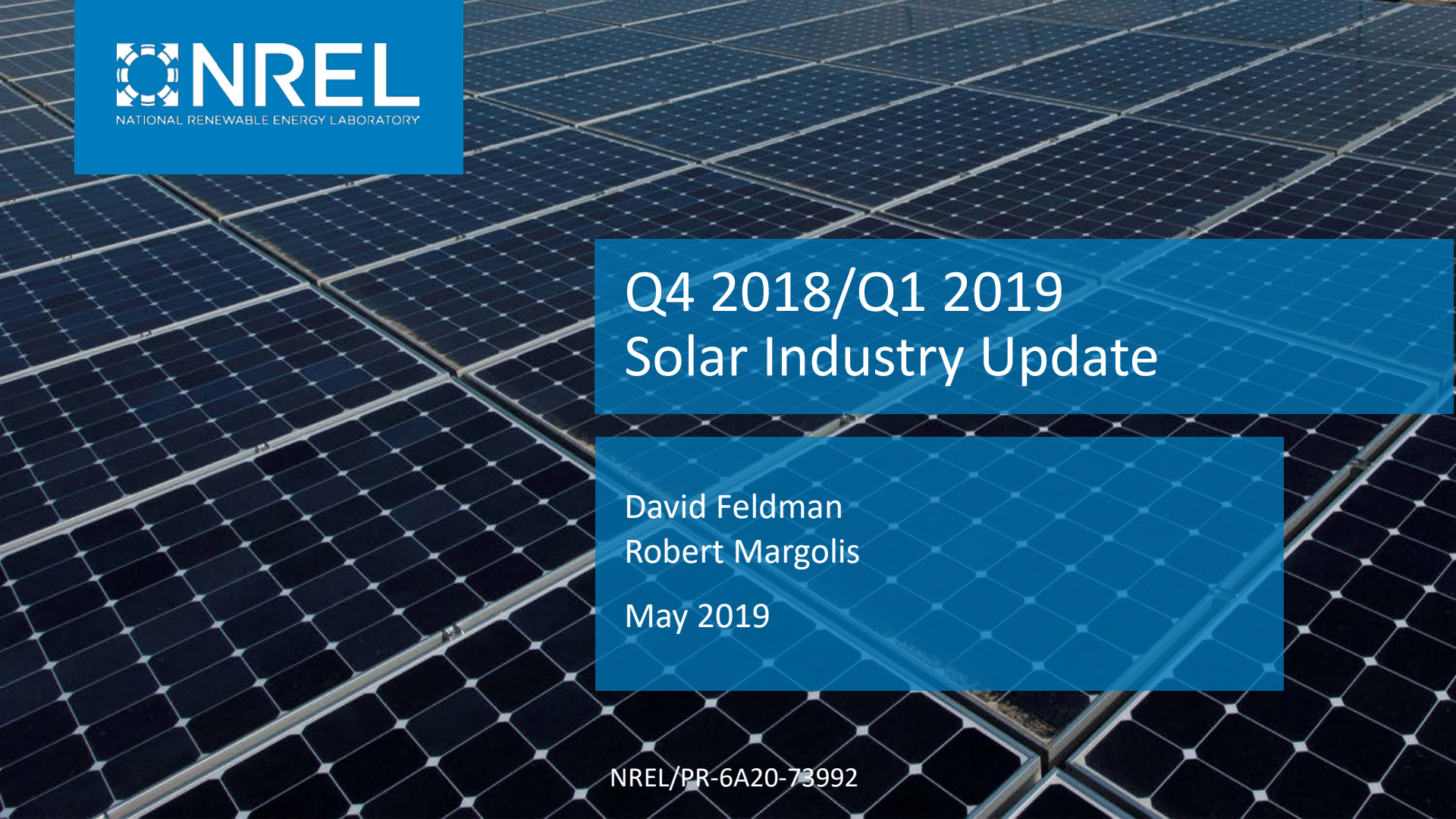

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Q4 2018/Q1 2019 Solar Industry Update

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May 2019

NREL/PR-6A20-73992

Executive Summary

- At the end of 2018, global PV installations reached 509 GW-DC, an annual increase of 102 GW-DC from 2017.
  - In 2018, the leading markets in terms of annual deployment were China (44 GW-DC), the United States (11 GW-DC), and India (8 GW-DC).
  - Analysts expect cumulative PV capacity to double by 2022.
- At the end of 2018, cumulative global CSP installations reached 6.2 GW, up 710 MW from 2017.
- Solar installations represented 22% of all new U.S. electric generation capacity in 2018—second to natural gas (58%).
- In 2018, solar represented 4.6% of net summer capacity and 2.3% of annual net generation.
  - However, 10 states generated more than 4% of their annual net electricity from solar, with California leading the way at 19%.
- The United States installed 10.7 GW-DC of PV in 2018 (8.3 GW-AC), with 4.2 GW-DC coming in Q4—cumulative capacity reached 62.5 GW-DC (49.7 GW-AC).
  - Analysts also expect U.S. PV capacity to double by 2022.
- In 2018, global PV shipments were approximately 89 GW—a decrease of 5% from 2017. More than 96% of those PV shipments used c-Si technology and were shipped from Asian countries.
- In 2018, the United States produced approximately 1 GW of c-Si modules and 0.4 GW of thin film.
  - The United States expanded its PV manufacturing capacity to 6 GW in Q1 2019 (up from 2.5 GW in 2017), and it is expected to add another 3 GW in the near future.
- In the first four months of 2019, solar stocks recovered dramatically, wiping away the 2018 losses.

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

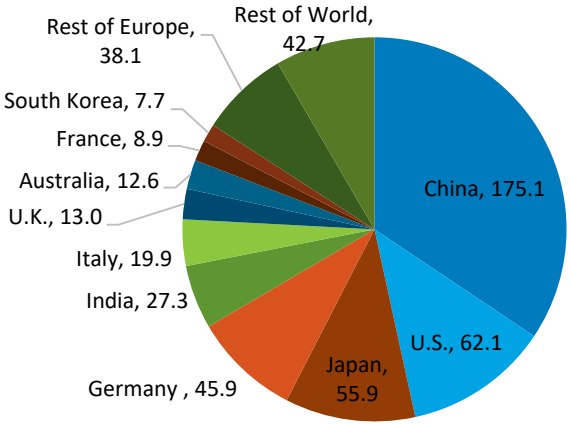
- **At the end of 2018, global PV installations reached 509 GW-DC—an annual increase of 102 GW-DC from 2017.**
  - **In 2018, the leading markets in terms of annual deployment were China (44 GW-DC), the United States (11 GW-DC), and India (8 GW).**
- **Analysts expect a significant increase in global PV deployment in 2019 and further increases through 2022.**
  - **The median analyst PV projection estimates the world will double its cumulative capacity between 2019 and 2022, to more than 1 TW.**
- **At the end of 2018, global CSP installations reached 6.2 GW—up 710 MW from 2017.**
  - **Most of the installs were in Morocco, China, South Africa, and Spain.**

Top PV Markets

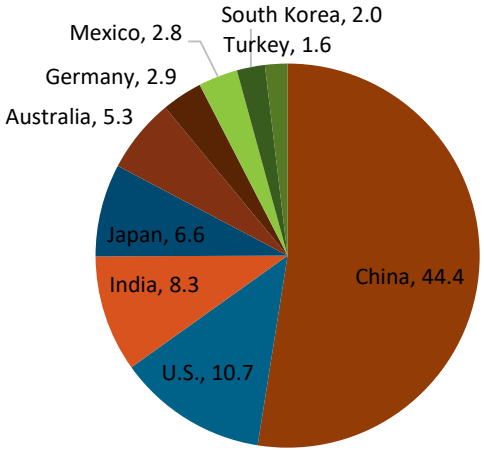
- The leading five markets, in cumulative and annual PV installations at the end of 2018 were China, India, the United States, Japan, and Europe.

- By the end of 2018, China had more than 175 GW of cumulative PV installations, an annual increase of 44 GW—less than the 53 GW China installed in 2017; however, still more than the other top nine markets combined.
- In 2018, the U.S. PV market was the second-largest market in terms of both cumulatively and annual installations.

