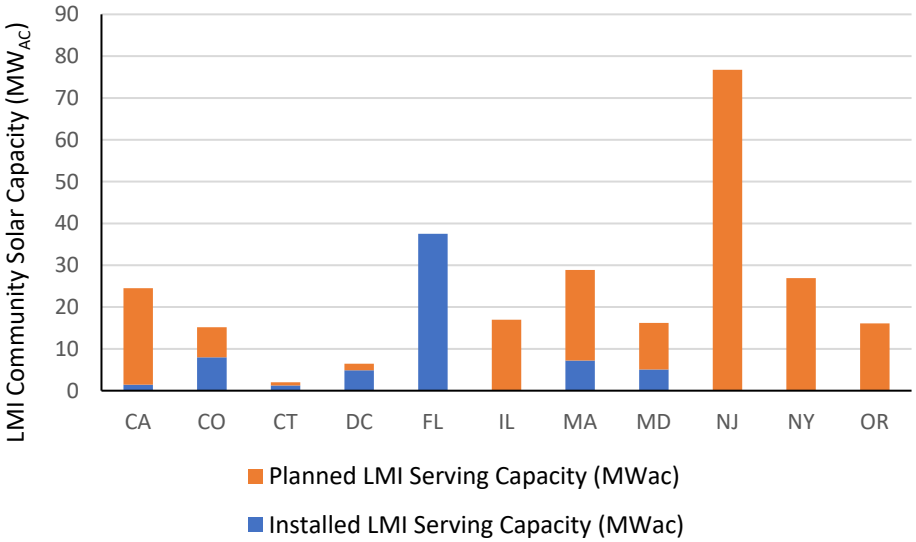
Planned Community Solar Installations, December 2021



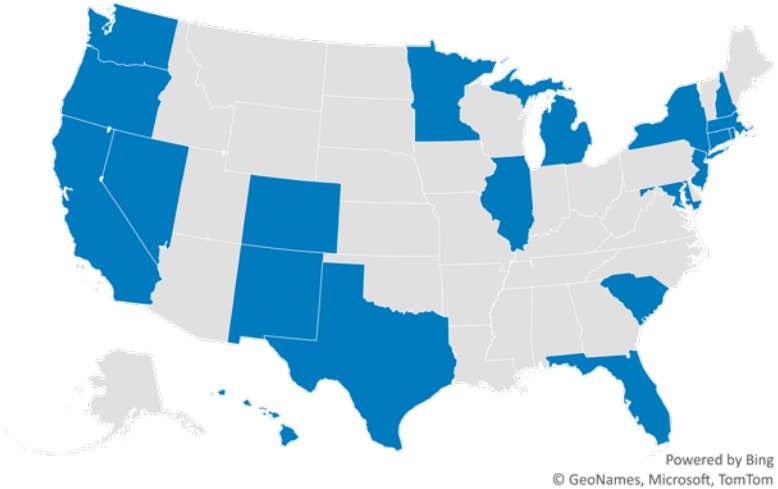
- Nearly 4.7 GW_{AC} of projects were in the NREL project queues as of December 2021, indicating the market is continuing to grow; most of the planned capacity was in Florida, New York, Massachusetts, and Minnesota.
  - Projects in the NREL queue are either under construction or were awarded and accepted project capacity from administrators.
  - If all these projects come online, it would nearly double cumulative community solar capacity.

Note: 2021 Data are as of mid-December 2021.
Data Source: NREL Sharing the Sun dataset (2021) and publication (2021)

Low- and Moderate-Income (LMI) Community Solar Tops 65 MW_{AC}, with >200 MW_{AC} in Queues, December 2021



Twenty states and Washington, D.C. have provisions requiring or incentivizing LMI community solar.

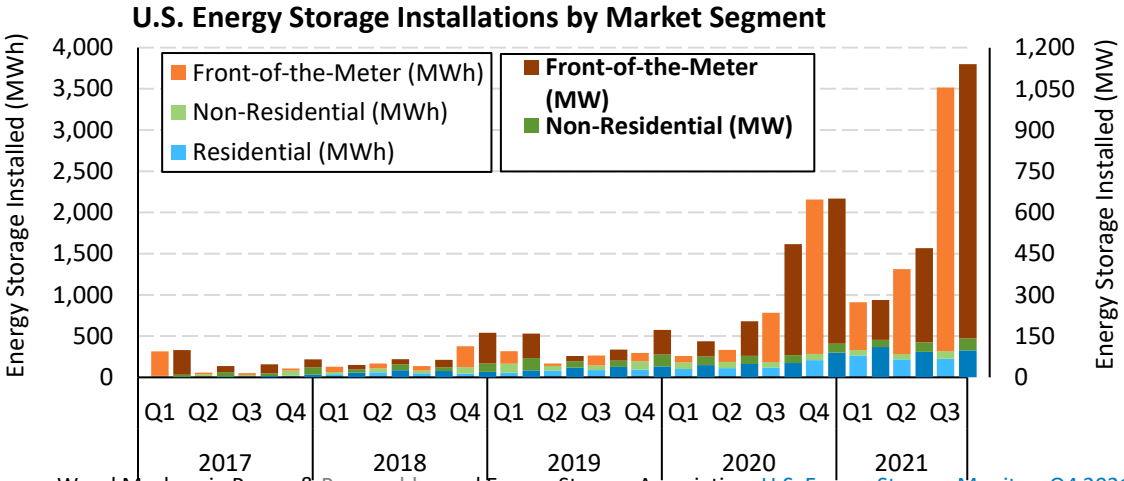


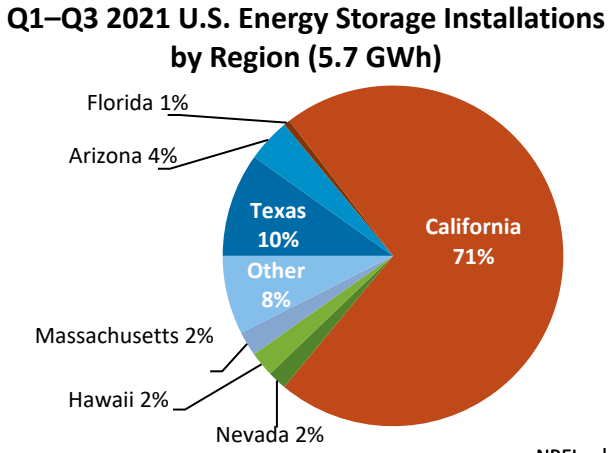
Note: 2021 data are as of mid-December 2021. Additional projects are likely to come online at the end of the year.
Note: Planned projects are either under construction or were awarded and accepted project capacity from administrators.

U.S. Energy Storage Installations by Market Segment

- The United States installed approximately 5.7 GWh (1.9 GW_{AC}) of energy storage onto the electric grid in Q1–Q3 2021, up 419% (231%) y/y, as a result of record levels of residential and front-of-the-meter deployment (mostly in California; 8 projects accounted for 2.7 GWh).
  - Q3 2021 is the first quarter during which >1 GW_{AC} of storage was installed.
  - Projects in the residential and nonresidential sectors have average durations around 2 hours, while front-of-the meter segments average above 3 hours. Growth in 4-hour front-of-the meter projects are expected to meet resource adequacy requirements.

- California continues to dominate front-of-the meter and residential installations, but Puerto Rico, Texas, and Arizona also had significant Q3 installations.
- Massachusetts continues to lead nonresidential deployment, with projects supported by SMART. New York is also beginning to see community-scale storage installed, with projects now coming online representing the beginning of a significant pipeline of planned projects there.
- Despite the record levels of storage deployment, Wood Mackenzie expects Q4 of 2021 alone to surpass Q1–Q3 totals.





