

H2 2020 Solar Industry Update

David Feldman Robert Margolis

April 6, 2021

NREL/PR-7A40-79758

Executive Summary

Global Solar Deployment

- Eight of the leading PV markets collectively installed 93 GW_{AC} of PV in 2020, up from 69 GW_{AC} in 2019.
 - The three leading markets were China (48 GW_{AC}), the United States (15 GW_{AC}), and Vietnam (8 GW_{AC}).

U.S. PV Deployment

- In 2020, PV represented approximately 40% of new U.S. electric generation capacity, compared to 4% in 2010.
 - Over 30 ${\rm GW}_{\rm AC}$ of renewable energy and storage capacity was installed in the United States in 2020.
- Solar represented only 6.6% of net summer capacity and 3.3% of annual generation in 2020.
 - However, 11 states generated more than 5% of their electricity from solar, with California leading the way at 22.7%.
- The United States installed 14.9 GW_{AC} (19.2 GW_{DC}) of PV in 2020, of which 10.4 GW_{AC} were utility-scale PV, 3.0 GW_{AC} were residential PV, and 1.5 GW_{AC} were commercial and industrial PV.
- At the end of 2020, there was 73.8 GW_{AC} (95.5 GW_{DC}) of cumulative PV installations, of which 46.1 GW_{AC} were utility-scale PV, 17.2 GW_{AC} were residential PV, and 10.5 GW_{AC} were commercial and industrial PV.

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

- Though 2020 U.S. solar and wind installations collectively achieved record levels, EIA expects 2021 to far exceed these levels, with 21 GW_{AC} of PV and 16 GW_{AC} of wind.
- The United States installed approximately 3.5 GWh, 1.5 GW_{AC} of energy storage onto the electric grid in 2020, up 214% y/y.

PV System and Component Pricing

- Mono c-Si PV module prices rose 6% in Q1 2021, with mono-crystalline PV modules being slightly higher than they were a year ago (\$0.22/W).
- Polysilicon was up 33% in Q1 2021 and 76% y/y to \$15.6/kg at the end of March.
- In Q4 2020, U.S. mono c-Si module prices fell, dropping to their lowest recorded level, but they were still trading at a 55% premium over global ASP.

Global Manufacturing

- In 2020, the United States produced a record 4.4 GW of PV modules, up 24% y/y, due mostly to a doubling of production capacity by First Solar.
- The United States stopped producing PV cells in Q4 2020, having produced 198 MW for the year.
- PV InfoLink reported that the top ten module manufacturers shipped 114 GW in 2020—or 81.5% of total shipments.



- 5 Component Pricing
- 6 Market Activity

Labor Practices in Xinjiang

1 Global Solar Deployment

- 2 U.S. PV Deployment
- **3** PV System Pricing
- 4 Global Manufacturing
- 5 Component Pricing
- 6 Market Activity

Labor Practices in Xinjiang

- Eight of the leading PV markets collectively installed 93
 GW_{AC} of PV in 2020, up from 69 GW_{AC} in 2019.
 - The three leading markets were China (48 GW_{AC}), the United States (15 GW_{AC}), and Vietnam (8 GW_{AC}).
- These leading eight markets represent approximately three-quarters of global cumulative PV installations, which was approximately three-quarters of a terawatt at the end of 2020.

2020 Global PV Deployment: Key Markets Update

- The eight leading markets collectively installed 93 GW_{AC} of PV in 2020, up from 69 GW_{AC} in 2019.
- While the pandemic suppressed 2020 deployment, it affected countries differently, with many countries experiencing significant growth.
 - India installed 56% less PV in 2020 than in 2019, whereas China installed 60% more.
- 60 48 50 2019 2020 39 40 30 30 20 15 8 10 6 6 433 3.2 0 Other China U.S. Vietnam Japan Germany Australia Spain India

Annual Capacity Additions (GW_{AC})

- In 2020, utility-scale projects represented 81% of Spanish demand, 78% of Indian demand, 73% of U.S. demand, 36% of Australian demand, and 15% of Vietnamese demand.
 - In 2019, most Vietnamese PV installs were groundmounted.
- The eight leading markets represent approximately threequarters of global cumulative PV installations, which was approximately three-quarters of a terawatt at the end of 2020.



Sources: Wood Mackenzie/SEIA, U.S. Solar Market Insight: 2020 Year-in-Review; IEA World Energy Outlook; Mercom (08/03/20, 01/25/21, 03/01/21); https://pv-map.apvi.org.au/analyses; PV Magazine (01/27/20, 01/15/21, 02/15/21); PVTech (01/06/21); IEEFA (01/12/21); Taiyang News; Japan FiT.

Chinese Generation Capacity Additions by Source

- In 2020, solar contributed 25% to new generation capacity in China (48.2 GW_{AC}) and 11% of cumulative capacity (252 GW_{AC}).
 - 2020 was the fourth-straight year that wind and solar contributed more than half of all new electric generation capacity in China (26%), with a record amount of wind deployment.
 - Coal and gas deployment has remained relatively flat over the past 11 years as renewables have grown.
 - Chinese annual electric generation capacity additions been on average 4–6 times greater than U.S. additions for the past 10 years.



Annual Capacity Additions (GW_{AC})

 As China grows its electricity infrastructure, it has rapidly incorporated non-carbon sources of electricity generation.

- Since 2010, China has more than doubled its installed electric generation capacity, and at the same time, it reduced the percentage of total coal and gas capacity from 74% to 57%.
- From 2010 to 2020, new non-carbon generation capacity as a percentage of total new capacity increased from 37% to 70%.



Cumulative Capacity (GW_{AC})

Source: China Electric Council, accessed (2017, 2018, 2019, 2020. 2021).

Chinese Market Update

- China installed 48.2 GW_{AC} of PV in 2020: 32.7 GW_{AC} were large-scale and 15.5 GW_{AC} were distributed PV projects, bringing cumulative Chinese PV capacity to 252 GW_{AC}.
 - December installations alone were 22.3 GW_{AC}, as developers rushed to meet an end-of-year deadline.
- China is gradually moving away from subsidizing PV installations; however, there is still uncertainty around this and differences by province, as policymakers want to minimize the market impact.
- In September 2020, China announced plans to become carbon neutral by 2060, though without a road map. Further announcements have been made to bolster that possibility.
 - China's National Energy Administration released a draft plan in February to boost non-hydro renewable electricity to 25.9% of overall power consumption generation by 2030, and to 12.7% by 2021 (an increase of 1.5%). One energy advisory company believes this will increase demand to 60–75 GW in 2021 and will increase cumulative capacity of wind and solar to 1.6 TW–1.7 TW by 2030 (from 0.5 TW in 2020). This is higher than President Xi's pledge to build 1.2 TW of solar and wind by 2030.
 - The Chinese Electric Council also urged the government to cap electricity generation from coal and transition these plants to backup power.

Vietnamese Market Update

• For the second year in a row, solar demand in Vietnam was stronger than expected, making it the third-largest market in 2020.



Annual Capacity Additions (GW_{DC})

- Virtually all of Vietnam's 16 GW_{DC} (13 GW_{AC}) of capacity has been installed in the past two years with 6.9 GW_{DC} of rooftop facilities in December 2020 alone, due to an expiring feed-in-tariff deadline.
 - The government had targeted 1 GW of rooftop PV installations by 2025.
- Vietnam switched from installing predominantly utilityscale projects in 2019, to industrial rooftop installations in 2020, demonstrating the importance of a change in FiT policies.
- Future rooftop and utility-scale PV projects must wait for the government to finalize new programs, likely with lower rates.
 - Future rooftop program may incentivize selfconsumption due to concerns over grid constraints.
 - Utility-scale projects will transition to a competitive bidding system in government's attempt to lower pricing. Utility-scale projects are at a standstill until the auction mechanism is finalized.