Cumulative PV Deployment—2018 (509 GW-DC)



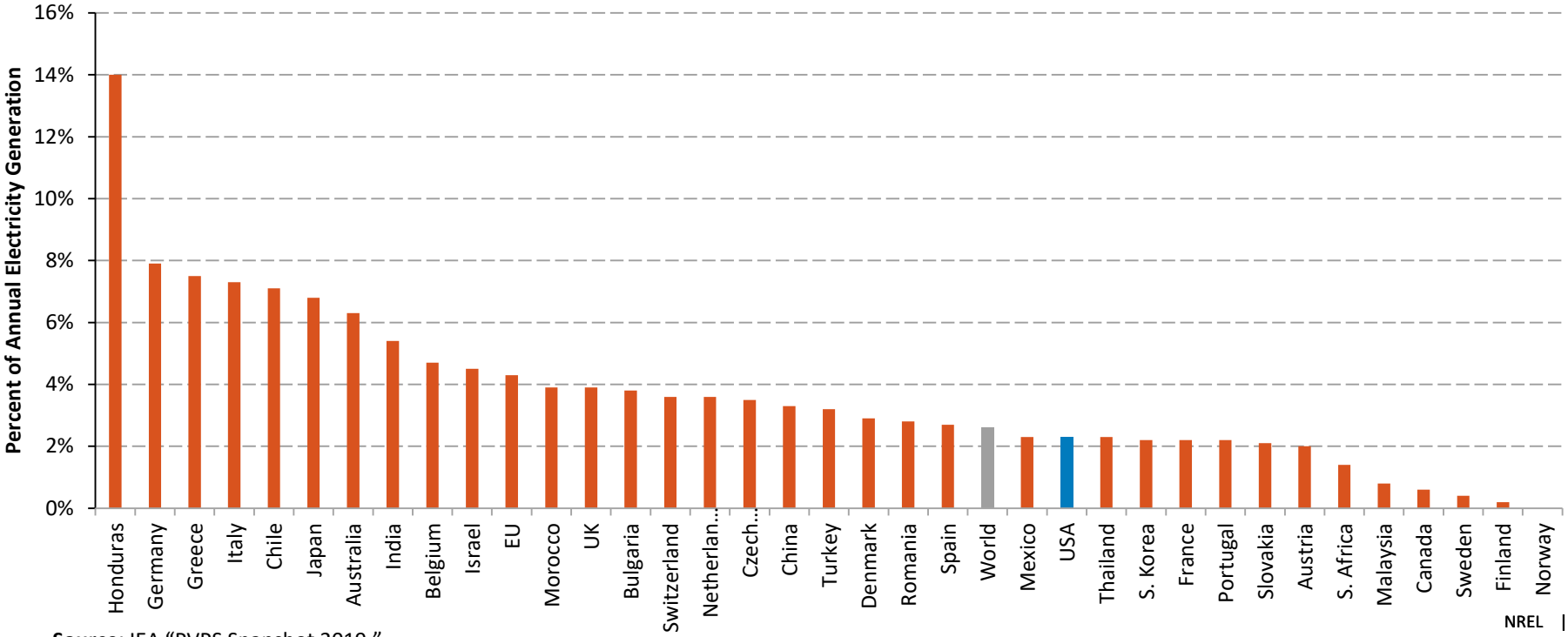
Annual PV Deployment—2018 (102 GW-DC)



Source: : Solar Power Europe "Global Market Outlook For Solar Power / 2019 – 2023"

Global PV Penetration

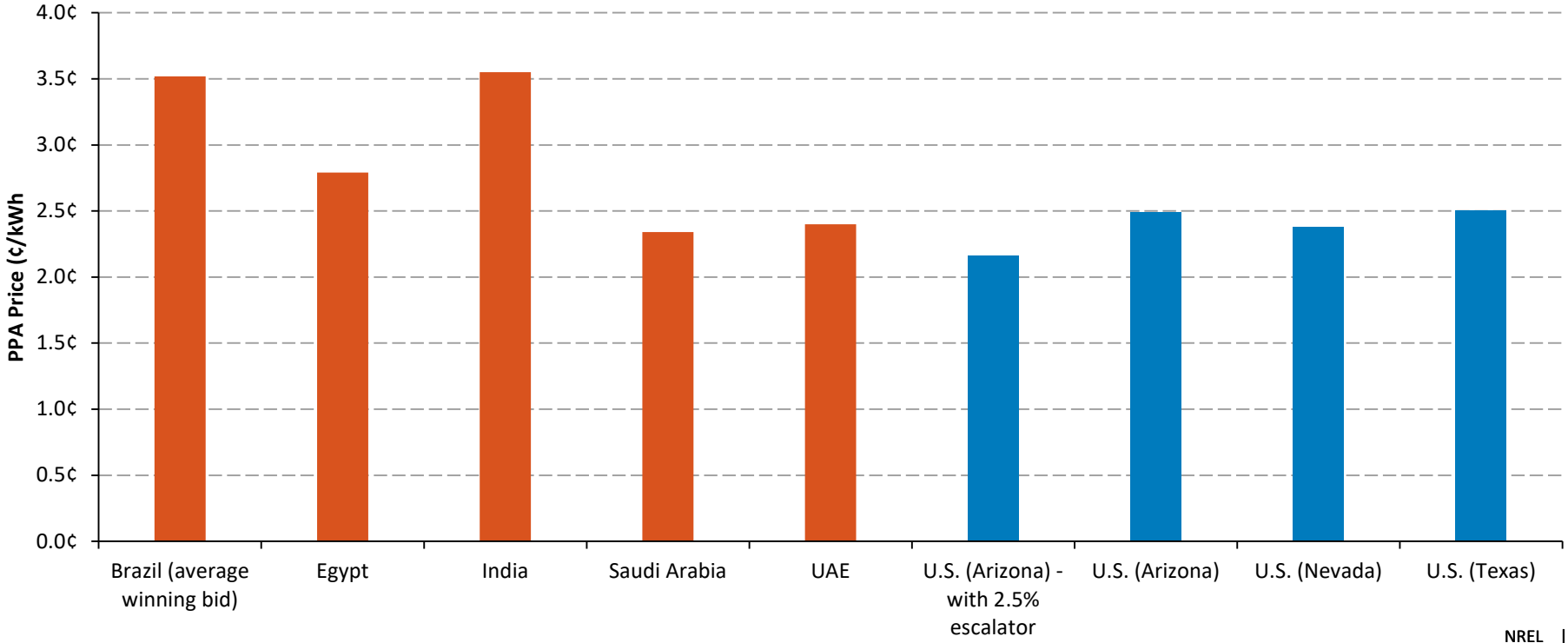
- The IEA estimates that in 2018, 2.6% of global electricity generation came from PV.
- The United States, despite being one of the leading PV markets, ranks below average in terms of PV penetration, with 2.3%.



Source: IEA "PVPS Snapshot 2019."

Selection of Lowest Solar Auction Bids around the World In 2018

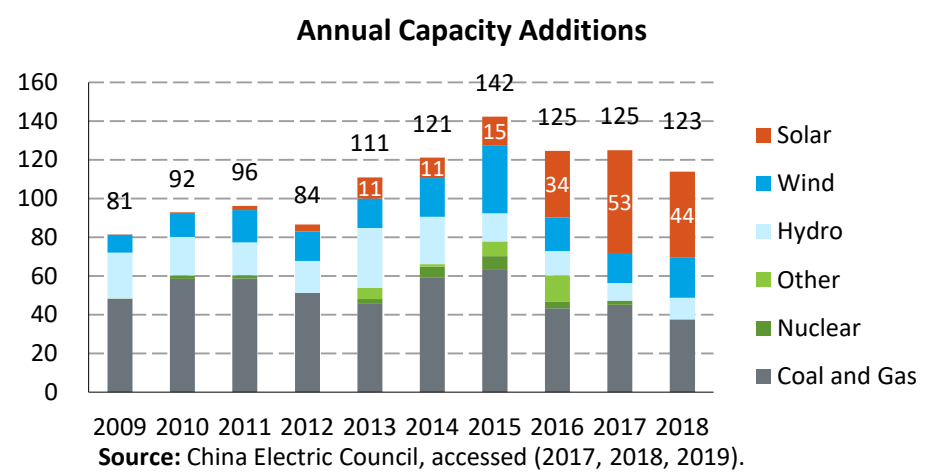
- While global solar auction bids varied around the world, several countries, including the United States, saw solar project bids between 2.1¢/kWh AND 3.5¢/kWh in 2018.
  - Some of these bids included escalators or incentives (e.g., the U.S. Investment Tax Credit).



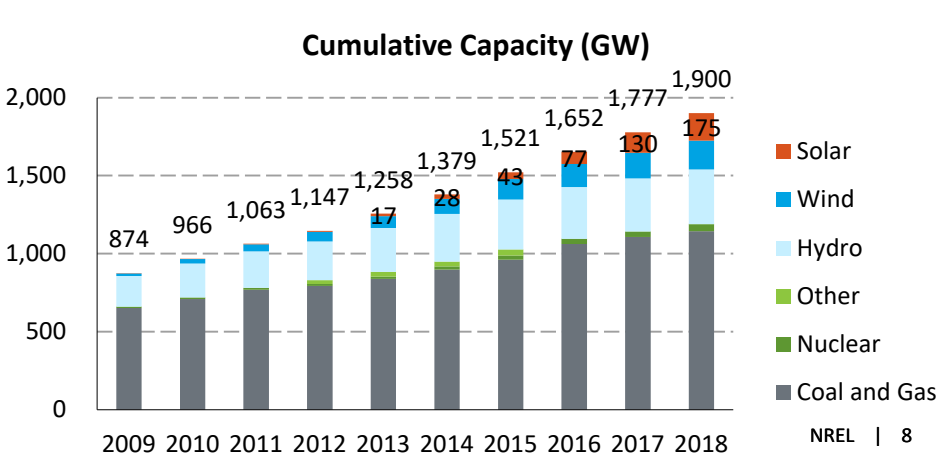
Source: Solar Power Europe "Global Market Outlook For Solar Power / 2019 – 2023"

Chinese Generation Capacity Additions by Source

- In 2018, solar contributed 36% to new generation capacity in China (44 GW; 23 GW were utility-scale and 21 GW were distributed PV) and 9% of cumulative capacity (175 GW).
  - 2018 was the second straight year that wind and solar contributed more than half of all new electric generation in China (53%).
  - Chinese annual electric generation capacity additions have been around 4–6 times greater than additions by the United States for the past 10 years.
- As China grows its electricity infrastructure, it has rapidly incorporated non-carbon sources of electricity generation.
  - Since 2009, China has doubled its installed electric generation capacity, and at the same time reduced the percentage of total coal and gas capacity from 74% to 60%.
  - From 2010 to 2018, non-carbon generation capacity as a percentage of total new capacity increased from 37% to 69%.