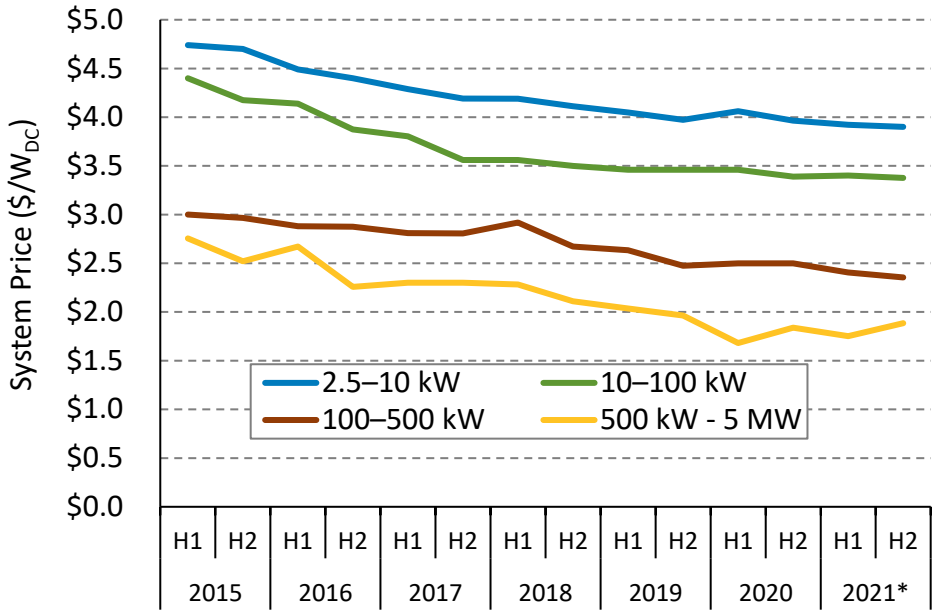
Source: Wood Mackenzie Power & Renewables and Energy Storage Association, U.S. Energy Storage Monitor: Q4 2021.

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

- **Despite supply chain shortages and component price increases, reported PV system prices from select states were relatively flat between H2 2020 and H2 2021.**
  - Prices were flat or declined slightly for system sizes smaller than 500 kW.
  - Prices increased slightly for system sizes larger than 500 kW.
- **Large residential PV installers reported higher installed costs in Q3 2021 compared with Q3 2020, with increasing numbers of installations including battery storage.**
- **When data are included from most of 2021, the median reported prices of residential PV+storage systems in select states were 8%–13% lower than full 2020 median values.**

System Pricing from Select States



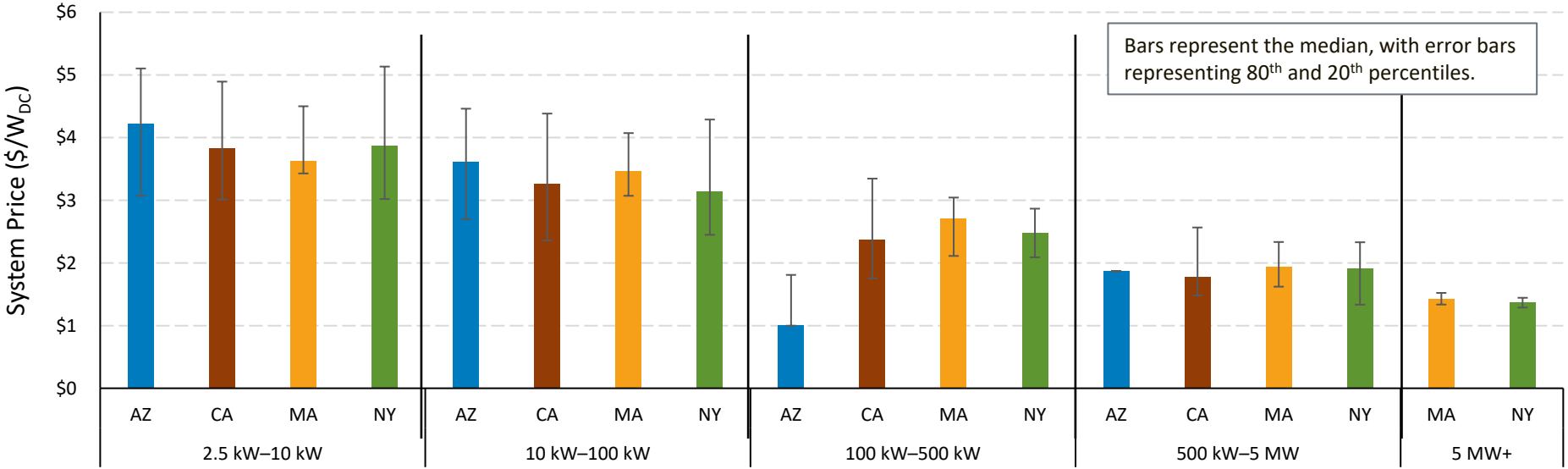
- From H2 2020 to H2 2021 YTD, the median-reported PV system price in Arizona, California, Connecticut, Massachusetts, and New York:
  - Fell 2% to $3.90/W for systems from 2.5 kW to 10 kW
  - Was flat at $3.38/W for systems from 10 kW to 100 kW
  - Fell 6% to $2.36/W for systems from 100 kW to 500 kW
  - Rose 2% to $1.88/W for systems from 500 kW to 5 MW.
- Prices for larger systems may be more affected by rising material costs, because they are more likely to have smaller margins and so are less able to absorb cost increases.

2021 YTD MW: Arizona (193), California (723), Connecticut (8), Massachusetts (182), New York (379)
***** YTD; see source dates below
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 this data set to show a trend over time.
Sources: Arizona (varies, as late as 12/6/21), California NEM database (9/30/21); Connecticut (05/14/21), Massachusetts SREC (09/01/21) and SMART (12/3/21) programs; NYSERDA (11/30/21).

System Pricing from Select States, H2 2021 YTD

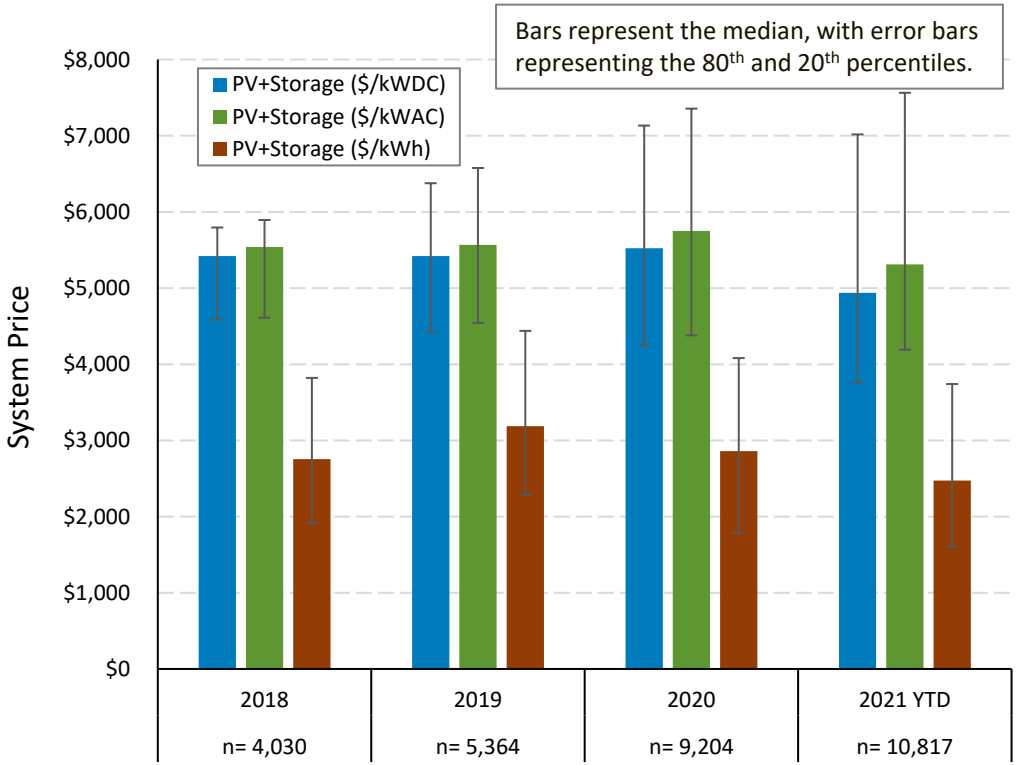
- In addition to price differences based on system size, there is variation between states and within individual markets.

- The median price of a 10–100 kW system in New York was 13% lower than the median in Arizona.
- The low Arizona price for 100–500 kW systems is mostly due to 26 Salt River Project systems in H2 2021.
- Sample sizes are small for larger systems: 13 total systems of 5 MW+, 56 total systems of 500 kW–5 MW, and 191 total systems of 100–500 kW.



2021 YTD MW: Arizona (193), California (723), Massachusetts (182), New York (379)
Note: System prices above $10/W and below $0.75/W were removed from the data set.
Sources: Arizona (varies, as late as 12/6/21), California NEM database (9/30/21), MA SREC (09/01/21) and SMART (12/3/21) programs, NYSERDA (11/30/21).