Japanese Market Update

- Japan's annual installations grew 17% in 2020 to 8.2 GW_{DC} (6.3 GW_{AC}).
 - BloombergNEF stated that the increase in demand is partially due to large-scale legacy projects that were approved for a FiT in 2012–2014 and which now face stricter operational deadlines.
- Japan's recent auctions (required for projects above 250 kW in size) have been significantly undersubscribed.
 - The average winning bid from the last auction was \$104/MWh (11,000 yen)
- Japanese projects under 10 kW in size built in FY20 received a FiT of approximately \$0.20/kWh; the FiT is set to be reduced to \$0.16/kWh for projects installed in FY22.
 - Systems between 10 kW and 250 kW will receive a FiT between \$0.10/kWh and \$0.12/kWh over the same period.

- In October 2020, Japan's prime minister made a pledge for the country to be carbon neutral by 2050.
 - Meeting this goal would require significantly more investments in renewable energy, which the prime minister acknowledged. Some of the Japan's leading companies recently wrote to the government asking it to increase its 2030 renewable energy targets from 22%–24% of total energy generation to 40%–50%.



Annual Capacity Additions (GW_{AC})

Indian Market Update



Annual Capacity Additions (GW_{DC})

- India installed 3.2 GW_{AC} of PV in 2020—its lowest level since 2015, primarily because of disruptions in site work and logistics caused by the pandemic.
 - Large-scale projects accounted for approximately 78% of 2020 installs.
- BloombergNEF expects a significant rebound in 2021, as "auctions have been going strong, the economics of solar remains attractive and delayed projects from 2020 will come online."
 - India auctioned 10–12 GW_{AC} of utility-scale PV projects from 2018 to 2020. However, this is expected to increase if India intends to hit its target of 300 GW_{AC} of PV by 2030.
- India released its budget in February 2021, providing 5-year federal financial support to stateowned power companies. This aid should help reduce payment delays to IPPs, which is currently a significant problem.

CSP Updates

The CSP landscape continues to be dominated by three major themes:

• Refinancing existing, well-performing CSP facilities

After filing for insolvency in February 2021, Abengoa sold its stake in the 100-MW South African CSP plant (Xina) it has operated since
 2018 to reduce its financial debt. According to Bloomberg, the company ran into trouble because of cash shortages following a global
 expansion drive. Abengoa had successfully restructured its debt in 2016 but was unable to do so this time.

• Working on R&D that will allow plants to operate at higher temperatures, which could significantly reduce electricity costs

- Researchers at Sandia National Laboratories worked with industry (including a nuclear power developer) to design a new flow control
 valve that will improve heat distribution and minimize risks at critical joints. The new valve should allow for higher CSP temperatures
 and greater energy conversion efficiency.
- Building out CSP plants to complement PV facilities, offering long-term storage
 - A recent Fraunhofer foundation report found that a hybrid CSP-PV plant with 13 hours of storage is the lowest cost power generation option (\$53/MWh) for low-carbon baseload power in Chile. In comparison, they found a gas-fired plant would have an LCOE of \$86/MWh.
 - Botswana plans to build 200 MW of CSP by 2026, in conjunction with other technologies, such as PV, wind, batteries, and coal.
 Botswana has large areas of low-cost land that record direct normal irradiance (DNI) of over 2,200 kWh per year.

U.S. CSP Project Generation Performance, 2010–2020



- Though it took a few years to optimize the operation of the five U.S. CSP plants brought online between 2013 and 2015, four of them now generally perform better than when they began operation.
 - Annual weather variation also caused some of the differences in annual production.
- Plants with newer technology, such as towers and storage, took longer to ramp up than trough plants, which have decades of operating experience.
 - The lone U.S. tower plant with storage, Tonopah, which began operating in 2015, had consistent operating problems, and was shut down for all of 2020 after its PPA was canceled.
- Absolute capacity factor is not necessarily the best metric for performance, as plants can be designed and operated differently.
 - The capacity factors of the SEGS plants have decreased over time as the PPAs of these plants have expired and they have shifted to merchant production.

1 Global Solar Deployment

- 2 U.S. PV Deployment
- **3** PV System Pricing
- 4 Global Manufacturing
- 5 Component Pricing
- 6 Market Activity

Labor Practices in Xinjiang

- In 2020, PV represented approximately 40% of new U.S. electric generation capacity, compared to 4% in 2010.
 - Over 30 $\mathrm{GW}_{\mathrm{AC}}$ of renewable energy and storage capacity was installed in the United States in 2020
- Solar still only represented 6.6% of net summer capacity and 3.3% of annual generation in 2020.
 - However, 11 states generated more than 5% of their electricity from solar, with California leading the way at 22.7%.
- The United States installed 14.9 GW_{AC} (19.2 GW_{DC}) of PV in 2020, ending the year with 73.8 GW_{AC} (95.5 GW_{DC}) of cumulative PV installations.
- Though 2020 U.S. solar and wind installations collectively achieved record levels, EIA expects 2021 to far exceed these levels, with 21 GW_{AC} of PV and 16 GW_{AC} of wind.
- The United States installed approximately 3.5 GWh, 1.5 GW_{AC} of energy storage onto the electric grid in 2020, up 214% y/y.

ITC Two-Year Extension

- Congress extended the ITC for solar projects by two years at the end of December, as part of a larger appropriations bill.
 - Consolidated Appropriations Act, 2021.

30%

2019

30%

20%

15%

10%

5%

0%

Credit 25%

Тах

Percent

- The act also raises the PTC for onshore wind to 60% for projects ٠ beginning construction in 2021 (from 40%) and provides a 30% ITC to offshore wind projects that begin construction before 2026.
- Wind and solar, which comprised 79% of a high ٠ level of U.S. electricity generation capacity additions in 2020, are likely to extend their dominance through at least the middle of the decade.
- Due to previous IRS issued guidance on the definition of "commence construction," projects may still need to complete construction within 4-years to get the full credit.



Q4 2020 State Updates

- Many states are working on adopting unique net metering successor policies; however, many utility proposals include minimum bills, higher fees, time-ofuse rates, and lower export credit rates.
- Community solar continues to expand, but many states are facing challenges achieving LMI participation goals.

Virginia adopted shared solar program regulations, capping the program at 150 MW and reserving 30% for low-income customers. The commission will determine the credit amount each year.

> Dominion proposed a net metering successor program with a 15-minute netting period and timevarying credit rates. Also, fees for solar would be increased.

Evergy is proposing a \$35 minimum bill and grid access fee after the Kansas Supreme Court ruled against DG demand charges.

Utah regulators issued a net metering successor tariff decision. Rocky Mountain customers will get 5.5–6.0 ¢/kWh for exported energy instead of the utility's proposed 1.3-2.6 ¢/kWh

> LG&E and KU proposed a net metering successor program, offering 2.2 ¢/kWh for exported electricity to those not grandfathered in for 25 years.

Source: Meister Consultants Group, *50 States of Solar: Net Metering Quarterly Update* (Q4 2020).