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



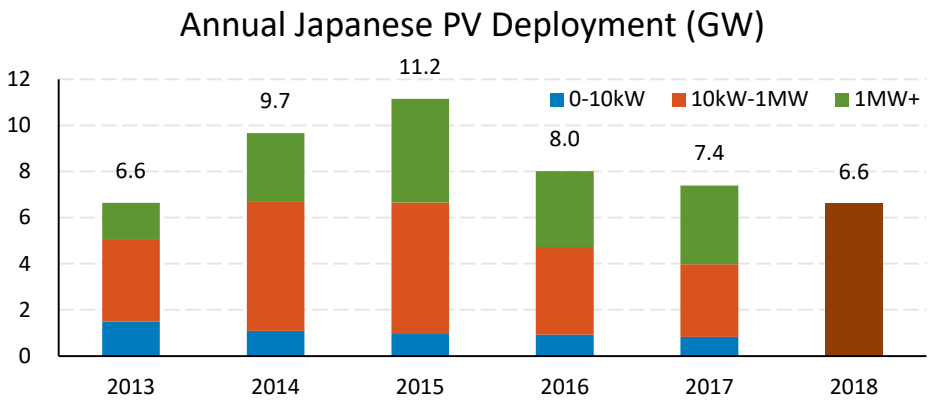
Chinese Market Update

- At the end of 2016, China issued its plan to reach 105 GW of PV by 2020; however, by the end of 2017, it had already reached 130 GW.
  - China adjusted its subsidy program in May 2018 to control the pace of deployment, with an effort for more gradual growth, better market design, and higher quality products.
- In late April 2019, China issued its FiT policy for 2019. While this should create more demand in the second half of 2019, the lack of a decision until well into Q2 caused a relatively weak market.
  - 5.2 GW were installed in Q1 2019 (2.4 GW ground-mounted and 2.8 GW distributed PV), compared to 9.7 GW in Q1 2018.
- The FiT rates range from:
  - $0.06/kWh to $0.08/kWh for centralized ground-mounted PV systems (depending on zone, and subject to competition)
  - $0.10 to $0.13/kWh for PV systems that fall under the "village level" poverty alleviation program
  - $0.15/kWh for C&I PV systems, designed for self-consumption
  - $0.27/kWh for residential PV systems, designed for self consumption.
- China has also issued supportive measures for unsubsidized grid-parity projects, which would not be subject to annual quotas and could be approved by local governments.
- Policies supporting greater renewable integration, along with power demand growth, helped reduce solar curtailment from 10% in 2016 and 6% in 2017 to 3% in 2018.

Sources: Solar Power Europe **"**Global Market Outlook For Solar Power / 2019 – 2023" Bank of America (05/01/19); Cleantechnica (05/01/19); Wood Mackenzie (11/17/17); PV Magazine (04/23/19).

Japanese Market Update

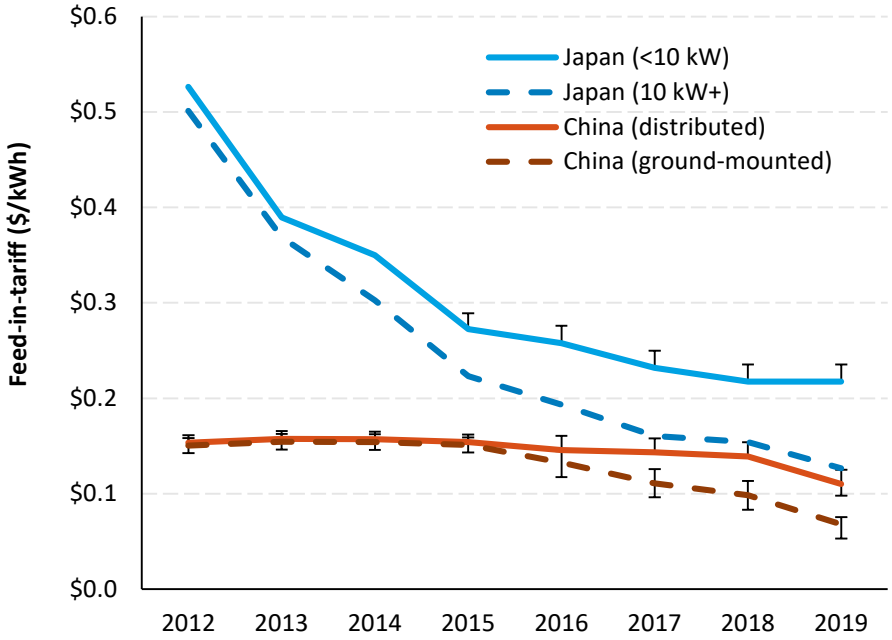
- Approximately 6.6 GW-DC of PV were installed in Japan in 2018, a reduction of 8%.
  - The Japan Photovoltaic Energy Association attributes the reduction in deployment to further FiT reductions for nonresidential PV systems and grid constraints, leading to greater expansion of curtailment on the mainland.
  - The Japanese market is struggling to transition from its FiT scheme to auctions and self-consumption.



- In January, Japan outlined its steepest ever yearly cut to it PV FiT, down to 14 yen/kWh for C&I projects—22% lower than 2018.
  - FiT for residential PV systems remain unchanged, though they are likely to be reduced next year.
  - The PV auction will change from systems of 2 MW+ to systems that are larger than 500 kW.
- Japan held its third solar auction in December 2018 and was fully subscribed for the first time (though only for 197 MW).
  - Average bids of $135/MWh were 37% below Japan's first auction in March 2017 but were still considerably higher than other parts of the world.
- In December 2018, Japan proposed a new rule that would cut the FiT price in half for solar projects awarded before 2015 that are not built by March 2020.
  - This rule could affect 11–17 GW of projects and is expected to cause an increase in deployment in 2019 and 2020.

Source: Solar Power Europe "Global Market Outlook For Solar Power / 2019 – 2023;" BNEF, "1H 2019 Japan Market Outlook." April 2019.

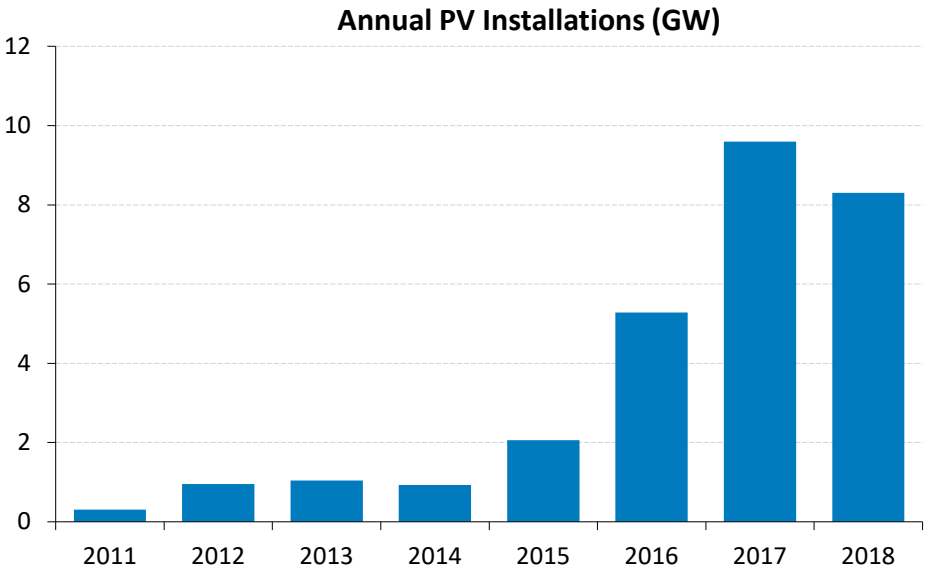
Japanese and Chinese Feed-in-Tariffs



- Since 2012, Japanese FiT rates have declined 65% for systems greater than 10 kW and 43% for systems fewer than 10 kW.
- Despite the rapid decline rates, Japanese FiTs are still double that of Chinese FiT rates, which also declined between 43% and 57% (depending on geography and market segment) over the same period.
- In 2017, Japan began competitively awarding tariffs to PV systems above 2 MW in size.
  - Next year, it will begin doing the same for systems greater than 500 kW.
- Beginning in 2019, China will also award FiT payments "subject to competition."

Sources: BNEF, IEA, U.S. Department of Trade, Federal Reserve, PV Magazine (05/01/19).

Indian Market Update



India installed 8.3 GW in 2018, down from its peak of 9.6 GW in 2017.

- The National Solar Energy Federation of India expects India to rebound in 2019 with 13 GW.
- In 2018, 74% of India's new power generation came from renewables, with solar contributing 50%.
- India has targeted 100 GW of solar installations by 2022; at the end of 2018, there were 28 GW.
- The Indian government is also in the process of establishing 66 GW of transmission line capacity by March 2020 to help bolster solar growth.