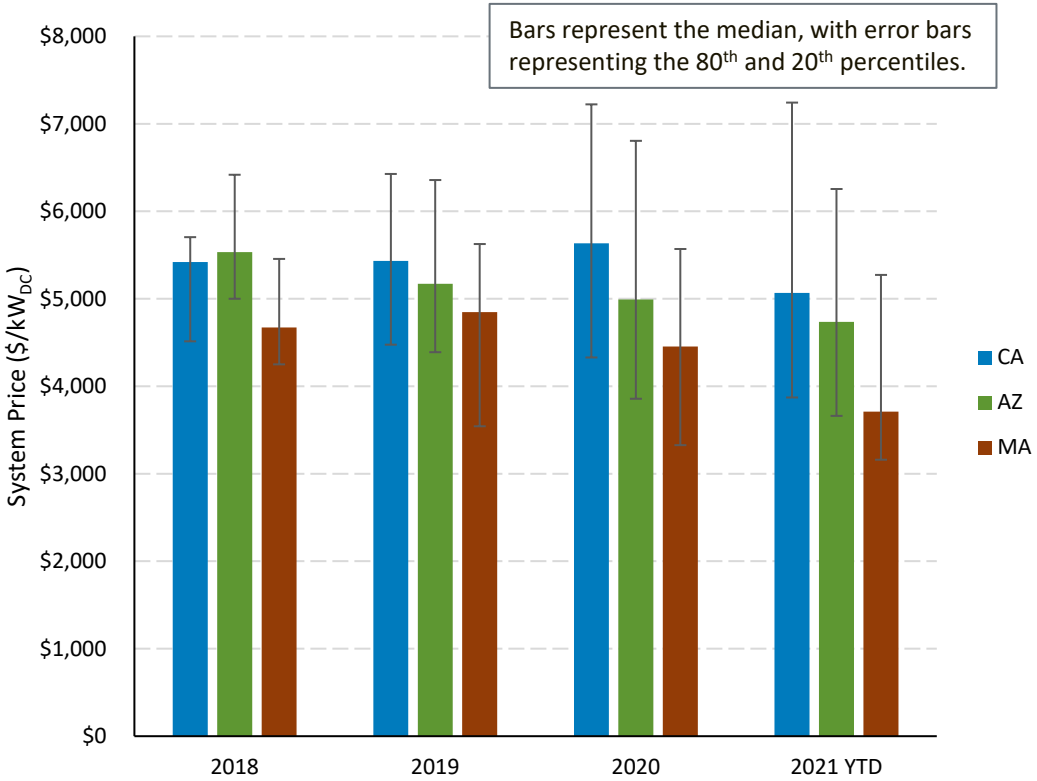
Residential U.S. PV+Storage Pricing



- In 2021 YTD, residential PV+storage systems in Arizona, California, and Massachusetts had a median system price of $2,500/kWh, or $5,300/kW$_{AC}$ ($4,900/kW$_{DC}$)—a reduction of 8%–13% compared to full 2020 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).

2021 YTD residential PV+storage MW: Arizona (10), California (84), Massachusetts (7)
Most recent sources: Arizona Goes Solar (12/6/21); California NEM database (9/30/21); Massachusetts SMART program (12/3/21)

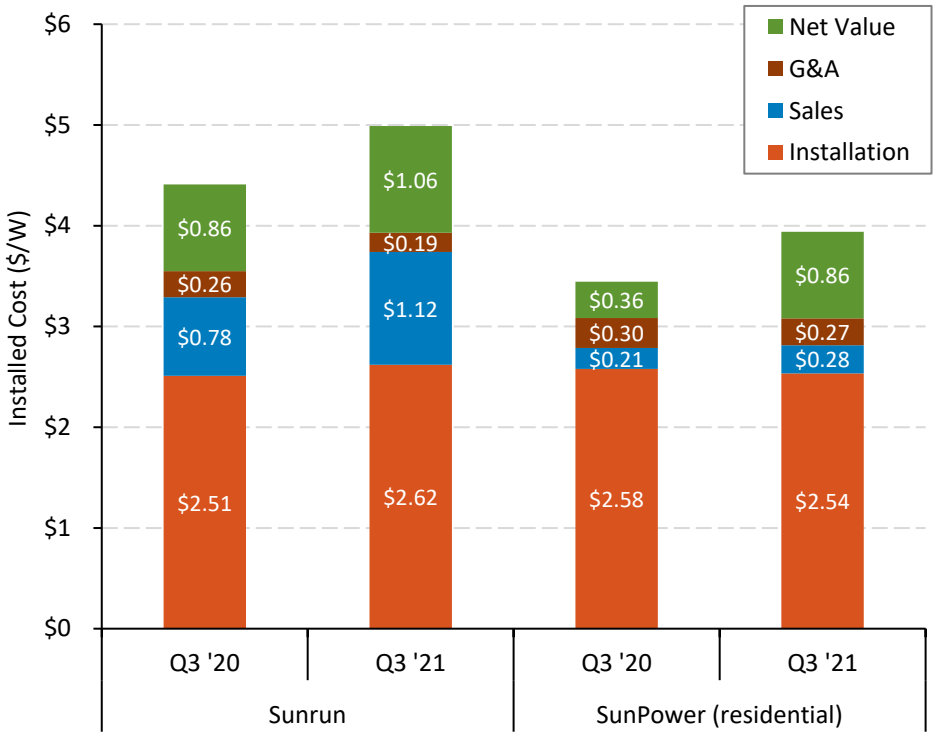
Residential U.S. PV+Storage Pricing



- In 2021 YTD, residential PV+storage systems 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.

2021 YTD residential PV+storage MW: Arizona (10), California (84), MA (7)
Most recent sources: Arizona Goes Solar (12/6/21); California NEM database (9/30/21); Massachusetts SMART program (12/3/21)

Sunrun and SunPower Cost and Value, Q3 2021



- Residential installers reported relatively high material and logistics costs in Q3 2021 as well as tightness in the supply of batteries.
- Costs include PV systems paired with batteries, which are increasing in popularity.
  - Sunrun expects battery installations to increase more than 100% in 2021 over 2020 levels; as of Q3 2021, it had installed more than 28,000 PV+storage systems (~4% of total customers).
  - In Q3 2021, SunPower reported 27% of its solar customers purchased battery storage directly through the company.
  - Sunnova reported the rate of battery attachment continues to recover as supply constraints loosen and customers continue to seek resiliency.
  - Tesla announced in April it would only sell solar paired with storage.

Sources: Corporate filings; UtilityDive (04/27//21).

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

- **In H1 2021, the top 10 companies in module and cell shipments remained the same as in H1 2020.**
- **Many Chinese companies are shifting to producing larger cell sizes.**
- **PV manufacturers, mostly Chinese companies, have generally been profitable since 2019.**

PV Shipment Rankings

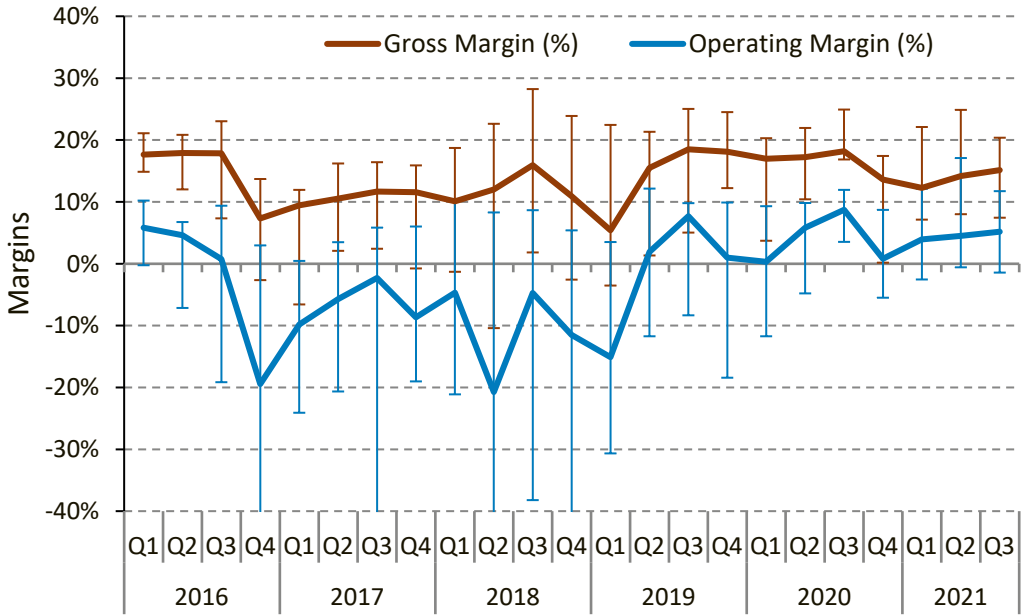
Rank	H1 2021 Shipments		
	Cells		**Modules**
1	Tongwei (14.9 GW, cells + modules)		LONGi (17.0 GW)
2	Aiko (10 GW- 15 GW)*	↑↑	Trina Solar (10.5 GW)
3	Runergy (10 GW- 15 GW)*		JA Solar (9.1 GW)
4	ShanXi Lu'An (3 GW- 5 GW)*	↓↓	Jinko Solar (8.5 GW)
5	Solar Space		Canadian Solar (6.8 GW)
6			Hanwha Q Cells
7			Risen Energy
8		↑	First Solar (3.7 GW produced)
9		↑	Suntech
10		↓↓	Astronergy