California's Net Metering 3.0

- Net metering was started in California in 1995, with a successor program (net metering 2.0) beginning in 2016. The state required utilities to submit proposals for the next version of net metering within the state (net metering 3.0) on March 15, with the new policies taking effect in 2022–2023.
- California's three IOUs proposed changes to the state's net metering policy:
 - Monthly fee for solar customers (\$49–\$79 for a 5-kW system); currently, there is a one-time interconnection fee of \$75–\$145.
 - Reduction of the credit for exported power from 2–3¢/kWh below time-of-use retail rates, to slightly above wholesale rates
 - Not allowing new customers to carry unused credits forward month-to-month.
- The utilities claim these changes are aimed at curbing the \$3 billion cost subsidy non-solar customers pay to solar customers, because so many fees are volumetric.
- Solar trade groups have filed their own proposals, which would have no monthly fee, would switch to net billing, and would reduce the rate of excess electricity by 25%–50% from current levels over 5 years (depending on the utility).
- California has represented 34% of the U.S. distributed market over the past five years.

New U.S. Capacity Additions, 2010–2020



- In 2020, PV represented approximately 40% of new U.S. electric generation capacity, compared to 4% in 2010.
 - Since 2016, PV has represented approximately 33% of new electric generation capacity.
- Over 30 GW_{AC} of new installed capacity was either from renewable energy or battery technologies in 2020, surpassing the previous record of 20 GW_{AC} set in 2016, by 50%.
- Combined with wind, 79% of all new capacity in 2020 came from renewable sources.

Note: "other" includes coal, geothermal, landfill gas, biomass and petroleum. DPV = Distributed PV; UPV = Utility-scale PV **Sources:** EIA, "Electric Power Monthly" Tables 6.1, 6.2B, 1.1, 1.1A; Forms 860M & 861M. February 2021.

2020 U.S. Generation and Capacity

- Renewables are becoming an increasingly large part of the U.S. electric generation mix, representing 25% of capacity and 21% of generation in 2020.
 - Adding nuclear, non-carbon sources represented 34% of capacity and 40% of generation.

Natural gas 40% Other. 2% Nuclear Geothermal 20% 1% Wind CSP Hydro 0.1% 7% DPV UPV 1.0% 2.2%

2020 U.S. Generation (Total 4,051 TWh)

- Solar still represents a small but growing percentage of the U.S. electric generation mix.
 - In 2020, solar represented 6.6% of net summer capacity and 3.3% of annual generation.
- Capacity is not proportional to generation, as certain technologies (e.g., natural gas) have lower capacity factors than others (e.g., nuclear).



2020 U.S. Generation Capacity (Total 1.1 TW)

Sources: EIA, "Electric Power Monthly" Tables 6.1, 6.2B, 1.1, 1.1A; February 2021.

U.S. Generation, 2010–2020



- Coal has been moving the opposite direction from natural gas and renewable generation during the past 10 years.
- In 2020, renewable energy facilities produced more electricity than electricity produced by coal or nuclear sources.
 - The percentage of electricity generated by fossil fuels in the United States dropped from 70% in 2010 to 60% in 2020, while renewable generation increased from 10%–21% over the same period.
- Despite solar only contributing 3.3% of electric generation in 2020, its percentage increased 36X since 2010.

Solar Generation as a Percentage of Total Generation, 2020



Note: EIA monthly data for 2020 are not final. Additionally, smaller utilities report information to EIA on a yearly basis, and therefore a certain amount of solar data has not yet been reported. "Net Generation" includes DPV generation. Net generation does not take into account imports and exports to and from each state, and therefore the percentage of solar consumed in each state may vary from its percentage of net generation. **Source:** U.S. Energy Information Administration (EIA), "Electricity Data Browser." Accessed March 10, 2021.

- During 2020, 11 states generated more than 5% of their electricity from solar, with California leading the way at 22.7%.
 - Five states generated more than 14% of their electricity using solar.
 - Nationally, 3.3% of electricity was generated from solar.
- The role of utility versus distributed solar varies by state, with northeastern states and Hawaii relying more on DPV.

Solar Generation as a Percentage of Total Generation, 2014–2020



From 2014 to 2020, leading solar deployment states greatly increased solar electricity penetration.

- In 6 years, California and Massachusetts shifted over 15% of their electricity generation to solar.
 - Some of the increase in Massachusetts's percentage is due to significant reduction in total electricity production within the state.
- The United States, as a whole, has a much lower levels, however still increased penetration by 365% over this time period.

Note: EIA monthly data for 2020 are not final. Additionally, smaller utilities report information to EIA on a yearly basis, and therefore a certain amount of solar data has not yet been reported. "Net Generation" includes DPV generation. Net generation does not include imports and exports to and from each state, and therefore the percentage of solar consumed in each state may vary from its percentage of net generation. **Source:** U.S. Energy Information Administration (EIA), "Electricity Data Browser." Accessed March 10, 2021.

Monthly U.S. Solar Generation, 2013–2020



Note: EIA monthly data for 2020 are not final. Additionally, smaller utilities report information to EIA on a yearly basis, and therefore, a certain amount of solar data have not yet been reported. "Net Generation" includes DPV generation. **Sources:** EIA, "Monthly Energy Review," (March 2021).

- Total peak monthly U.S. solar generation increased by a factor of seven from 2013 to 2020.
 - U.S. electric generation in December 2020 (during the low seasonal period of electric generation) was slightly below the peak solar production in 2017.
 - In May 2020, solar produced 4.5% of all U.S. electricity production.
- Utility-scale solar electricity production (including PV and CSP technologies) has generally dropped by approximately 40%–50% from summer to winter, and DPV systems dropped 30%–40%.
 - This drop in production would likely be exacerbated without continued build of solar installations throughout the year.

Duck Curve: Predicted vs. Actual



need for an increased ramp rate, particularly in the springtime when PV is generating a lot of energy midday but demand is low (i.e., it is not hot enough for AC use). The duck curve has generally come to pass—midday net load has dropped more than predicted, though evening peak has not been as great.

Actual

Average Hourly Net Load (March 15 - April 15)

The "duck curve" graphic, which was developed in 2013,

predicted that as solar became a larger part of CAISO's electricity mix, there would be potential periods of overgeneration and the



Note: net load = load - solar and wind production; includes curtailment Sources: CAISO: <u>http://www.caiso.com/informed/Pages/ManagingOversupply.aspx</u> DOE: https://www.energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy

Duck Curve: Predicted vs. Actual (specific days of year)

Individual days have experienced significantly lower minimum net load and larger evening ramps.

Predicted



Actual



Note: net load = load - solar and wind production

Sources: CAISO: <u>http://www.caiso.com/informed/Pages/ManagingOversupply.aspx</u> DOE: https://www.energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy

Duck Curve: Seasonality

The duck curve problem is most severe at particular times of the year. In the summer, midday demand for cooling within CAISO mitigates much of the dip in net load. In other parts of the year, solar does not produce as much. Also, other regions do not necessarily have the same solar production and demand profiles to cause such a problem.



Net Load (July-September)

Note: net load = load – solar & wind production.

Sources: CAISO: http://www.caiso.com/informed/Pages/ManagingOversupply.aspx

DOE: https://www.energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy

Duck Curve: Curtailment

- CAISO has mostly delt with overproduction through curtailment of solar electricity, but over the course of the year, this has not represented a large amount of energy. Curtailment has also been driven by other non-duck curve factors, such as local transmission and reliability constraints. Ramping, while also an issue, is something that has been managed.
- Solar curtailment in CAISO varies greatly by season, with curtailment over 12% in April 2020, but close to 0% in July and August of 2020.