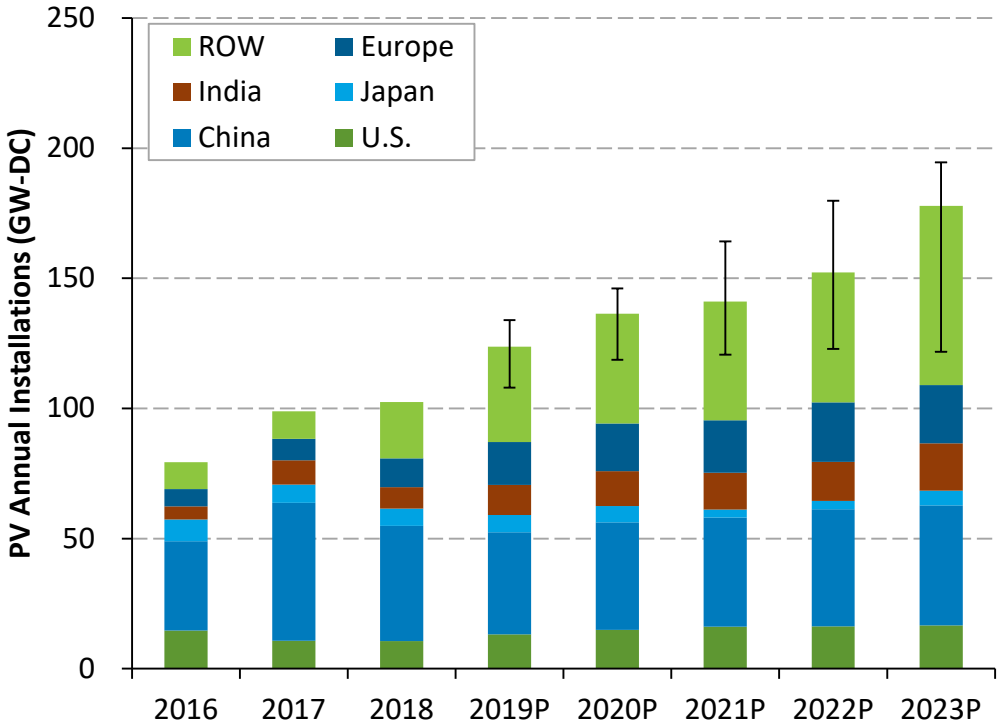
Source: Solar Power Europe **"**Global Market Outlook For Solar Power / 2019 – 2023." BNEF, "1H 2019 India Market Outlook." January 2019. BNEF, "Capacity & Generation" data set. Accessed May 5, 2019.

Indian Auction Market Update

- In India, most PV capacity is installed through a competitively bid auction for large-scale systems.
  - These auctions have had difficulties in the past, which has caused a delay in installations. For example, part of the reason H2 2018 utility-scale installations shrank y/y was due to a poor bidding process in 2016 (combined with a 25% tariff on modules and a falling rupee).
- India awarded 11.4 GW-AC of PV under auction in 2018, by far its largest year ever—up from 5.3 GW-AC in 2017.
  - 16 GW-AC of solar project tenders were announced in H2 2018, which should keep activity going in 2019 and beyond.
- Auction prices ranged from $35/MWh to $44/MWh.
  - The low prices were attributed to the fall in module prices, even after the 25% safeguard duty for modules from China and Malaysia; 84% of modules imported in 2018 came from China, and another 5% came from Malaysia.
  - The lowest bids came from Indian IPPs.
- India has tried to boost local manufacturing by tying generation project awards to having local supply. However, they have to date not had success, as manufacturers are reluctant to make a big investment without certainty of future demand.

Source: BNEF, "1H 2019 India Market Outlook." January 2019. BNEF, "Capacity & Generation" data set. Accessed May 5, 2019.

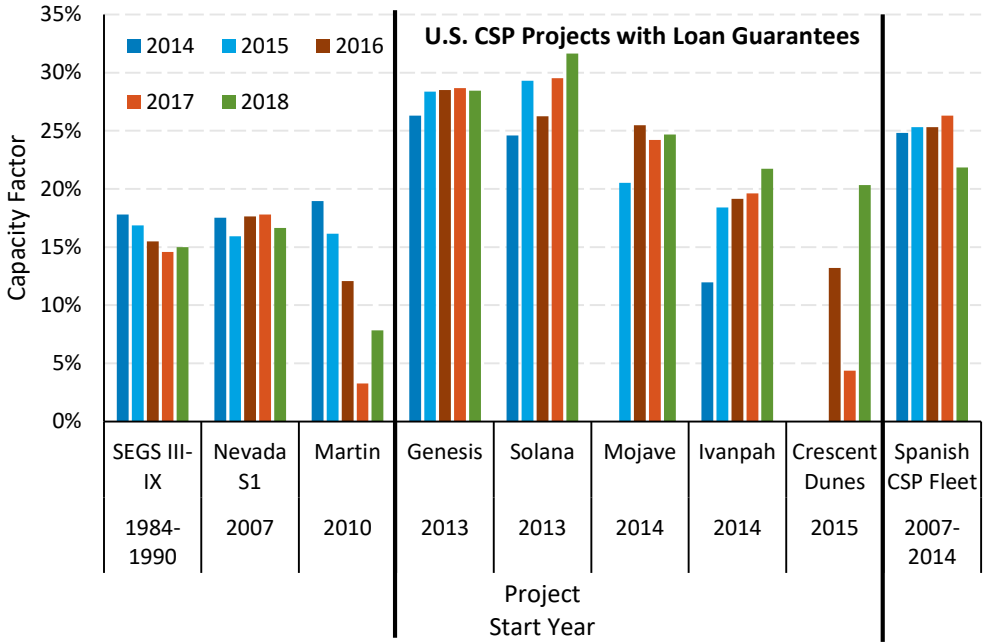
Annual Global PV Demand



- Analysts expect a significant increase in global PV deployment in 2019, increasing further through 2023.
  - The median analyst PV projection estimates that the world will double its cumulative capacity from 509 GW in 2019 to more than 1 TW in 2022.
- Analysts expect China, with ~one-third of the total global market, to remain the largest PV market through 2023.
  - Developing markets, such as the Middle East and Latin America, are expected to contribute a significant portion of overall global PV growth.

Note: P = projection. Bar represents median projection. Error bars represent high and low projections.
Sources: BNEF (February 2019); Goldman Sachs (03/13/19); Wood Mackenzie Power & Renewables, Global solar outlook: Q1 2019 https://www.woodmac.com/reports/power-markets-global-solar-pv-market-outlook-update-q1-2019-299162 Solar Power Europe "Global Market Outlook For Solar Power / 2019 – 2023;" UBS (02/07/19).

U.S. and Spanish CSP Project Generation Performance, 2014–2018

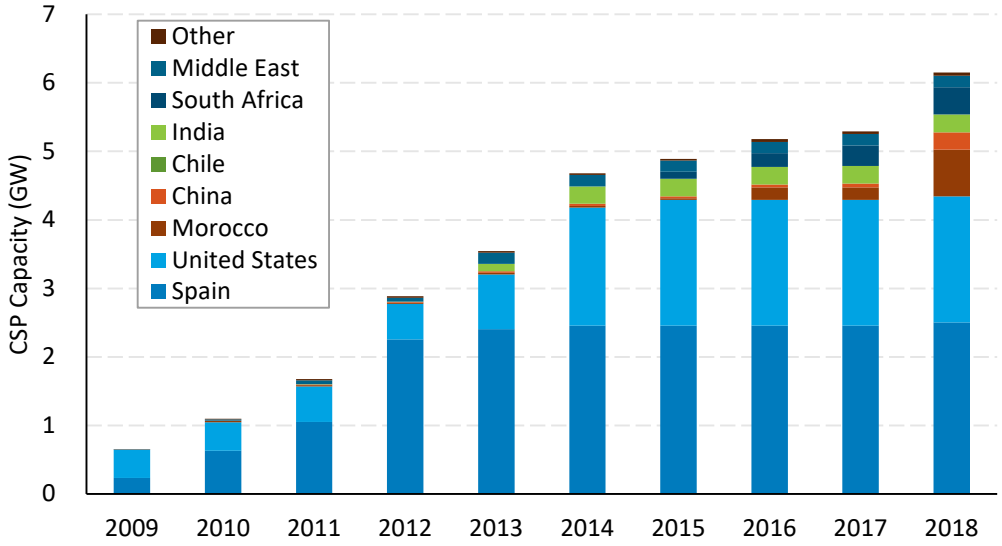


- All the U.S. CSP projects that received loans guarantees from the U.S. Department of Energy continue to improve operations and increase system production.
  - In 2018, Mojave, Genesis and Solana (trough plants) showed higher capacity factors than the Spanish fleet, most of which is trough plants.
- In 2018, Solana, with six hours of storage, had the highest capacity factor on record (32%), for a U.S. CSP plant.
  - The plant generated 776 GWh in 2018—more than any other U.S. CSP plant and the third most of any U.S. solar plant (behind Solar Start and Topaz).
- Crescent Dunes, with 10 hours of storage, continues to improve operations, with 2018 being the first year in which it was operational every month of the year.
  - Previous operational issues have been addressed.

Sources: Mark Mehos. EIA, "Electric Power Monthly" 1.1, 1.1A; 2018; EIA, "Monthly Energy Review" (2019); TSO (REE).

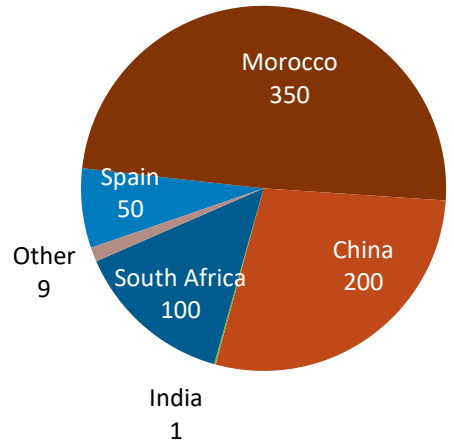
Global CSP Installed

- At the end of 2018, global CSP installations reached 6.2 GW.
- The majority of CSP is still located in Spain and the United States, but other countries' global market share has grown from 1% in 2009 to 31% in 2018.