** Estimate based on projected 2021 manufacturing capacity*

- Despite changes in rankings, the top 10 companies in module shipment remained the same as in 2020, and the companies and rankings are identical for cells.
  - Vertically integrated companies notably overtook Tier-2 manufacturers, which PV InfoLink attributed to advantages in controlling production costs.
  - The top 10 manufacturers shipped 70.5 GW in H1.
  - The module sector's low utilization rates drove cell manufacturers to trim capacity utilization in May and June.
- Many Chinese companies are shifting to producing larger cell sizes.
  - The top three cell manufacturers saw 182-mm and 210-mm cells accounting for around 38% of total shipment in the first half of 2021, as calculated by PV InfoLink.
  - PV InfoLink predicts demand for 166-mm cells will quickly switch to larger formats.
  - But some U.S. companies have reported challenges with integrating these larger cell sizes.

Sources: PV InfoLink: 2021H1 cell shipment rankings, 2021H1 Module shipment ranking, 1H21 financial statements of vertically integrated companies, 2020 module shipment ranking, 2020 cell shipment rankings; public filings; and the pv magazine: Large format modules present a new set of challenges.

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 continued to increase in Q3 2021, remaining above historical averages.
- There continues to be significant variation by individual companies as individual factors come into play, although variation has been substantially less since 2019.

Lines represent the median, with error bars representing 80th and 20th percentiles for the following companies in Q3 2021: Canadian Solar, First Solar, JA Solar, Jinko Solar, LONGi, Maxeon, Motech Industries, Renesola, Risen, 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 2021 where available.

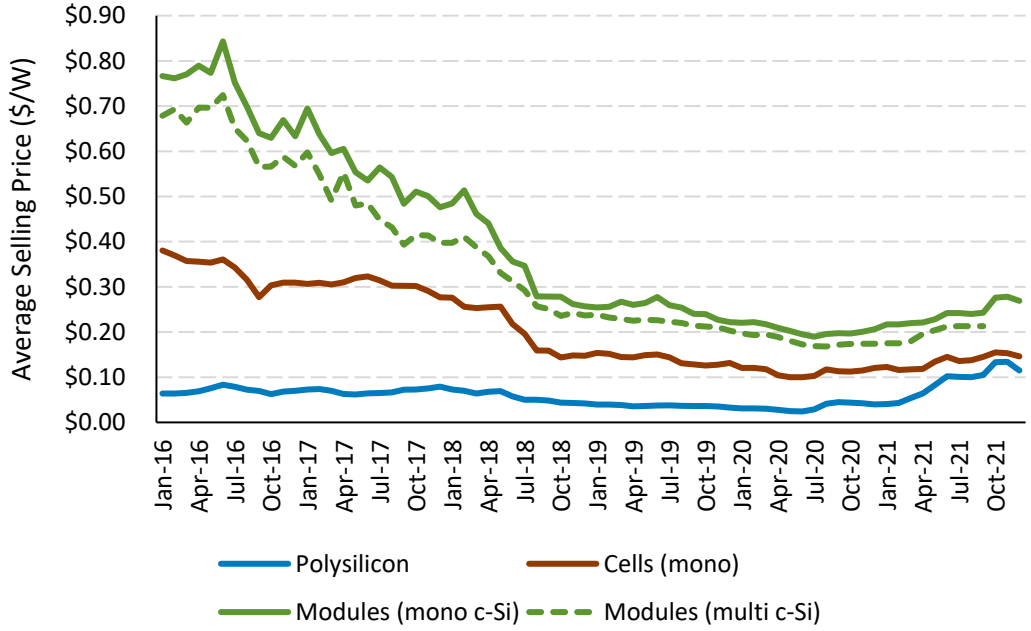
Source: Company figures based on public filings and finance.yahoo.com.

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

- **In November, the spot price of polysilicon climbed above $37/kg—its highest mark in 10 years—before dropping to around $32/kg by the end of the year.**
  - The increased price of polysilicon is driving up wafer, cell, and module pricing but not to the same degree.
- **After dropping 89% from 2010 to 2021, average lithium-ion battery pack prices are projected to rise for the first time in 2022, driven by higher raw material and component prices in the auto industry.**
- **In Q3 2021, U.S. mono c-Si module prices rose $0.01/W, y/y, and were flat q/q— trading at a 59% premium over global ASP.**

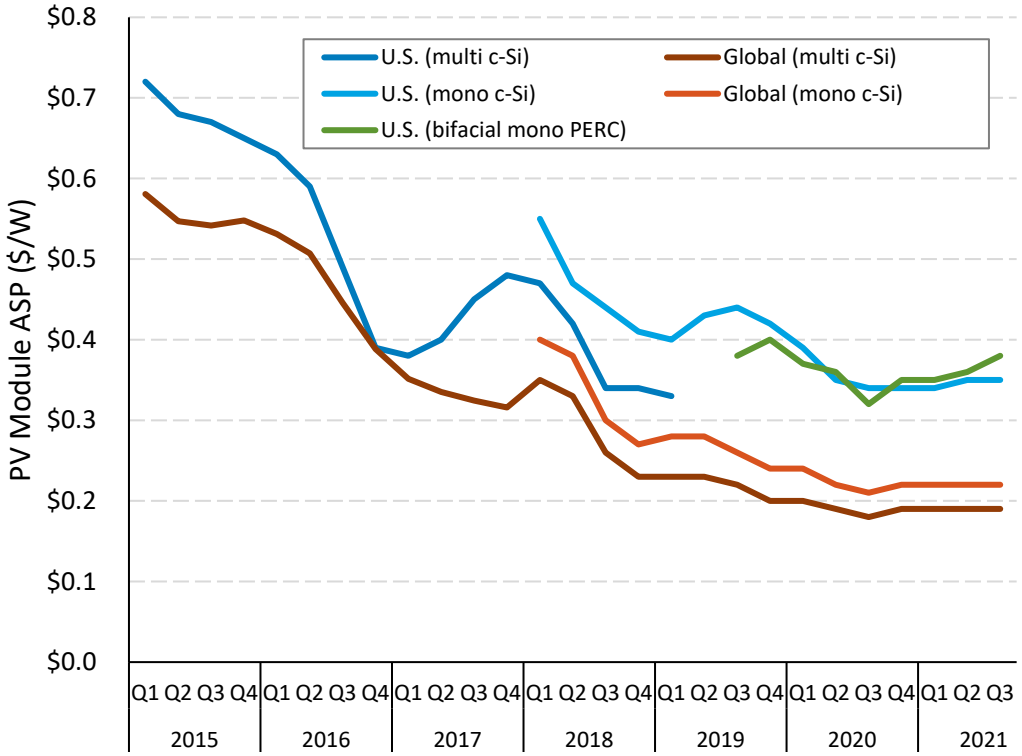
PV Value Chain Spot Pricing



- In November, the spot price of polysilicon climbed above $37/kg owing to a spike in the price of silicon feedstock metal and concerns about a power shortage in China.
  - Prices stayed relatively high because of continued buying by wafer makers, finishing the year around $32/kg—still three times the $11/kg average price at the end of 2020.
  - The price impact has been muted, historically, due to lower polysilicon use per watt over time.
- The increased price of polysilicon is driving up wafer, cell, and module pricing but not to the same degree.
  - Mono-c-Si module global price averages ended 2021 at $0.27/W compared to $0.22/W at the end of 2020.
  - Mono-c-Si cell global price averages ended 2021 at $0.15/W compared to $0.13/W at the end of 2020.