CAISO Solar Curtailment (by % of power) Annual

CAISO Solar Curtailment (by % of capacity) Monthly

Duck Curve: Future Issues

As solar deployment increases over time, there will likely be a need for additional mitigation factors. When curtailment increases to the point of being uneconomical, several strategies can be implemented: better energy forecasting, lowering minimum generation levels, demand shifting, and storage. The duck curve prediction of low net load in the middle of the day has come to pass; as solar becomes a larger share of electricity supply, there will likely be a need for significant storage deployment to shift load.



As PV penetration increases, more of this load shifting will occur with the use of storage.

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

- Despite the impact of the pandemic on the overall economy, the United States installed 14.9 GW_{AC} of PV in 2020, its largest total ever—up 61% y/y.
 - Residential, C&I, and utility-scale PV were up 18%, 34%, and 86% respectively in 2020.



• Approximately 54% of U.S. PV capacity installed in 2020 was in Texas, Florida, and California.

- Despite a concentration of PV installations in the top three markets, diversification of growth continues across the United States.
 - $-\,$ 17 states had more than 1 ${\rm GW}_{\rm AC}$ of cumulative PV installations at the end of 2020.



NREL

28

2020 U.S. PV Installations by Region (14.9 GW_{AC})

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

U.S. Installation Breakdown by State

At the end of 2020, there were 73.8 GW_{AC} of solar PV systems in the United States, of which 46.1 GW were utility-scale PV, 17.2 GW were residential PV, and 10.5 GW were commercial and industrial PV.

In 2020, approximately 14.9 GW_{AC} of PV capacity were installed, of which 10.4 GW were utility-scale PV, 3.0 GW were residential PV, and 1.5 GW were commercial and industrial PV.



Note: EIA monthly data for 2020 are not final. Additionally, smaller utilities report information to EIA on a yearly basis, and therefore, a certain amount of solar data have not yet been reported. "Net Generation" includes DPV generation. **Sources:** EIA, "Electric Power Monthly," forms EIA-023, EIA-826, and EIA-861 (February 2021, February 2020).

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

- SEIA reports that the United States installed 19.2 GW_{DC} of PV in 2020 up 43% y/y.
- Q4 2020 installations totaled 8 GW_{DC}.
- At the end of 2020, there were 95.5 GW_{DC} of cumulative PV installations. In the first half of 2021, the United States should reach 100 GW_{DC}.



U.S. PV Installations by Market Segment

Unlike the previous slide, these values are in ${\rm GW}_{\rm DC}$, instead of ${\rm GW}_{\rm AC}$.

- Four states installed more than 1 GW_{DC} of PV in 2020, and 18 states have more than 1 GW_{DC} of cumulative PV installations.
- Despite California's shrinking market share, it still represents 31% of cumulative U.S. PV installations.



U.S. Off-Site Corporate Solar PPAs



- Led by the tech industry and Fortune 500 companies,
 U.S. corporate solar contracts were up 34% in 2020, y/y, and 7.4X over 5 years.
 - The United States represented approximately 65% of the global offsite corporate market in 2020, followed by Spain (22%) and Brazil (5%).
 - 82% of the 2020 U.S. solar contracts were in the form of virtual PPAs, with the remainder coming mostly from green tariffs.
 - In addition to the 11 GW of solar PPAs, companies signed 2 GW of U.S. wind projects.
- At the end of 2020, the leading five offsite corporate solar offtakers were Amazon, Total, Facebook, Google, Microsoft, and Verizon, with a collective 18 GW of PPAs.
 - Amazon and Verizon signed more than 2.5 GW and 1.5 GW of offsite U.S. solar PPAs in 2020 alone, respectively.

Near-Term Projections for U.S. Solar and Wind Installations



- Though 2020 U.S. solar and wind installations collectively achieved record levels, EIA expects 2021 to far exceed these levels, with 37 GW_{AC}.
 - Wind installations are projected to peak in 2021 with 16 $\mathrm{GW}_{\mathrm{AC}}.$
 - EIA estimates solar will install 21 GW_{AC} in 2021 and 19 GW_{AC} 2022, compared to 15 GW_{AC} in 2020. EIA estimates approximately three-quarters of the new solar capacity will be large-scale.
- The large amount of wind installations in 2020 and 2021 is because these are the last years wind projects can receive the full PTC without another change in law.
 - The IRS granted wind projects that began construction in 2016 (100% PTC) and 2017 (80% PTC) a one-year extension to the Continuity Safe Harbor due to the pandemic and now provides these projects a 5-year construction window.

2050 Projections from Different Reports



- EIA's AEO2021 reference-case projects 13% more electricity generation from solar than the 2020 version, though 33% and 38% lower than NREL's 2020 Standard Scenarios mid-case and BloombergNEF's New Energy Outlook 2020, respectively.
 - Except for coal (which shrinks 13%), EIA projects more electricity from all technologies in AEO2021 versus AEO2020.

Sources: BloombergNEF, New Energy Outlook 2020; EIA, 2021 Annual Energy Outlook, reference case; EIA, 2020 Annual Energy Outlook; NREL, 2020 Standard Scenarios, mid case.

EIA Projections Over Time



- Between EIA's Annual Energy Outlook (AEO) 2017 and EIA's AEO2021, PV projections have increased significantly.
 - 2030 projections of solar generation more than doubled between AEO2017 and AEO2021 from 273 TWh (123 GW) to 611 TWh (250 GW).
 - 2050 projections increased from 628 TWh (374 GW) to 1,071 TWh (517 GW) between AEO2017 and AEO2021.
- Since 2017, many states have significantly increased their RPS.

U.S. Energy Storage Installations by Market Segment

- The United States installed approximately 3.5 GWh, 1.5 GW_{AC} of energy storage onto the electric grid in 2020, up 214% y/y, as a result of record levels of front-of-the-meter deployment in California.
 - Approximately 40% of cumulative battery storage capacity occurred in H2 2020.
 - More than one-third of 2020 deployment came from the world's largest battery system: the 300-MW/1.2-GWh Moss Landing Power Plant in California.



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

- California continues to be the largest market in all sectors, representing more than half of all 2020 U.S. residential and front-of-the-meter storage capacity.
- The Texas market has grown to be a leader in 2020, as storage projects were installed to manage power-price spikes and higher ancillary services clearing prices.
- Despite the record levels of battery storage deployment in 2020, Wood Mackenzie expects significant growth over the next 5 years, with annual deployment projects to grow eightfold.





PV Projects in ISO Queues



- Over 148 GW of PV projects within these six ISO interconnection queues are scheduled to begin operation between 2021 and 2024; 62 GW of this is associated with storage.
- Interconnection costs often vary greatly and ٠ are unknown before applying (in part because the process often requires sequential studies). Wind and solar developers often submit multiple interconnection applications, leading to high cancellation rates.
 - ISO-NE estimates a 70% attrition rate; a 2017 MISO West study group had a success rate of 1%.
 - FERC and RTOs have attempted to reduce cancellation rates through reforms, such as eliminating fully refundable milestone payments, requiring site control demonstrations, and a greater use of cluster interconnection studies. NREL
PV & Storage Projects in ISO Queues

- Over 155 GW of storage projects within these six ISO interconnection queues are scheduled to begin operation between 2021 and 2024; 52 GW of this is associated with PV.
- Over 148 GW of PV projects within these six ISO interconnection queues are scheduled to begin operation between 2021 and 2024; 62 GW of this is associated with storage.