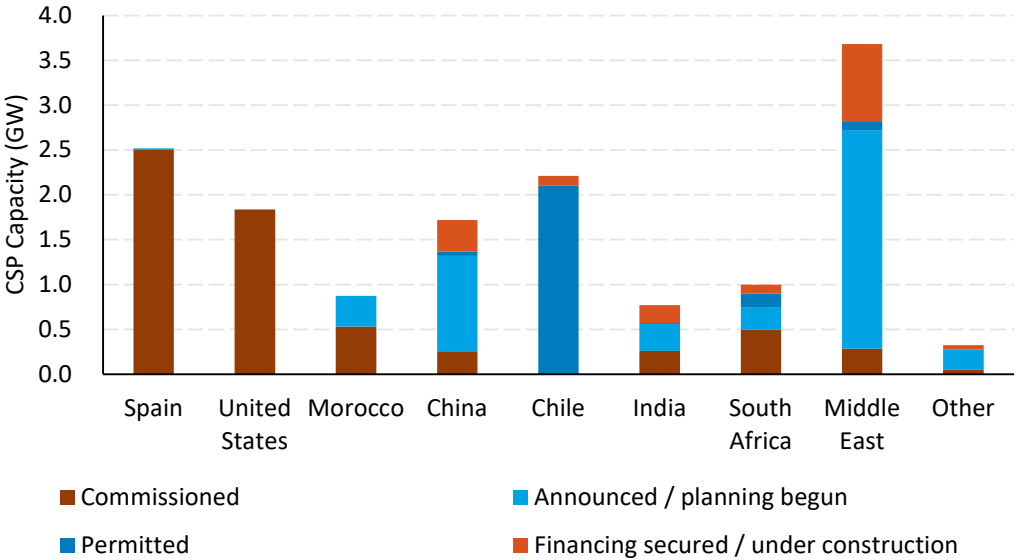
- 710 MW of CSP were added in 2018, representing its largest year since 2014.
  - Most of the installs were in Morocco, China, South Africa, and Spain.
- In the first four months of 2019 another 221 MW of CSP plants were placed in service.
  - A 121-MW power tower in Israel (Ashalim B) and a 100-MW trough plant with 4.5 hours of storage in South Africa (Redstone).
  - IEA forecasts that 900 MW of CSP could be added in 2019.

2018 Global CSP Additions (Total: 710 MW-AC)



Source: BNEF, "Capacity & Generation" data set. Accessed April 26, 2019; : IEA, "Renewables 2018 – Analysis and Forecasts to 2023". Report. Accessed May 14th, 2019.

Global CSP Pipeline



- While Spain and the United States are global market leaders in CSP, most active development is happening in other parts of the world.
  - The areas with the largest solar development are China, Chile, the Middle East, Morocco and South Africa.
- New Energy Update (from CSP Today) announced in March 2019 that the $4.4B Noor Energy 1 CSP/PV hybrid project in the UAE reached financial close, with $2.9 billion in debt and $1.5 billion in equity (700 MW CSP, 250 MW PV).
  - When complete, the CSP plant will be the largest in the world and have a bundled electricity price of $73/MWh. The CSP portion on its own is $83/MWh.
    - The PV PPA price on its own is $24/MWh.
- New Energy Update reports that GE and the Southwest Research Institute have designed, built, and tested the world's highest-temperature supercritical carbon dioxide turbine, which could boost CSP plant efficiency from 35%-40% to nearly 50%.
  - Researchers will incorporate the technology into a 10-MW CSP plant currently under construction in San Antonio.

Sources: BNEF, "Capacity & Generation" data set. Accessed April 26, 2019; New Energy Update (04/17/19; 04/03/19). New Energy Update. "World's largest CSP plant ties tariffs to big storage to hit record price". Online. Accessed May 14th 2019

1 Global Solar Deployment

2 **U.S. PV Deployment**

3 PV System Pricing

4 Global Manufacturing

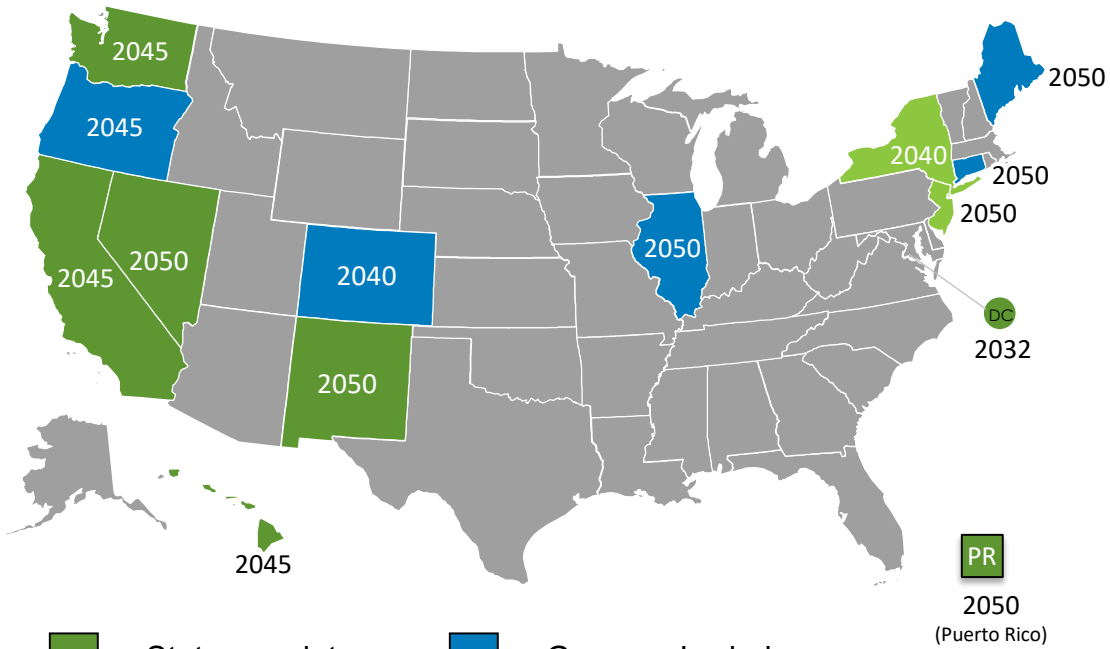
5 Component Pricing

6 Market Activity

7 Opportunity Zones

- **Solar installations represented 22% of all new U.S. electric generation capacity in 2018—second to natural gas (58%).**
- **Solar still represents a relatively small but growing percentage of the U.S. electric generation mix.**
  - **In 2018, solar represented 4.6% of net summer capacity and 2.3% of annual generation.**
- **The 10 states with the highest percentage of solar penetration generated at least 4% of their energy from solar in 2018, with California leading the way at 19%.**
- **At the end of 2018, there were approximately 2 million residential PV systems in the United States, representing around 1.7% of households.**
- **The United States installed 10.7 GW-DC of PV in 2018 (8.3 GW-AC), 4.2 GW-DC in Q4—cumulative capacity reached 62.5 GW-DC (49.7 GW-AC).**
  - **Analysts expect cumulative installations to double by 2022.**
- **The United States installed approximately 777 MWh (310 MW) of energy storage onto the electric grid in 2018—up 80% y/y, and 15X annual installations in 2013.**

States' Commitments to 100% Carbon-Free Electricity



- In the first four months of 2019, Puerto Rico, Nevada and Washington joined California, Hawaii, and Washington D.C. committing to 100% carbon-free electricity.

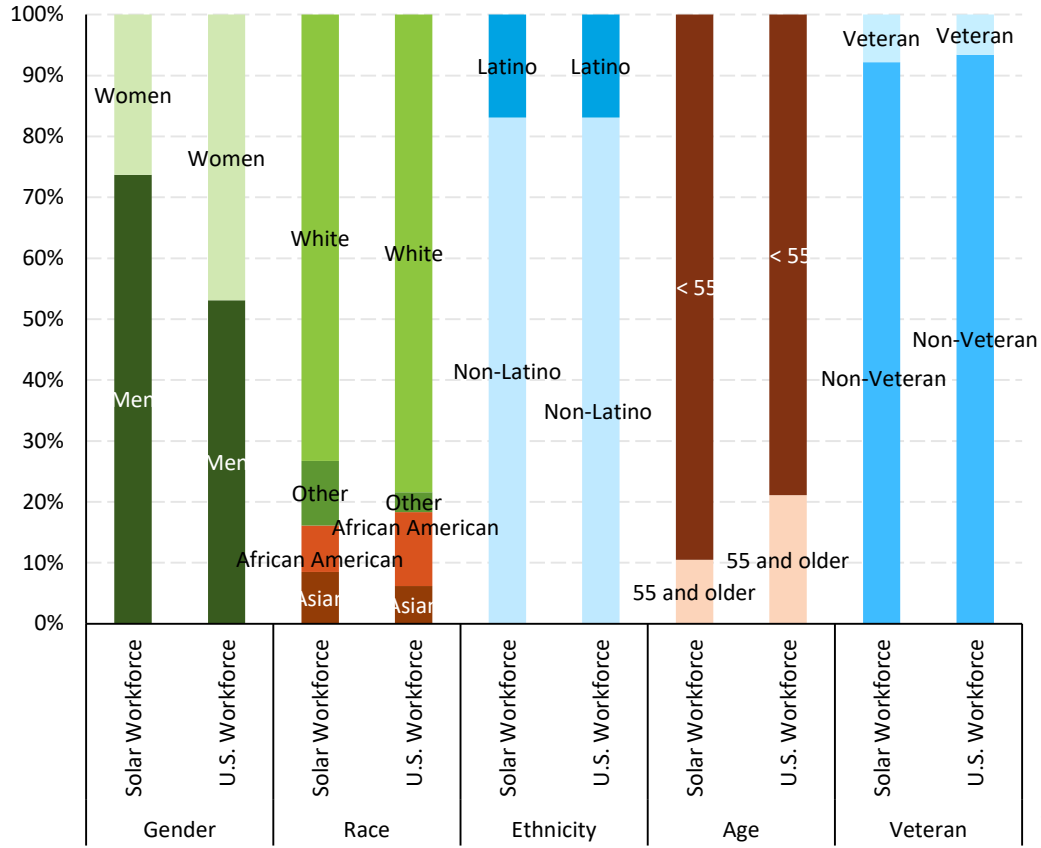
  Additionally, the governors of New Jersey and New York have signed executive orders—and the governors of Colorado, Connecticut, Illinois, Massachusetts, Maine, and Oregon have made pledges—to achieve 100% carbon-free electricity.