Source: BloombergNEF Solar Spot Price Index (1/4/22); BloombergNEF Bimonthly PV Index (12/20/21).
Kilogram to Watt Conversion: 4.78 grams per watt (2016); 4.73 grams per watt (2017), from Cowen & Co. (05/11/17) add Deutsche Bank (07/19/17); 4.35 (2019); 4.10 (2019); 3.85 (2020); 3.60 (2021) from Bernreuter.

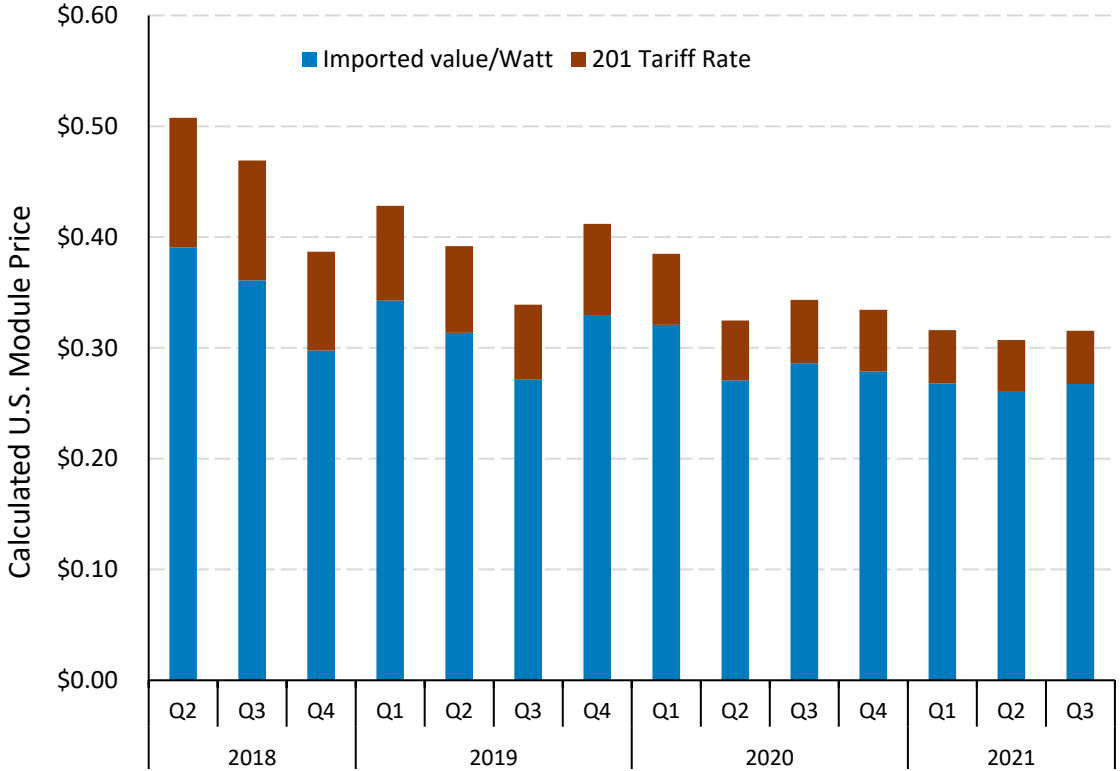
Module Average Selling Price: Global Versus United States



- In Q3 2021, U.S. mono c-Si module prices rose $0.01/W, y/y, and were flat q/q—trading at a 59% premium over global ASP
  - The U.S. premium for bifacial modules over mono c-Si modules rose after the bifacial exemption to the Section 201 tariffs was removed in Q4 2020.
  - The bifacial exemption to the Section 201 tariffs was reinstated in Q4 2021.

Source: Wood Mackenzie Power & Renewables/SEIA.

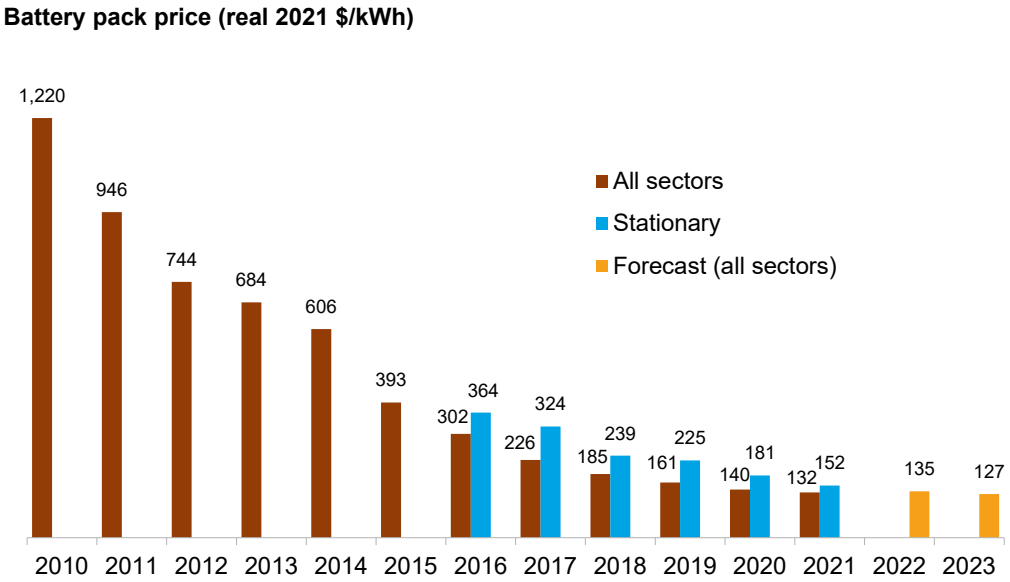
Calculated U.S. Module Pricing



- Based on the reported value and capacity of imported PV modules, the average price of a PV module in the United States before tariffs dropped from $0.36/W in Q3 2018 to $0.27/W in Q3 2021.
- And as a result of the underlying price reduction and step down of the Section 201 tariff, these duties have been cut by 60%, on a per-watt basis (from approximately $0.12/W to $0.05/W).

Source: Imports, by value and megawatt: U.S. International Trade Commission, 2018-2021.

Volume-Weighted Average Lithium-ion Battery Pack Price, 2010–2021 (Forecast to 2023)



- From 2010 to 2021, average pack prices dropped 89%.
  - The drop between 2020 and 2021 was 6%.
  - The survey includes 229 data points across various electric vehicle types and stationary storage.
- From 2016 to 2021, average battery pack prices within the stationary storage sector dropped 58%.
  - Over this period, stationary batteries were purchased at a 15%–43% premium over average prices across all sectors.
  - The smallest premium (15% in 2021) resulted from the outsized stationary-sector price drop from 2020 to 2021 largely due to switching from NMC batteries to LFP cells and racks from China plus procurement strategy changes.
- BNEF expects the average battery pack price to rise for the first time in 2022, driven by higher raw material and component prices in the auto industry
- BNEF expects prices to reach $94/kWh by 2024 and $45/kWh by 2035 if the historical learning rate holds.
  - But the relatively high prices expected in 2022–2023 could delay reaching the $100/kWh milestone by 2 years.

Sources: BNEF. “2021 Lithium-Ion Battery Price Survey.”