Storage Projects in ISO Queues

- Interconnection costs often vary greatly and are unknown before applying (in part because the process often requires sequential studies). Wind and solar developers often submit multiple interconnection applications, leading to high cancellation rates.
 - ISO-NE estimates a 70% attrition rate; a 2017 MISO
 West study group had a success rate of 1%.
 - Regulators have attempted to reduce cancellation rates through reforms, such as eliminating fully refundable milestone payments, requiring site control demonstrations, and a greater use of cluster interconnection studies.

PV Projects in ISO Queues



Sources: CAISO; ISO-NE; MISO; NY-ISO; PJM; SPP; ISO-NE; Americans for a Clean Energy Grid, Disconnected: The Need For A New Generator Interconnection Policy.

Residential BIPV Uptick in California



- In 2020, 1.8 MW of residential BIPV was installed in the California IOU territories—its highest amount in over a decade.
 - 1.4 MW was installed in the last six months of the year. This trend continued through January 2021, with 262 kW of BIPV being installed.
 - Tesla installed 85% of this capacity, followed by SunPower (14%).
- Despite the growth of residential BIPV, it represented only 0.2% of total residential PV installed in the California IOU territories in 2020.



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

• From 2019 to 2020, the median reported PV system price in Arizona, California, Connecticut, Massachusetts, and New York was relatively flat for smaller systems and fell by 10% for larger systems.

In 2020, residential PV+storage systems in Arizona, California, and Massachusetts had a median price of 2,900/kWh, or 5,600/kW_{AC} (5,500/kW_{DC}).

System Pricing from Select States



- It is unclear what, if any, impact the reduction of the residential ITC from 30% to 26% in 2020 had on reported prices for smaller systems, on average.
- From 2019 to 2020, the median reported PV system price in Arizona, California, Connecticut, Massachusetts, and New York:
 - Remained flat at \$4.00/W for systems from 2.5 kW to 10 kW
 - Fell 1% to \$3.43/W for systems from 10 kW to 100 kW
 - Fell 2% to \$2.50/W for systems from 100 kW to 500 kW
 - Fell 10% to \$1.80/W for systems from 500 kW to 5 MW.

2020 MW: AZ (131), CA (784), CT (76), MA (247), NY (400)

YTD

Note: System prices above \$10/W and below \$1/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 trends over time.

Sources: AZ (04/07/21), CA NEM database (01/31/21); CT (03/03/21), MA SREC (02/17/21) and SMART (03/17/21) programs ; NYSERDA (03/31/21).

System Pricing From Select States, 2020

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

- The median price of a large system in New York was about 21% less than the median price in Massachusetts.
- In 2020, the 20th and 80th percentile prices in California for a small system were \$3.23/W and \$4.94/W respectively.



2020 MW: AZ (131), CA (784), CT (76), MA (247), NY (400)

Note: System prices above \$10/W and below \$1/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 trends over time. Sources: AZ (04/07/21), CA NEM database (01/31/21); CT (03/03/21), MA SREC (02/17/21) and SMART (03/17/21) programs ; NYSERDA (03/31/21).

Residential U.S. Storage Pricing



In 2020, residential PV+storage systems in Arizona, California, and Massachusetts had a median price of 2,900/kWh, or 5,600/kW_{AC} (5,500/kW_{DC}).

- Most of these systems offer 2–3 hours of storage and have standard capacities of 27.0 kWh, 13.5 kWh, and 9.8 kWh.
- Median prices in the first few months of 2021 are 10%–15% below 2020 values, but this may reflect differences in the composition of the data set.

1 Global Solar Deployment

- 2 U.S. PV Deployment
- **3** PV System Pricing
- 4 Global Manufacturing
- 5 Component Pricing
- 6 Market Activity

- Despite tariffs and the pandemic, PV modules were imported at historically high levels in 2020, up 44% y/y to 26.7 GW.
 - Some of the demand is likely due to developers attempting to "safe harbor" panels to get the 26% ITC (before it was extended).
 - More than half of the panels did not report a duty, likely because of the exemption from Section 201 tariffs for bifacial modules.
- In addition to imports, First Solar's 2.2-GW_{DC} Ohio manufacturing facility averaged over 100% capacity utilization for much of 2020.
- With 5.5 GW_{DC} of annual c-Si PV module assembly capacity, 2.2 GW_{DC} of imported cells in 2020 implies a 41% utilization rate.
- In 2020, the United States produced a record 4.4 GW of PV modules, up 24% y/y, mostly because of a doubling of production capacity by First Solar.
- The United States stopped producing PV cells in Q4 2020, having produced 198 MW for the year.
- PV InfoLink reported that the top ten module manufacturers shipped 114 GW in 2020 or 81.5% of total shipments.

PV Manufacturers' Margins



Lines represent the median, with error bars representing 80th and 20th percentiles for the following companies in Q4 2020: Canadian Solar, First Solar, Motech Industries, Tongwei, Maxeon, Renesola, Risen, Trina Solar, and United Renewable Energy. Margin data from Hanwha Q Cells, Jinko Solar, JA Solar, LONGi, Shanghai Aerospace, Sunpower, and Yingli are also included from Q1 2010 to Q4 2020 where available.

 The median gross margin of the publicly traded PV companies represented to the left declined in Q4 2020; margins are still above historical averages.

 There continues to be significant variation by individual companies as individual factors come into play.

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

Module and Cell Import Data

- Despite tariffs and the pandemic, PV modules were imported at historically high levels in 2020, up 44% y/y to 26.7 GW.
 - 2.2 GW_{DC} of cells were also imported 2020.



- March and June had the highest import levels, likely as a result of uncertainties surrounding future Section 201 tariffs on imported bifacial modules (which were reimposed in Q4 2020).
- Starting February 7, 2020, Section 201 tariffs dropped from 25% to 20%, and then to 18% starting February 7, 2021, although additional tariffs still exist for Chinese products.
- Some of the demand is likely due to developers attempting to "safe harbor" panels to get the 26% ITC (before it was extended).
- In addition to imports, First Solar's 2.2-GW_{DC} Ohio manufacturing facility averaged over 100% capacity utilization for much of 2020.
- With 5.5 GW_{DC} of annual c-Si PV module assembly capacity,
 2.2 GW_{DC} of imported cells in 2020 implies a 41% utilization rate.
 - The actual utilization rate may be slightly higher because of the domestic production of cells and the drawing down of inventory.

Sources: First Solar public filings; Imports, by Value and MW: U.S. International Trade Commission, 2021; Wood Mackenzie Power and Renewables/SEIA: U.S. Solar Market Insight Q4 2020.

2020 U.S. Module Imports by Tariff

2020 U.S. Module Imports by Tariff



In 2020, 14.7 $\mathrm{GW}_{\mathrm{DC}}$ of imported PV modules did not report a tariff.

- Historically, most of these modules have been thin-film, but in 2020 most of them (10.1 GW) were reported to be c-Si and exempt from the Section 201 duties—largely they were from South Korea, Vietnam, Thailand, and Malaysia.
 - Most of these were likely bifacial modules, which were exempt from duties for most of 2020, despite legal challenges. However, in November 2020, the U.S. Court of International Trade reinstated the tariffs.
- For approximately 0.9 GW of imported c-Si modules—subject to Section 201—no duties were reported. Why this happened is unclear.