- In 2017, these 14 jurisdictions consumed more than 18% of U.S. electricity.

- All these commitments have a target date between 2030 and 2050.

Sources: Bloomberg (04/22/19); Cleantechnica (03/24/19) Washington State Wire (04/26/19).

Solar Workforce Diversity

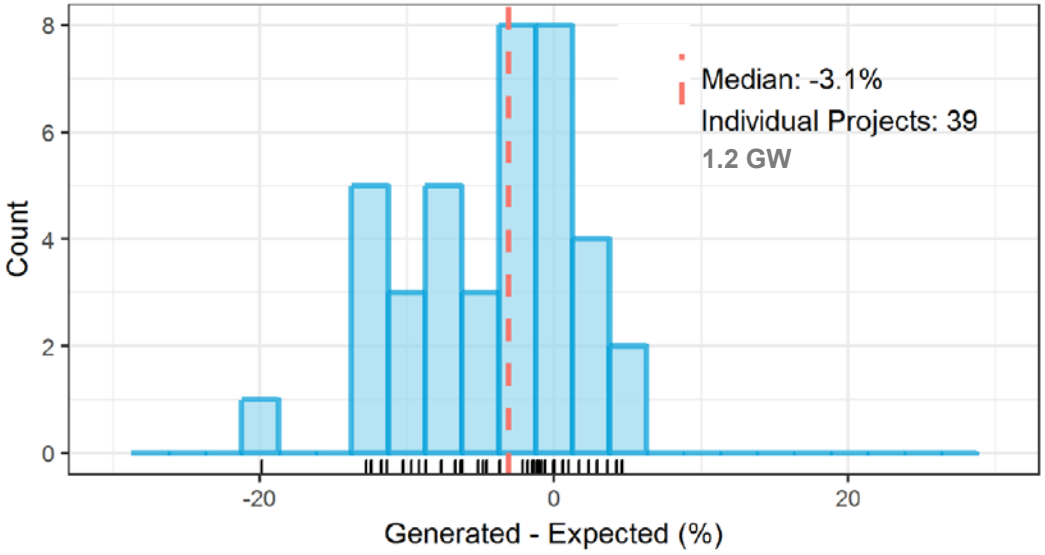


- SEIA and the Solar Foundation published a study on diversity and inclusion in the solar workforce, as well as a compendium of best practices on improving workforce diversity.
- The solar industry tends to have fewer women, older staff, and African Americans than the U.S. workforce overall.
- At solar firms, men are more likely to be represented at the management level than women (37% to 28% respectively), and executive-level positions are predominantly comprised of white males (88% white, 80% men).
  - Consistent with this trend, women make 74% of the wages men earn in the solar industry.
- Three of the top five solar-firm recruitment methods relied on the use of professional or personal networks to find candidates, which can lead to a lack of diversity.
  - People of color were much less likely to find their current position by employee referral or word of mouth.
- Companies that are more diverse tend to be more profitable; additionally, the United States is growing more diverse over time so it will be critical for companies to tap into the full labor market.

Sources: SEIA and The Solar Foundation: "U.S. Solar Industry Diversity Study 2019;" "Diversity Best Practices Guide for the Solar Industry."

PV System Underperformance

- A recent report, *Solar Risk Assessment: 2019*, published data and analysis from 10 leading solar firms on PV performance and the underlying drivers of deviation from electricity generation predictions.
- The report found that, over a data sample size of 1 GW of projects, predicted energy was approximately 3% greater than measured production, in the median case. However, that gap disappeared when omitting first-year production data, suggesting lower availability in the first year.



- After analyzing a separate data set, the authors of the report also found that of more than 200,000 PV projects, the probability of the P99 production occurring (i.e., the annual production value in which it is estimated will be exceeded 99% of the time) would actually occur 6.3% of the time, not 1%.
  - P99 values help determine PV loan sizing and therefore, defaults are actually more likely to occur.
- The report attributes several explanations to the lower than expected production:
  - Variation in module quality of Tier 1 module manufacturers and manufacturing lines
  - Significant underperformance from certain systems due to 30+ days of inverter downtime caused by slow turnaround from the inverter manufacturer when a problem occurs (and a lack of accountability in the original sales contract)
  - Significant reduction in O&M pricing, caused by competition—well below what is required to sufficiently service a system
  - Incomplete EPC punch list due to project scheduling and budget.

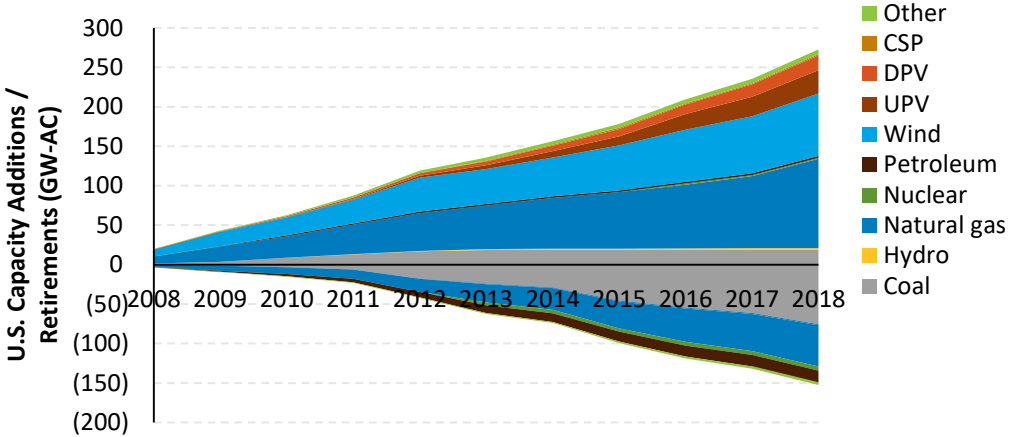
Source: "Solar Risk Assessment: 2019 Quantitative Insights from the Industry Experts."

U.S. Electric Generation Capacity Additions by Source

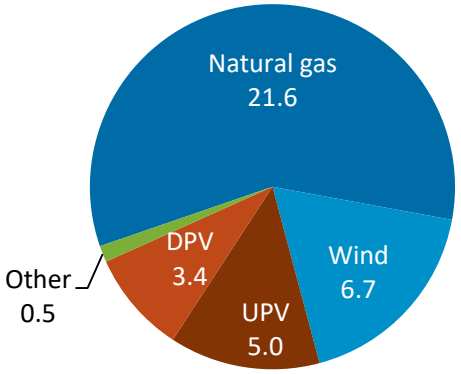
- From 2008 to 2018, solar installed the third most electric generation capacity in the United States (50 GW-AC), behind natural gas (113 GW-AC) and wind (79 GW-AC)
  - Wind led net capacity additions during that time, as 52 GW-AC of natural gas facilities were also retired (netting 61 GW-AC).
  - Coal capacity declined the most over that time, retiring 75 GW-AC while adding 19 GW-AC.

- 37 GW-AC of new U.S. electricity generating capacity came online in 2018, growing 44% y/y.
  - The growth is attributed to a 105% increase in natural gas deployment to 21.6 GW—its highest level since 2003.
  - From 2008 to 2018, average annual U.S. electric capacity additions was 23 GW.
  - Solar installations represented 22% of all new U.S. electric generation capacity in 2018—second to natural gas (58%).
- 2018 was the first year since 2013 that solar and wind did not represent more than 50% of new U.S. electric generation capacity.