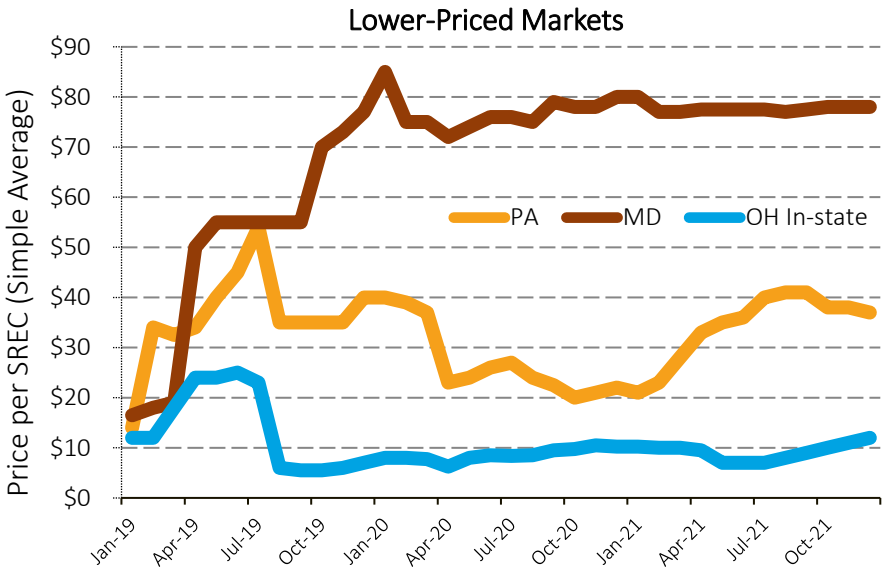
Agenda

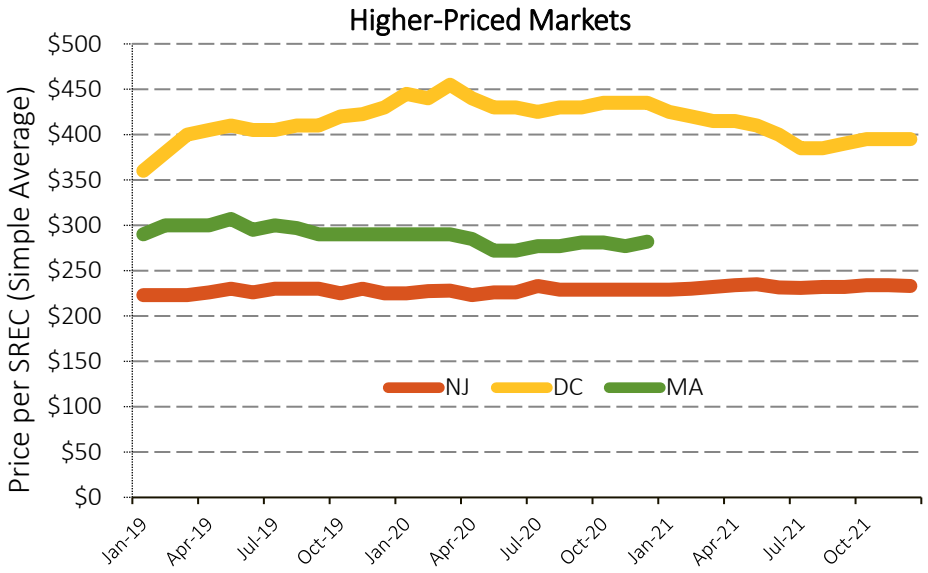
1. Global Solar Deployment
2. U.S. PV Deployment
3. PV System Pricing
4. Global Manufacturing
5. Component Pricing
6. **Market Activity**
7. U.S. PV Imports

- **After the runup of solar stocks that followed the U.S. presidential election peaked in February, the trend was generally downward in 2021 due to factors including logistical problems, policy uncertainty, supply chain disruption, and higher costs.**
- **The solar stock trend was positive for much of Q4 2021, but clean energy stocks declined toward the end of the quarter due in part to stalling of the U.S. Build Back Better bill, which would have funded major efforts related to clean energy.**

SREC Pricing

- SREC prices stayed relatively flat in the past quarter.
- Active SREC programs have closed in New Jersey, Massachusetts, and Ohio.

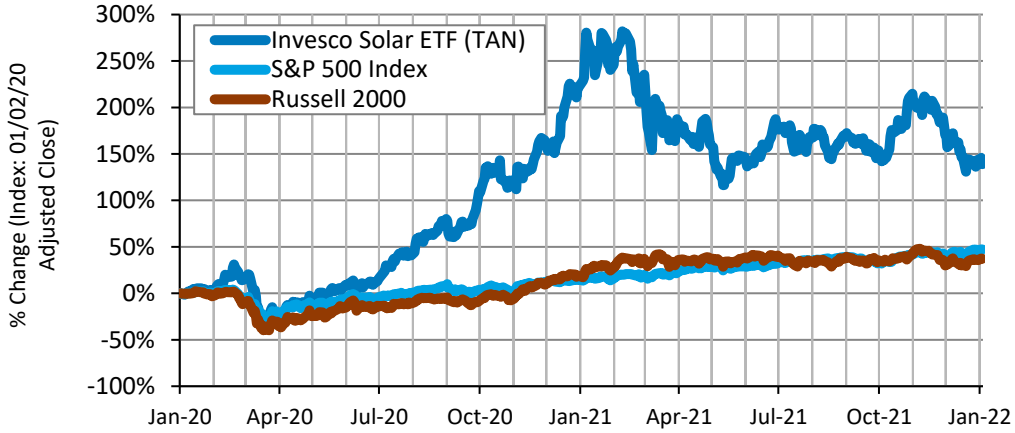




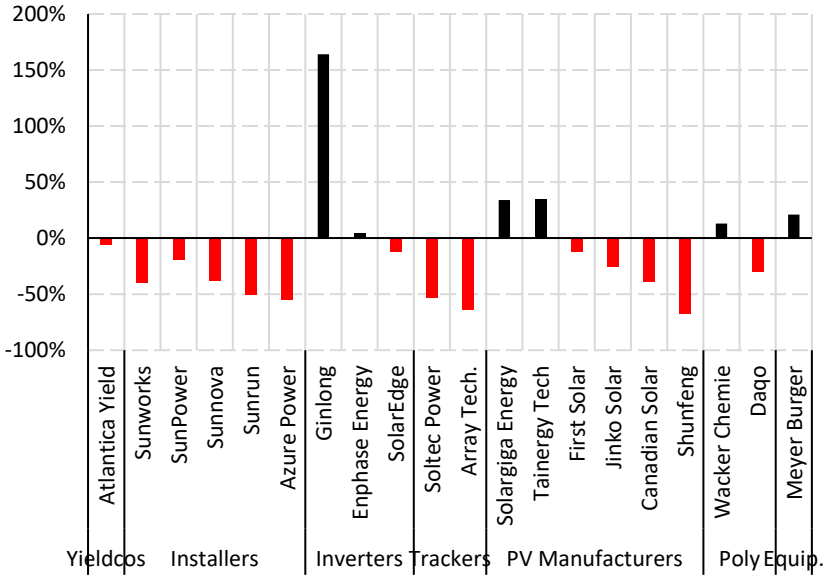
Source: SRECTrade, https://www.srectrade.com/, accessed 12/9/21.

Stock Market Activity

- After the runup of solar stocks that followed the U.S. presidential election peaked in February 2021, the trend was generally downward, with the Invesco Solar ETF dropping 27% across the entire year. Factors included logistical problems, policy uncertainty and supply chain disruption caused by U.S.-China disputes, and higher costs.
- The solar stock trend was positive for much of Q4 2021, but clean energy stocks declined toward the end of the quarter due in part to stalling of the U.S. Build Back Better bill, which would have funded major efforts related to clean energy.



Individual Stock Performance (Q1-Q4 2021)



Note: The TAN index is weighted toward particular countries and sectors. As of 01/03/22, 48% of its funds were in U.S. companies. Its top 10 holdings, representing 55% of its value, were SolarEdge, Enphase, First Solar, Xinyi, Sunrun, Daqo, Sunnova, Shoals Technologies, Atlantica Sustainable Infrastructure, and Flat Glass Group.

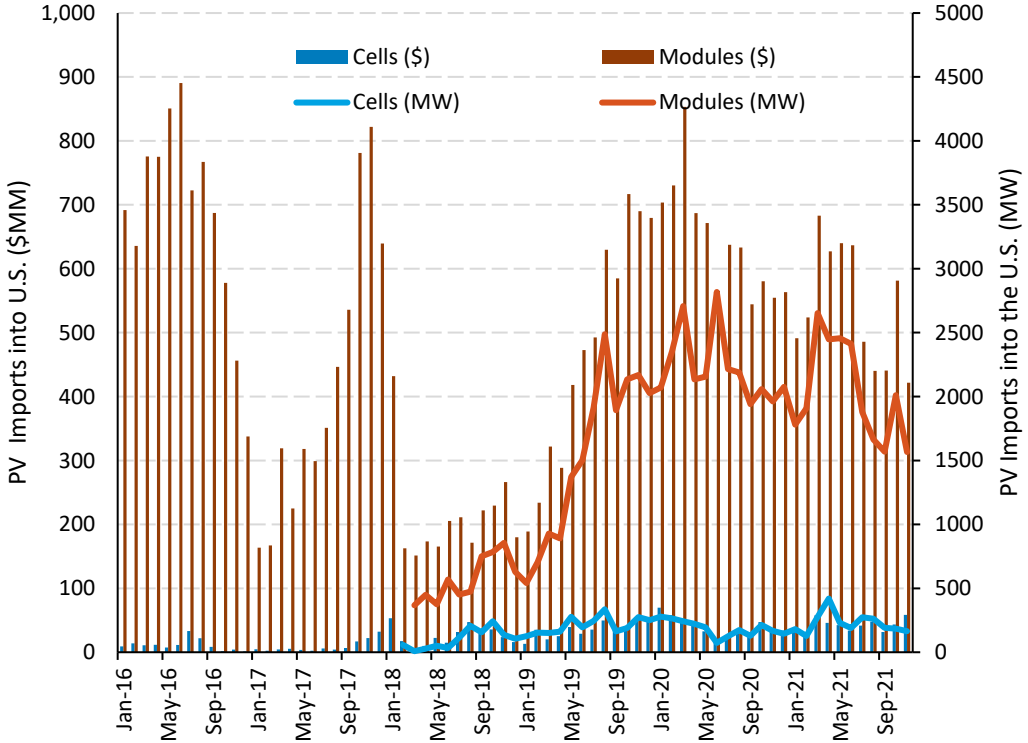
Sources: Bloomberg (08/31/21). Forbes (1/4/22). Stock market: Yahoo Finance (1/4/22).