Note: Module data uses codes: 8541406015, 8541406020, 8541406035. We assume 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."

Source: Imports, by MW: U.S. International Trade Commission, 2021.

Module and Cell Imports by Region

 Module imports in the United States grew from approximately 6–7 GW in 2018 to 26.7 GW in 2020, with growth coming from a few Asian countries.

- U.S. PV cell imports shrank 12% y/y in 2020, though they are still approximately 2X 2018 PV cell imports.
 - Cell imports are concentrated in fewer countries because of the cell manufacturing locations of companies with U.S. module assembly capacity (e.g., Hanwha and LG [South Korea]; China Sunergy, Seraphim Solar, and Jinko Solar [China]).

U.S. Cell Imports by Region



U.S. Module Imports by Region

Note: Cell data uses HTS codes: 8541406030, 8541406025; module data uses codes: 8541406015, 8541406020, 8541406035. January and February 2018 data unavailable. Sources: Imports, by value and MW: U.S. International Trade Commission, 2021.

Chinese PV Imports

- Until late 2019, Chinese PV imports into the United States ٠ had decreased steadily over the decade.
 - Chinese PV cell imports fell first with tariffs introduced in 2012, and these were followed by subsequent module tariffs in 2014.

- From Q3 2019 to Q2 2020, U.S. module and cell ٠ imports from China increased dramatically.
 - The Section 201 bifacial exemption was enacted in June 2019 before imports took off.
 - China has significant bifacial PV manufacturing capacity.
- From Q2 to Q4 2020, U.S. imports of Chinese PV modules and cells dropped precipitously, falling from 8% of total imports to 1%.



Percentage of U.S. PV Imports from China

Cell Import Data by Tariff

A 2.5-GW_{DC} quota exempts the first 2.5 GW of imported c-Si PV cells, each reporting year, subject to the Section 201 tariff.

• In the first three years of the tariffs, the United States did not reach the cap.

2.5 2.5 PV Cells Imported Into U.S. (GW) PV Cells Imported Into U.S. (GW) 2.0 2 1.5 1.5 1.0 1 0.5 0.5 0.0 1312020 212912020 31312020 413012020 51312020 613012020 131/2020 11/30/2020 91301202 1013112029 3/31/2021 A13012021 51312021 613012022 71312021 81312021 913012022 10/31/2021 11/30/2021 1312021 212812022 213212022 1312022

U.S. Cell Cap (February 2020 – February 2021)

Based on import levels for February and March 2021, the United States is unlikely to reach the cap in the final year either, though it is still very early in the year.

U.S. Cell Cap (February 2021 – February 2022)

Note: Cell data uses HTS codes 8541406025.

Sources: Imports, by MW: U.S. International Trade Commission, 2021; U.S. Customs and Protection Commodity Status Reports.

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 \$0.39/W in Q2 2018 to \$0.28/W in Q4 2020.
- Additionally, as a result of the underlying price reduction and step down of the Section 201 tariff, these duties have been cut in half, on a per-watt basis (from approximately \$0.12/W to \$0.06/W).

PV Shipment Rankings

Rank	2020 Shipments	
	Cells	Modules
1	Tongwei (28 GW _{DC} sales volume)	LONGi (~20 GW)
2	Aiko (10-15 GW)*	Jinko Solar (~19 GW _{DC})
3	Runergy (6 GW-10 GW)*	JA Solar (15.9 GW)
4	ShanXi Lu'An (5 GW)*	Trina
5	Solar Space	Canadian Solar (11.3 GW)
6		Hanwha Q Cells
7		Risen Energy
8		Chint (Astronergy)
9		First Solar (5.5 GW)
10		Suntech

*Estimates are based on reported capacity.

- PV InfoLink reported that the top ten module manufacturers shipped 114 GW in 2020—or 81.5% of total shipments.
 - Each of the top 10 companies shipped at least 30% more than they did in 2019.
 - Based on corporate guidance of 2021 shipment from these top companies, PV InfoLink estimates they could represent more than 90% of this year's shipments.
- PV InfoLink reports 55 GW of cell shipments in 2020 from the five-largest cell manufacturers.
 - Shipment of each manufacturer grew more than 60% compared with 2019, reflecting an increasingly concentrated market.

U.S. Module and Cell Manufacturing



Note: 2018–2019 inverter production represent estimates based on inverter shipments in the United States by company and company manufacturing facility location.

Source: Wood Mackenzie Power & Renewables & SEIA, "U.S. Solar Market Insight" (2014–2020).

From 2010 to 2020, U.S. manufacturers faced varying degrees of challenges:

- PV-assembled modules stagnated for most of the past decade before scaling up significantly in 2018 and 2019.
 - In 2020, the United States produced a record 4.4 GW of PV modules, up 24% y/y, mostly as a result of a doubling of production capacity by First Solar.
- Production of cells varied year to year, but cell producers suffered a series of bankruptcies in 2018. In 2019, cell production started to rebound; however, in Q4 2020, cell production stopped, having produced 198 MW for the year.
- Wafer production in the United States ended in 2015.
- China placed tariffs on U.S.-produced polysilicon in 2014, cutting off most buyers and significantly reducing sales. It is unclear how much, if any, solar-grade polysilicon is currently being produced in the United States.
- U.S. inverter manufacturing grew with increasing U.S. demand, however due to economic pressures, many manufacturers closed U.S. plants to consolidate operations in Europe or manufacture in China. Companies with U.S. inverter manufacturing now include: TMEIC, Chint Power Systems, Ingeteam, and Yaskawa Solectria.

Additional parts of the U.S. PV manufacturing supply chain not covered here, such as racking, laminates, and backsheets.

Revenue of U.S. PV



- In 2010, revenue from PV manufacturing was greater than revenue from PV deployment.
- Between 2010 and 2020, as manufacturing revenue declined, revenue from PV deployment increased.
- In 2020, revenue from PV deployment was 14X revenue from PV manufacturing.
- Despite a record level of PV module assembly, revenues from U.S. PV manufacturing in 2020 was approximately one-third of 2010 levels.
 - PV equipment was significantly cheaper in 2020 than it was in 2010.
 - More than half of 2010 U.S. revenues came from polysilicon, wafers, and cells, all of which ceased or significantly reduced production by the end of 2020.
- Similarly, despite a record level of U.S. PV deployment, revenue from PV system sales was lower in 2020 than in 2016, due to the falling price of PV systems.

Silicon PV Supply Chain With Current Tariffs



- To build a c-Si module requires various manufacturing steps, from making the poly(silicon), turning that into an ingot and then a wafer, producing PV cells from wafers, and then finally assembling the cells into a module.
- The majority of the PV supply chain is in China.
- The U.S. could build its domestic capabilities to manufacture all, or a portion of these steps here, or import these products, facing various levels of tariffs.
- NREL performed a bottom-up PV cost modeling exercise for 1 GW product throughput, with the results shown on the left.
- While NREL estimates that it only cost \$0.24/W to manufacture a PV module in China, with the shipping and import tariffs, the final price to the U.S. consumer is \$0.41/W, compare to \$0.39/W for a PV module fully manufactured in the U.S.
 - Modules imported from southeast Asia only have \$0.06/W import costs, and with similar manufacturing costs to China, they cost U.S. consumers \$0.30/W.
 - Also, importantly, the U.S. does not have 1 GW ingot, wafer, or cell manufacturing lines, while many Chinese producers have manufacturing lines greater than 20 GW.