Cumulative U.S. Generation Capacity Additions (2008-2018)



2018 U.S. Generation Capacity Additions (Total 37.2 GW-AC)



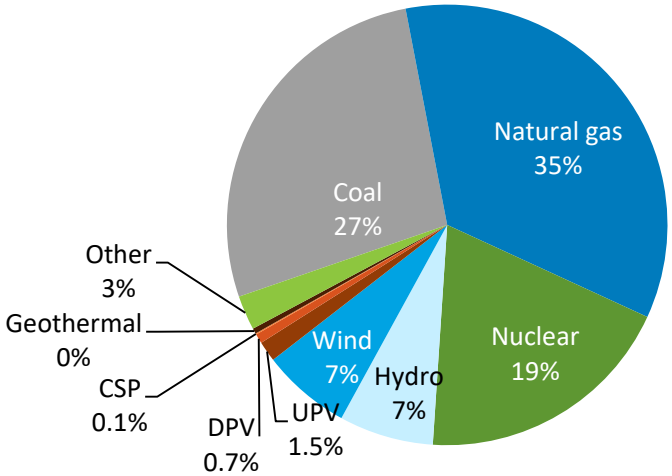
Sources: EIA "Preliminary Monthly Electric Generator Inventory" (December 2018). EIA, "Electric Power Monthly" Table 6.1; 2018. PV data prior to 2015 from Wood Mackenzie Power & Renewables / SEIA, assuming an ILR of 1.2.

2018 U.S. Generation and Capacity

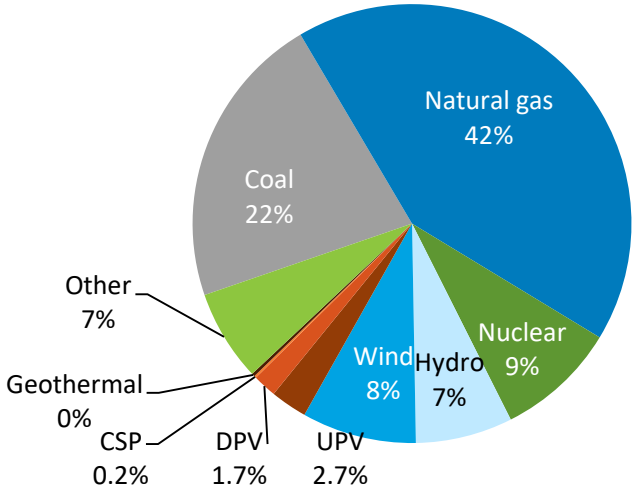
- Renewables are becoming an increasingly large part of the U.S. electric generation mix, representing 22% of capacity and 18% of generation in 2018 when including hydro.
  - Adding nuclear, non-carbon sources represented 31% of capacity and 37% of generation.

- Solar still represents a relatively small, but growing, percentage of the U.S. electric generation mix.
  - In 2018, solar represented 4.6% of net summer capacity and 2.3% 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).

2018 U.S. Generation (Total 4,207 TWh)

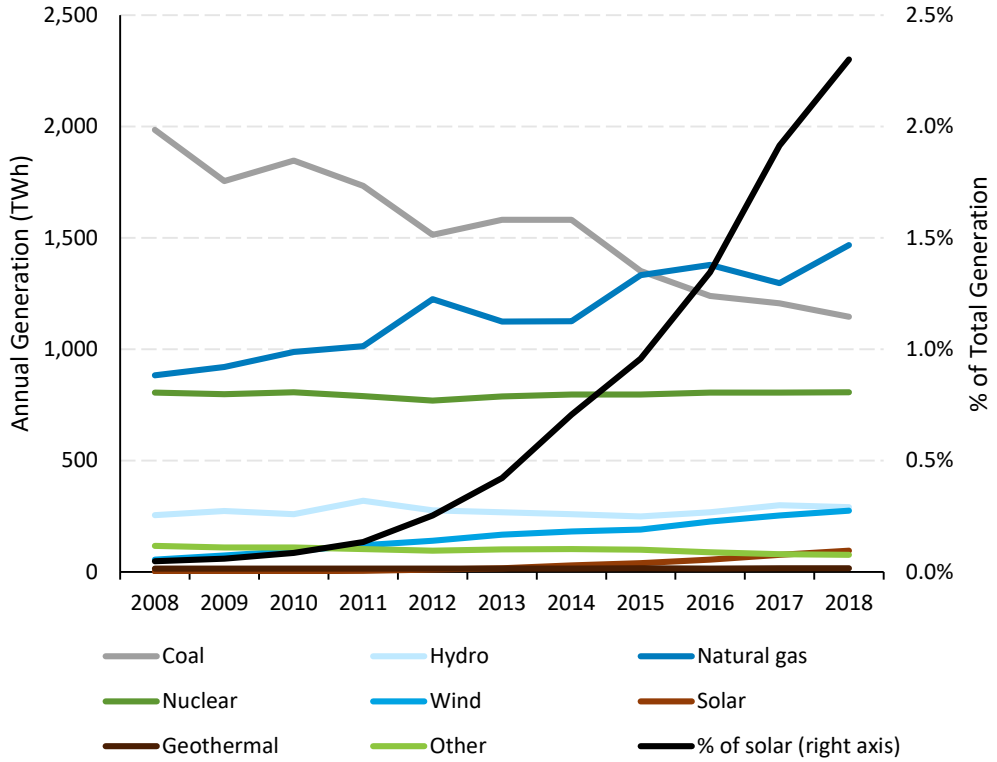


2018 U.S. Generation Capacity (Total 1.1 TW)



Sources: EIA, "Electric Power Monthly" Tables 6.1, 6.2B, 1.1, 1.1A; February 2019. Note: "Other" includes some renewable sources.

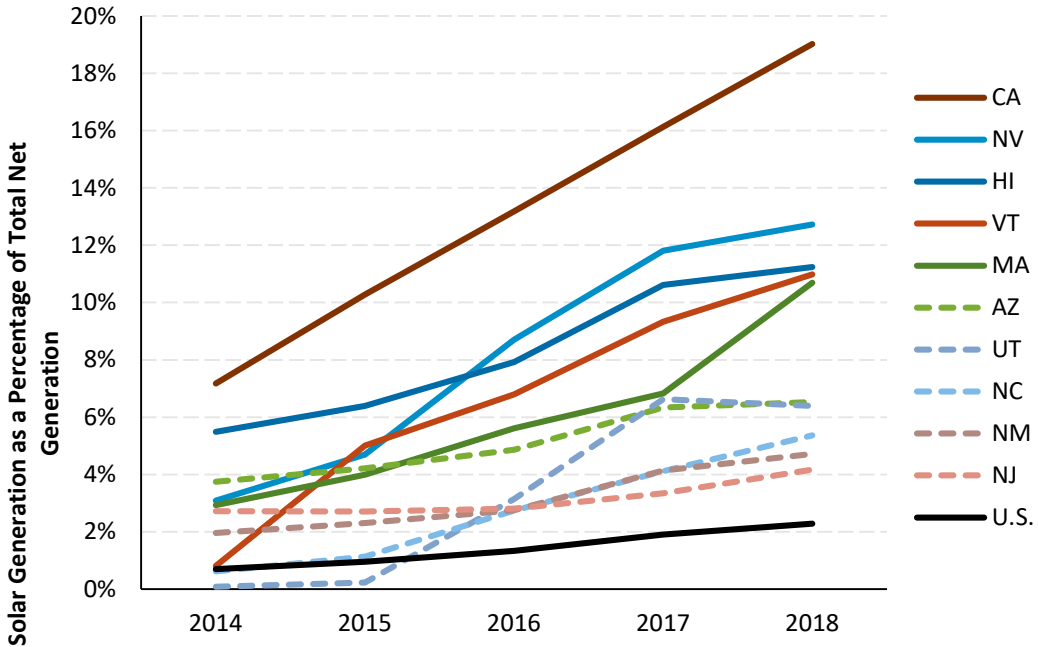
U.S. Generation, 2008–2018



- Coal and natural gas generation have been heading in opposite directions over the past 10 years.
- The percentage of electricity generated by fossil fuels in the United States dropped from 71% in 2008 to 63% in 2018, while over the same period, renewable generation increased from 9% to 18%.
- Despite solar only contributing 2.3% of electric generation, its percentage has increased 47X since 2008.

Sources: EIA, "Electric Power Monthly" 1.1, 1.1A; 2018; EIA, "Monthly Energy Review" (2018).

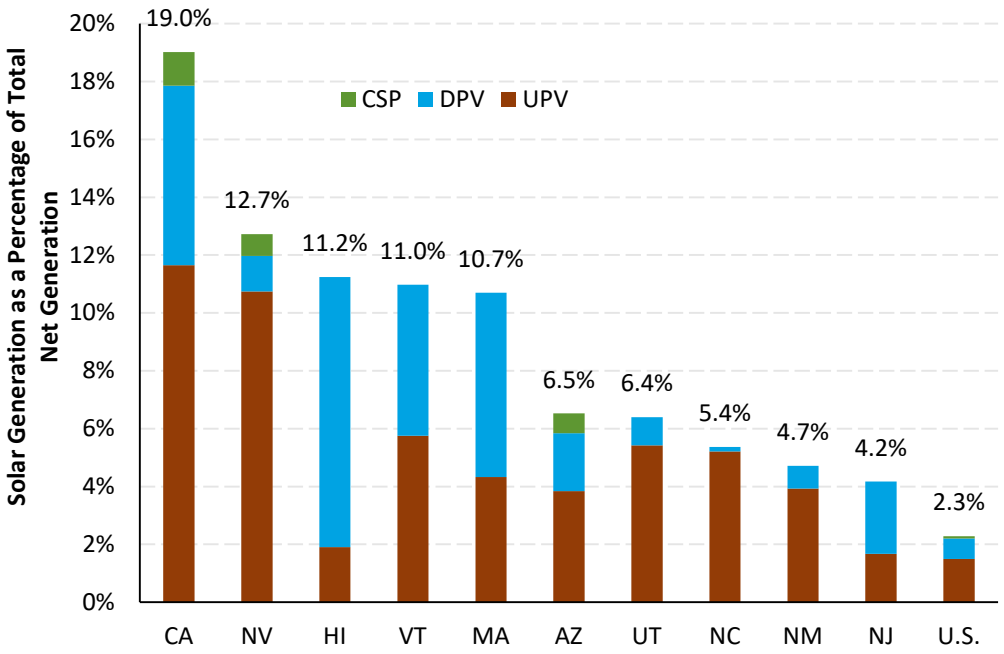
Solar Generation as a Percentage of Total Generation, 2014–2018



- The 10 states with the highest percentage of solar penetration generated at least 4.0% of their energy from solar in 2018.
  - California lead the way at 19.0% in 2018, representing a 165% increase from 2014 (7.2%).
  - Utah's percentage of 6.4% in 2018 was slightly down, y/y, due to growth in production of other generation sources.
- In 2018, the United States as a whole produced approximately 2.3% of its electricity using solar technologies.
  - This represents an approximate 3X growth from 2014 (0.7%).