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**

- **18.8 GW of PV modules were imported into the United States in first nine months of 2021, down 9% y/y.**
  - Imports likely fell due to U.S. Customs and Border Protection's (CBP's) decision in June to stop imports that might contain material made from forced labor, as well as a trade case filed in June accusing Chinese manufacturers of circumventing AD/CVD duties.
- **2.5 GW_{DC} of cells were also imported in the first nine 2021, up 26%.**
  - The increase in demand for cells to supply domestically assembly modules may be driven by supply chain issues, causing installers difficulty in procuring module supply.

Module and Cell Import Data

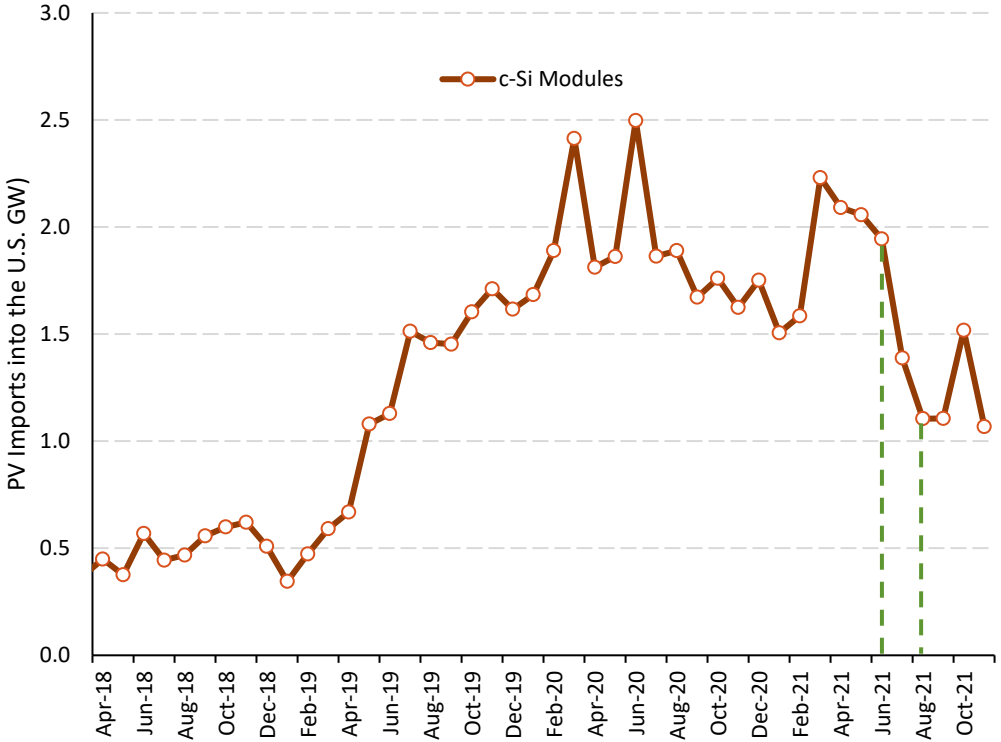


- 18.8 GW_{DC} of PV modules were imported into the United States in Q1–Q3 2021, down 9% y/y.
  - Q3 2021 shipments were down 19%, y/y.
- 2.2 GW_{DC} of cells were also imported in Q1–Q3 2021, up 26%.
- In addition to imports, First Solar produced approximately of 1.3 GW_{DC} of CdTe PV modules in the United States from Q1 to Q3.

Note: We adjusted Thailand's reported imports in megawatts for February because of a likely reporting error.

Sources: First Solar public filings; imports, by Value and MW: U.S. International Trade Commission, 2016-2021.
Source: Wood Mackenzie/SEIA: U.S. Solar Market Insight: Q4 2021.

Impact of Withhold Release Order and AD/CVD Petition



- In June 2021, the U.S. Customs and Border Protection (CBP) released a withhold release order (WRO) on shipments containing silica-based products made by Hoshine and its subsidiaries (which are estimated to supply 25%–35% of the Chinese polysilicon market). Which products would be stopped at the border was unclear.
- In August 2021, an anonymous group of solar manufacturers asked the U.S. Department of Commerce to investigate whether Chinese module manufacturers were circumventing AD/CVD duties by setting up cell and module plants in Southeast Asia (most imported c-Si panels now come from Southeast Asia).
  - If duties were determined, they would apply to the subject panels from the date investigations began.
- These decisions appear to have significantly impacted imports, with July-November 2021 c-Si imports being 30% lower than July-November 2020 imports.

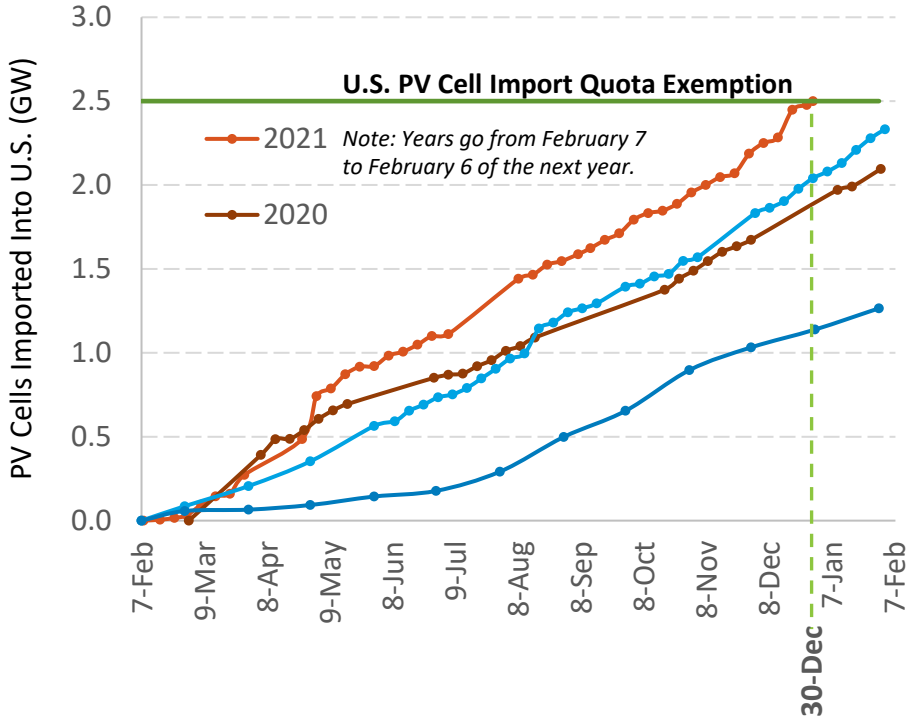
Note: We adjusted Thailand's reported imports in megawatts for February because of a likely reporting error.
Sources: First Solar public filings; Imports, by Value and MW: U.S. International Trade Commission, 2016-2021; CBP and Commerce press releases; Wood Mackenize opinion.

Recent News on WRO, AD/CVD Petition, and Section 201 Tariffs

- The solar industry got some near-term relief on November 10 when the U.S. Department of Commerce dismissed petitions to issue AD/CVD on solar cells from Southeast Asia (specifically Malaysia, Thailand, and Vietnam).
- Also on November 10, U.S. Customs and Border Protection (CBP) clarified policies around the enforcement of its withhold release order (WRO) against silica-based products from Hoshine Silicon Industry Co. in China's Xinjiang region. The CBP's newest FAQ document says that importers can *lower the risk of detentions by demonstrating that the polysilicon in their products came from outside of Xinjiang*.
  - Traceability for component materials like polysilicon is easier than it is for metallurgical-grade silicon. However, a significant amount of uncertainty remains about which shipments will be detained or what documentation is required.
  - Suppliers have thus begun seeking polysilicon sources outside the scope of the WRO.
- Finally, on November 16, the U.S. Court of International Trade reinstated the exemption for bifacial modules from the Section 201 tariffs. Additionally, the court's decision reduced the Section 201 tariffs for crystalline-silicon modules from the 18% to 15%. This presents some near-term pricing relief for utility solar projects intending to use bifacial modules.
  - The government could appeal this decision and get the exemption removed again.
- The USITC determined in December that the Section 201 tariff "continues to be necessary to prevent or remedy serious injury." Hearings are ongoing, and the final decision regarding extension remains to be made.