Source: NREL internal analysis.

Key assumptions: 18 g/wafer, 6 W/cell, 200W/m², Overhead: 15% China, 25% U.S., \$100k/job-year, All costs include sustainable overhead and are for established facilities operating in steady-state. Costs will be higher for the first few years during ramp-up. Assumes U.S. ancillary supplies and equipment are imported. Tariff assumptions: 2021 AD/CVD Tariffs (cell & module) - 15%; 2021 Section 201 Tariffs (module) - 18%; Section 301 Tariffs - 25%; Shipping - 5% + \$300/tonne. Figures may not add due to rounding.

Silicon PV Supply Chain Without Current Tariffs



- NREL estimates that without existing Chinese tariffs in place, the U.S. would not longer be competitive with China producing PV modules with a 1 GW manufacturing facility.
- NREL estimates that there would be a reduction in U.S.produced module costs as there would no longer be tariffs in place on other products used to assemble PV modules, as is the case now (e.g. frames, glass).
 - The U.S. currently imports these things, however given enough domestic demand, a domestic supply chain may develop.
- NREL has also performed analysis on CdTe module production costs and estimates that it cost approximately the same amount (\$0.36/W) to produce a CdTe in the U.S. domestically as it does to import it (\$0.33/W to produce in Asia and \$0.03/W to import into the U.S.).
 - CdTe PV modules are not currently subject to U.S. PV import tariffs.

Source: NREL internal analysis.

Key assumptions: 18 g/wafer, 6 W/cell, 200W/m², Overhead: 15% China, 25% U.S., \$100k/job-year, All costs include sustainable overhead and are for established facilities operating in steady-state. Costs will be higher for the first few years during ramp-up. Assumes U.S. ancillary supplies and equipment are imported. Tariff assumptions: 2021 AD/CVD Tariffs (cell & module) - 15%; 2021 Section 201 Tariffs (module) - 18%; Section 301 Tariffs - 25%; Shipping - 5% + \$300/tonne.

Labor & CapEx Requirements by Step

	Poly	Ingot & Wafer	Cell	Module
CapEx Intensity	\$120M	\$90M	\$50M	\$40M
Labor Intensity ²	100 jobs	500 jobs	600 jobs	800 jobs

- If the U.S. did decide to focus on scaling a portion of the domestic PV supply chain, the amount of money required, and the resulting job growth, would not be even across steps.
- NREL estimated the facility CapEx and labor for each GW/year of capacity, as shown on the left.
- There is currently 7.6 GW/year of US module capacity.
 - 5.5 GW c-Si, 1.9 GW CdTe.
- In order to decarbonize the power sector, the U.S. needs to install approximately 50 GW/year.
- The one sector that would not require as significant an expansion, domestically, would be polysilicon, which currently has 30 GW/year of manufacturing capacity.



1 Global Solar Deployment

- 2 U.S. PV Deployment
- **3** PV System Pricing
- 4 Global Manufacturing

5 Component Pricing

6 Market Activity

- Mono c-Si PV module prices rose 6% in Q1 2021, and mono-crystalline PV modules were slightly higher (\$0.22/W) than they were a year ago.
- Polysilicon was up 33% in Q1 2021 and 76% y/y to \$15.6/kg at the end of March.
- In Q4 2020, U.S. mono c-Si module prices fell, dropping to their lowest recorded level, but they were still trading at a 55% premium over global ASP.
- From 2016 to 2020, average battery pack prices within the stationary storage sector dropped 50%, to \$177/kWh.

PV Value Chain Spot Pricing



Source: BloombergNEF Solar Spot Price Index (03/31/21).

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 <u>Bernreuter</u>.

- Mono c-Si PV module prices rose 6% in Q1 2021, and mono-crystalline PV modules slightly higher (\$0.22/W) than they were a year ago.
 - Multi c-Si PV modules rose 3% in Q1 2021 to \$0.18/W but were still down 8% y/y due to lack of demand.
 - BloombergNEF reported higher shipping costs outside China, because of logistical challenges some related to the pandemic.
- Polysilicon was up 33% in Q1 2021 and 76% y/y to \$15.6/kg at the end of March; prices were as low as \$6.3/kg in May and June of 2020. BNEF reports polysilicon manufacturers are enjoying higher margins as poly production capacity has not scaled up to the same degree as wafers, cells, and modules. In response, cell and module manufacturers have reduced production, as developers are unwilling to pay the higher prices and there is no immediate installation deadline.

Module Average Selling Price: Global vs. United States



- In Q4 2020, U.S. mono c-Si module prices fell, dropping to their lowest recorded level, but they were still trading at a 55% premium over global ASP.
 - U.S. multi c-Si module prices dropped precipitously because of a significant lack of demand, to global pricing.
 - Prior to Q4 2020, bifacial modules were trading a few cents below mono c-Si in the United States because of an exemption to the Section 201 tariffs; however, that exemption was removed in Q4 2020.

Average Lithium-ion Battery Pack Price, 2010–2019

Battery pack price (real 2020 \$/kWh)



- From 2010 to 2020, average battery pack prices dropped 89%.
 - From 2019 to 2020 alone, prices dropped 13%.
 - The survey includes 100 data points across electric vehicles and stationary storage.
- From 2016 to 2020, average battery pack prices within the stationary storage sector dropped 50%.
 - Over this period, they were purchased at a 20%–40% premium over average prices across all sectors.
- BloombergNEF said cost decreases could be attributed to increased sales volume, the adoption of new cell designs, and the introduction of higher energy-density cathodes.
 - The introduction of new pack designs and falling manufacturing CapEx is expected to continue price reductions.
- BloombergNEF expects that if batteries follow their historical learning rate, average prices will fall to \$92/kWh by 2024 and \$45/kWh by 2035.



1 Global Solar Deployment

- 2 U.S. PV Deployment
- **3** PV System Pricing
- 4 Global Manufacturing
- 5 Component Pricing

6 Market Activity

- Despite the downturn in the stock market in March 2020, the broader market more than recovered, with the S&P 500 up 15% in 2020.
 - Solar stocks, which were up 222% in 2020, well outperformed the broader market in 2020.
- In Q1 2021, the S&P 500 was up 7%, while solar stocks were down 13%.
 - The downturn in solar stocks was likely due to a broader correction in clean energy ETFs after the huge gains that followed last year's U.S. presidential election.

SREC Pricing

- Despite the pandemic's effect on electricity sales (a driver of SREC demand) and PV deployment (a driver of SREC supply), SREC markets were relatively flat in 2020.
 - SRECTrade estimated DC had an oversupply of SRECs in 2020, but pricing was relatively flat, y/y, until Q1 2021.

- In March 2021, legislation was introduced to increase Pennsylvania's solar RPS carve-out from 0.5% to 5.0%. The legislation was introduced days after Pennsylvania's governor pledged that 50% of the state government's energy will come from solar by 2023 (through 191 MW of projects across the state).
 - PA SREC pricing jumped in March 2021.
- New Jersey and Massachusetts have moved away from offering SRECs to new projects in recent years, in lieu of fixed payments.



Source: SRECTrade, https://www.srectrade.com/, accessed 04/09/21. SRECTrade (11/17/20, 04/05/21)

Stock Market Activity

- Despite the downturn in the stock market in March 2020, the broader market more than recovered, with the S&P 500 up 15% in 2020.
 - Solar stocks, which were up 222% in 2020, well outperformed the broader market in 2020.
- In Q1 2021, the S&P 500 was up 7%, while solar stocks were down 13%.
 - The downturn in solar stocks is likely due to a broader correction in clean energy ETFs after the huge gains that followed last year's U.S. presidential election.

• 2020 stock performances and the Q1 2021 pullback varied by company.



Individual Stock Performance



Note: The TAN index is weighted toward particular countries and sectors. As of 08/31/20, 52% of its funds were in U.S. companies. Its top ten holdings, representing 63% of its value, were Sunrun, SolarEdge, Enphase, First Solar, Xinyi, Vivint Solar, Daqo, SunPower, Solaria Energia, and Encavis.

Source: Stock market: Yahoo Finance (04/09/21).

Cost of Capital 2021: Challenges

- Some developers reported difficulty finding capital.
 - Tax equity returns increased in 2020 by ~0.5% as a result of supply constraints.
- There is more competition for tax equity now as new technologies search for capital (e.g., offshore wind, carbon capture, PV+storage [higher cost than just PV]).
- The pandemic forced some providers out of the marketplace (potentially temporarily).
 - There is still uncertainty in how the pandemic will affect construction, demand, and plant operation, and the pandemic makes it more difficult to perform due diligence with travel restrictions.
- Looking forward, there is uncertainty for tax equity investors caused by:
 - Potential changes in tax code (e.g., increase in corporate tax rate)
 - Profit uncertainty caused by the pandemic
 - Questions about whether some tax equity supply will come back or there will be new market entrants.
- Changes to property insurance received attention in 2020. Recent claims for wind (hurricanes, flooding) and solar (hail) caused the insurance industry to:
 - 1. Lower coverage
 - 2. Have higher restrictions for payout
 - 3. Have higher premiums.

In response, financiers and developers are becoming very cognizant of where a project is located and are trying to systematize risk.



Sources: Norton Rose Fulbright Cost of Capital: 2021 Outlook; Photo by Dennis Schroeder / NREL

Cost of Capital 2021: Opportunities

- While there was a pause in the marketplace due to the pandemic, capital for solar projects was still available and relatively cheap for most of 2020 and continues to be cheap looking forward.
 - Supply issues mostly affect "marginal" projects; when there are good market opportunities, capital will come in to fill the void.
- Investors have a great appetite for ESG (environmental, social, and corporate governance) projects and in some cases prioritize that over return.
 - New financiers are also entering marketplace.
- A record number of projects are available for financing.
- Bank debt pricing has dropped due to declining underlying interest rates.
- Combined resource investments (i.e., bundled wind and solar projects) are becoming more popular due to complementary resource and tax credit characteristics.

- The pandemic has created efficiencies in the marketplace by having more offsite due diligence practices. Remote monitoring has allowed for more efficiency and better quality (ensuring things are happening properly at every site).
- Banks are now offering credit for 5 years of merchant risk after PPA.



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

- In the Chinese Province of Xinjiang, the rising solar energy technology sector is accused of being connected to a broad program of assigned labor in China, including methods that fit well-documented patterns of forced labor.
- The majority of PV manufacturing capacity in Xinjiang is ingots (8% of global) and polysilicon (36% of global).

- According to a report by the consultancy Horizon Advisory, Xinjiang's rising solar energy technology sector is connected to a broad program of assigned labor in China, including methods that fit welldocumented patterns of forced labor. The report states that:
 - Laborers undergo "military-style" training that may be aimed at instilling loyalty to China and the Communist Party.
 - The government has forced many people from farms to work in factories in the cities—fulfilling government quotas—under the belief that this will bring minorities out of poverty and break down cultural barriers
 - Many laborers are Uighurs (Muslim minority) and other ethnic minorities in China.
- The Chinese government disputes the presence of any forced labor in its supply chains, arguing that employment is voluntary.

- In January 2021, the Trump administration imposed sanctions on dozens of companies and banned some exports from the region, which is also a major exporter of cotton.
 - Many companies that used Xinjiang's cotton (e.g., H&M and Patagonia) have recently cut ties.
 - While solar companies are denying these claims, they are now considering similar changes to their supply chain.
- Congress is also considering sweeping legislation that would ban all products with materials from Xinjiang unless companies certify that the goods are made without forced labor. The House of Representatives passed this bill in September with bipartisan support.
 - A bipartisan commission of the U.S. Congress said China possibly committed genocide in its treatment of Uighurs and other minorities. A response to this finding may be taken soon by the U.S. government.

Xinjiang PV Manufacturing Capacity

- Most PV manufacturing capacity in Xinjiang is ingots (8% of global) and polysilicon (36% of global).
 - Major PV companies have operations in Xinjiang, including GCL-Poly, East Hope Group, Daqo New Energy, Xinte Energy, and Jinko Solar.
 - Rapid expansion in the region was helped by cheap electricity from coal-fired plants and government support.

Global Polysilicon Manufacturing Capacity

- Global PV polysilicon manufacturing is heavily concentrated, with Xinjiang representing the largest such manufacturing region.
 - Lack of access could have an impact on the supply/demand balance, possibly driving prices up in restricted markets, like the U.S. market.

Special thanks to Nate Blair, Mike Meshek, Madeline Schroeder, and Adam Warren.

Thank You

www.nrel.gov

NREL/PR-7A40-79758

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

List of Acronyms and Abbreviations

•	AC	alternating current	•	LG&E	Louisville Gas and Electric
•	AD	antidumping duty	•	LMI	low and moderate income
•	ASP	average selling price	•	m	meter
•	BIPV	building-integrated photovoltaic	•	MLPE	module-level power electronics
•	BNEF	Bloomberg New Energy Finance	•	Mono c-Si	monocrystalline
•	CapEx	capital expenditures	•	Multi c-Si	multicrystalline
•	C&I	commercial and industrial	•	MW	megawatt
•	C-Si	crystalline silicon	•	MWh	megawatt-hour
•	CdTe	cadmium telluride	•	NEM	net energy metering
•	CSP	concentrating solar power	•	Poly	polysilicon
•	CVD	countervailing duty	•	PPA	power purchase agreement
•	DC	direct current	•	PTC	production tax credit
•	DPV	distributed PV	•	PV	photovoltaic
•	EIA	U.S. Energy Information Administration	•	R&D	research and development
•	ETF	exchange traded fund	•	ROW	rest of world
•	FiT	feed-in-tariff	•	Q	quarter
•	G&A	general and administrative expenses	•	S&P	Standard and Poor's
•	GW	gigawatt	•	SEGS	solar energy generation systems
•	H1	first half of year	•	SEIA	Solar Energy Industries Association
•	H2	second half of year	•	SG&A	selling, general and administrative expenses
•	IOU	investor-owned utility	•	SMART	Solar Massachusetts Renewable Target
•	ISO	independent system operator	•	SREC	solar renewable energy certificate
•	ISO-NE	ISO – New England	•	TAN	Invesco Solar ETF
•	ITC	investment tax credit	•	TW	terawatt
•	kg	kilogram	•	TWh	terawatt-hour
•	KU	Kentucky Utilities	•	W	watt
•	kW	kilowatt	•	y/y	year over year
•	kWh	kilowatt-hour	•	YTD	year to date
•	LBNL	Lawrence Berkeley National Laboratory			