Sources: Wood Mackenzie/SEIA: U.S. Solar Market Insight: Q4 2021, USITC Commission Publications Library, CBP Hoshine FAQ

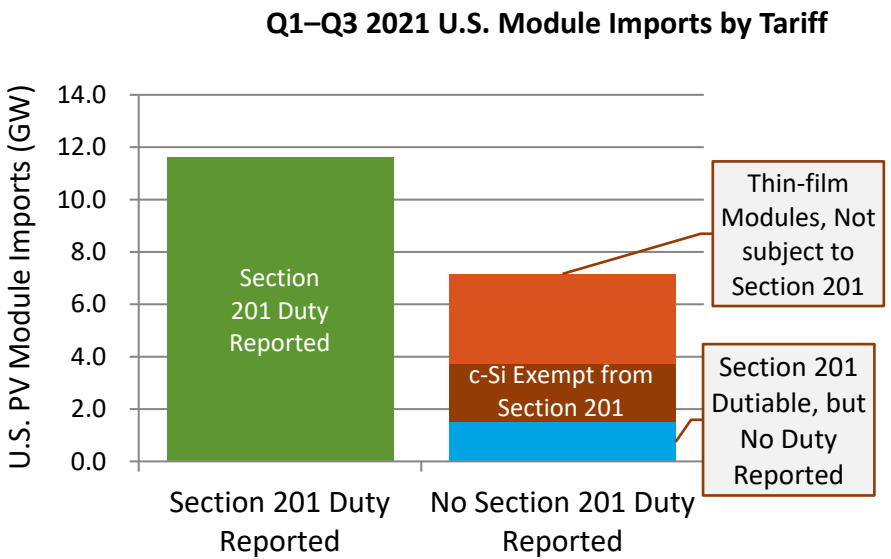
Cell Import Data by Tariff



- A 2.5-GW_{DC} quota exempts the first 2.5 GW_{DC} of imported c-Si PV cells each reporting year subject to the Section 201 tariff.
  - In the first 3 years of the tariffs, the United States did not reach the cap; however, in the fourth year the cap was hit on December 30 (2021), and all further eligible imports will be subject to a 15% tariff through February 6, 2022.
- The 2021 increase in demand for domestically assembly modules may be driven by supply chain issues, causing installers difficulty in procuring supply.

Note: Cell data uses Harmonized Tariff Schedule (HTS) codes 8541406025.
Sources: Imports, by MW: U.S. International Trade Commission, 2018-2021; U.S. Customs and Protection Commodity Status Reports Feb 2019 - Jan 2021.

Q1–Q3 2021 U.S. Module Imports by Tariff



- In Q1–Q3 2021, 11.6 GW_{DC} of imported PV modules (62% of all PV module imports) reported a tariff.
- Most of these modules were thin-film and not subject to tariffs or c-Si technology panels exempt from Section 201 tariffs (e.g., IBC cells).
  - For approximately 1.5 GW of imported c-Si modules—subject to Section 201—no duties were reported. Why this happened is unclear.
- The U.S. Court of International Trade reinstated the Section 201 tariff bifacial exemption in November 2021 and reset the tariffs to 15% (from 18%).

Note: Module data uses codes 8541406015, 8541406020, and 8541406035. 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, and technologies not applicable reported under HTS code 854140603. We assume all panels subject to Section 201 duties have been reported under "Dutiable- HS chapter 99." We adjusted Thailand's reported imports in megawatts for February because of a likely reporting error.

Source: Imports, by MW: U.S. International Trade Commission, Oct 2021; USITC Commission Publications Library

Uyghur Forced Labor Prevention Act

Signed into law December 23, 2021, the Uyghur Forced Labor Prevention Act includes:

- A period of public comment, followed by a public hearing, and then the development of a strategy by the Forced Labor Enforcement Task Force (FLETA) for "how best to ensure that goods mine, produced, manufactured *wholly or in part* with forced labor in the People's Republic of China, including by Uyghurs, Kazakhs, Kyrgyz, Tibetans, and members of other persecuted groups in the People's Republic of China, and especially in the Xinjiang Uyghur Autonomous Region (XUAR), are not imported into the United States."
- Creation of a list of entities in the XUAR that use or facilitate forced labor (or the "poverty alleviation" program or "pairing-assistance" program or any other government labor scheme that uses forced labor) and creation of an enforcement plan by FLETA including the use of WRO orders by the CBP.
  - Building on the Hoshine WRO, polysilicon is mentioned as a "high-priority sector" for enforcement (42% of global polysilicon capacity is in the XUAR).
- The creation of *guidance to importers* with respect to due diligence, effective supply chain tracing, and supply chain management measures, and how to provide evidence their goods are not the products of the XUAR or forced labor
- There is a *presumption of guilt for all goods produced in the XUAR and/or by any entity on the created list*.
  - An importer may be granted an exception if they have fully complied with all guidance and inquiries from the CBP and can provide "clear and convincing evidence" that forced labor was not used.

- China's response was to "admonish the US to correct the mistake immediately, and stop using Xinjiang-related issues to spread lies, interfere in China's internal affairs and contain China's development" (Global Times).

Sources: Public Law No.: 117-78; Global Times Chinese Foreign Ministry Spokesperson's Statement on the UFLPA; PV InfoLink: Impacts of U.S.'s ban on goods from China's Xinjiang

Thank You

www.nrel.gov

NREL/PR-7A40-81900

Special thanks to Nate Blair, Adam Warren, and Mike Meshek.
This research was supported in part by the Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy administered by the Oak Ridge Institute for Science and Education (ORISE) for the DOE. ORISE is managed by Oak Ridge Associated Universities (ORAU) under DOE contract number DE-SC0014664. All opinions expressed in this presentation are the author's and do not necessarily reflect the policies and views of DOE, NREL, ORAU, or ORISE.

List of Acronyms and Abbreviations

AD: antidumping
ARRA: American Recovery and Reinvestment Act
ASP: average selling price
BNEF: Bloomberg New Energy Finance
CAPEX: capital expenditures
CBP: U.S. Customs and Border Protection
C&I: commercial and industrial
c-Si: crystalline silicon
CdTe: cadmium telluride
CNRS: Centre National de la Recherche Scientifique
COP: Conference of Parties
CPUC: California Public Utility Commission
CSP: concentrating solar power
CVD: countervailing
DC: direct current
DOE: U.S. Department of Energy
DPU: Department of Public Utilities
DPV: distributed PV
EIA: U.S. Energy Information Administration
EERE: Office of Energy Efficiency and Renewable Energy
ETF: exchange traded fund
FLETA: Forced Labor Enforcement Task Force
G&A: general and administrative expenses
GW: gigawatt
GWh: gigawatt-hour
H1: first half of year
H2: second half of year
HTS: harmonized tariff schedule
IBC: interdigitated back contact
IEA: International Energy Agency
kg: kilogram
kW: kilowatt
kWh: kilowatt-hour
kWt: kilowatt-thermal
LFP: lithium-ion phosphate
LMI: low and moderate income
mono c-Si: monocrystalline
multi c-Si: multicrystalline
MW: megawatt
MWh: megawatt-hour
NEM: net energy metering
NMC: nickel manganese cobalt
NREL: National Renewable Energy Laboratory
NYSERDA: New York State Energy Research and Development Authority
OCED: Office of Clean Energy Demonstration
PROMES: PROcédés Matériaux et Energie Solaire
PV: photovoltaics
RPS: renewable portfolio standard
Q: quarter
SEIA: Solar Energy Industries Association
SETO: Solar Energy Technologies Office
SMART: Solar Massachusetts Renewable Target
SMUD: Sacramento Municipal Utility District
SREC: solar renewable energy certificate
TAN: Invesco Solar ETF
TPO: third-party ownership
USITC: U.S. International Trade Commission
W: watt
WRO: withhold release order
XUAR: Xinjiang Uyghur Autonomous Region
y/y: year over year
YTD: year to date