Note: EIA monthly data for 2018 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, "Electricity Data Browser." Accessed April 3, 2019.

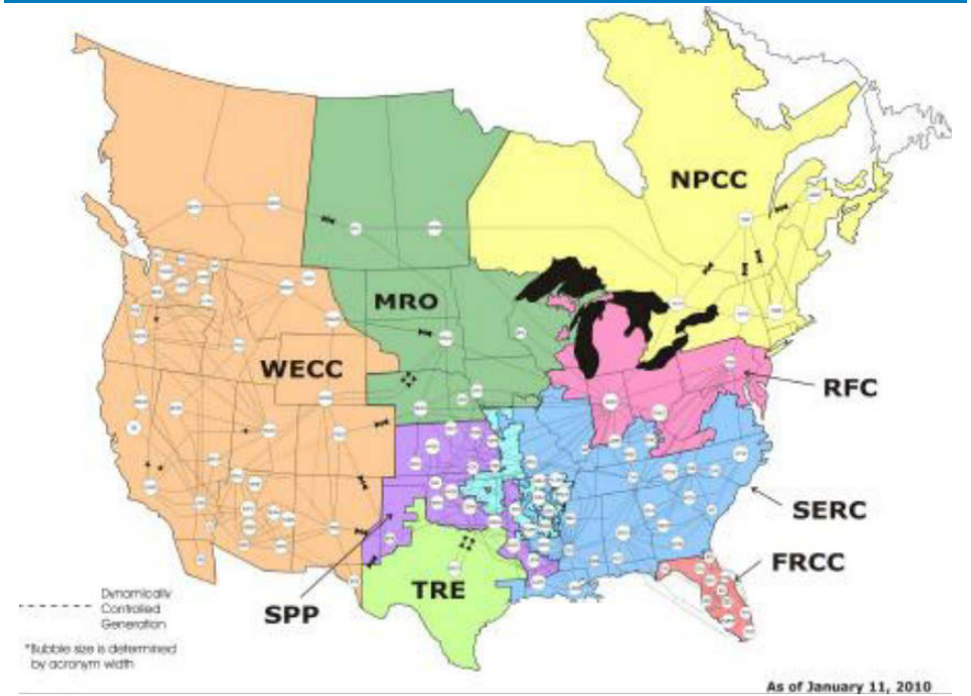
Solar Generation as a Percentage of Total Generation, 2018



- The role of utility versus distributed solar varies by state, with northeastern states and Hawaii relying more on DPV.

Note: EIA monthly data for 2018 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, "Electricity Data Browser." Accessed April 3, 2019.

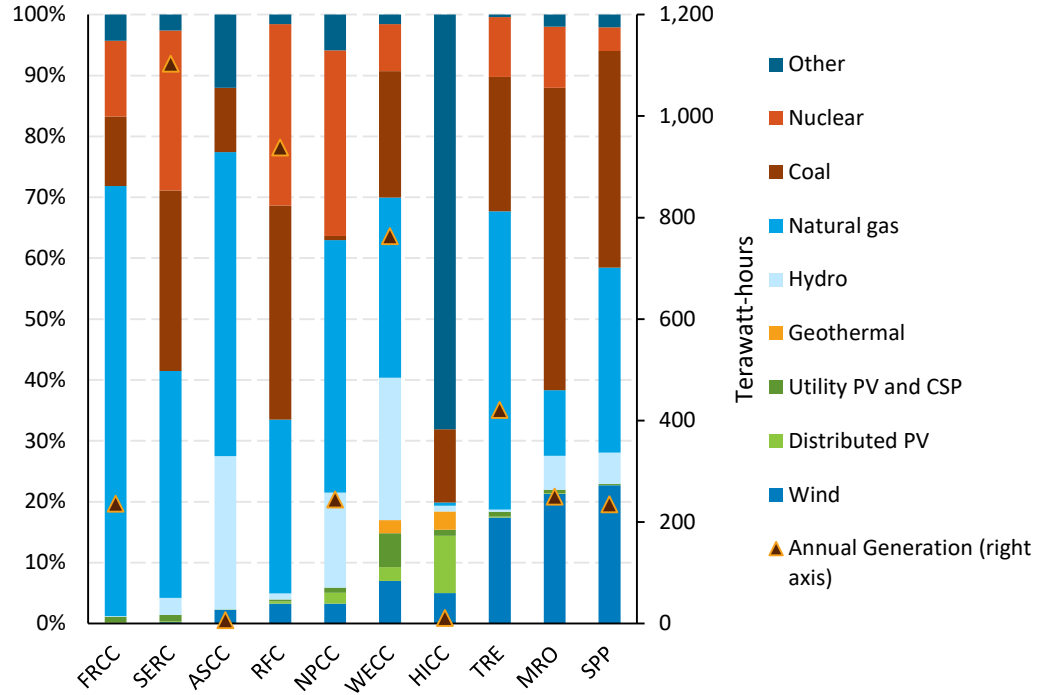
Regions and Balancing Authorities



- NERC regional reliability entities ensure the reliability of bulk power systems in the United States and Canada.
- In addition to NERC, more than 70 balancing authorities maintain load balance and support interconnection frequency.

Source: Mccalley, James. (2019). Introduction to System Operation, Optimization, and Control.

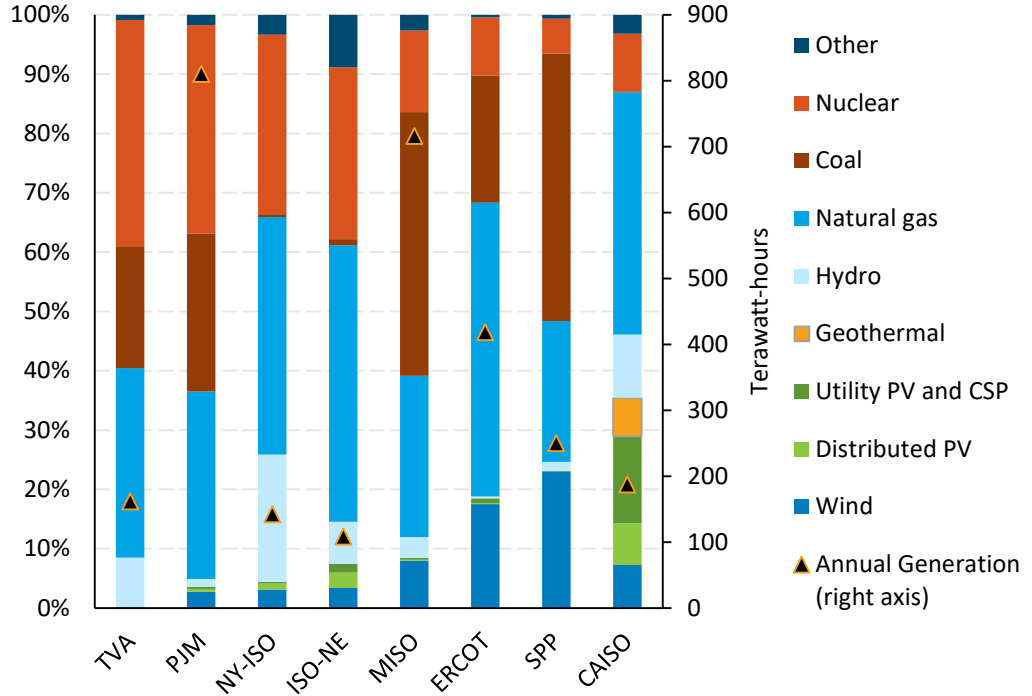
2018 Generation Mix by NERC Region



- Currently, solar and wind represent a range of each NERC region's electricity, varying from approximately 1% to 23%.
- In 2018, the majority of electricity generated by solar (62%) occurred in WECC, representing approximately 8% of all electricity generated in that area.
  - However, Hawaii generated a higher percentage (10%) of its generation from solar.
  - Solar and wind together represented 15% of 2018 WECC electricity generation and all renewables represented approximately 40%.
- SPP lead all NERC regions with 23% of its electricity from variable generation in 2018 (all wind).

Note: All numbers are approximate and only include U.S. generation. EIA monthly data for 2018 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. EIA-923 data does not include NERC classification for a significant portion of solar, and other, generating facilities designated as "State-Fuel Level Increment"; for these systems, we approximated the NERC region using state designation. NERC regions do not strictly follow state lines, so best estimates were made in NERC designations for states. We also used these state categorizations to designate distributed PV generation to NERC regions.
Sources: U.S. Energy Information Administration, EIA-923; distributed PV (EIA "Electric Power Monthly").

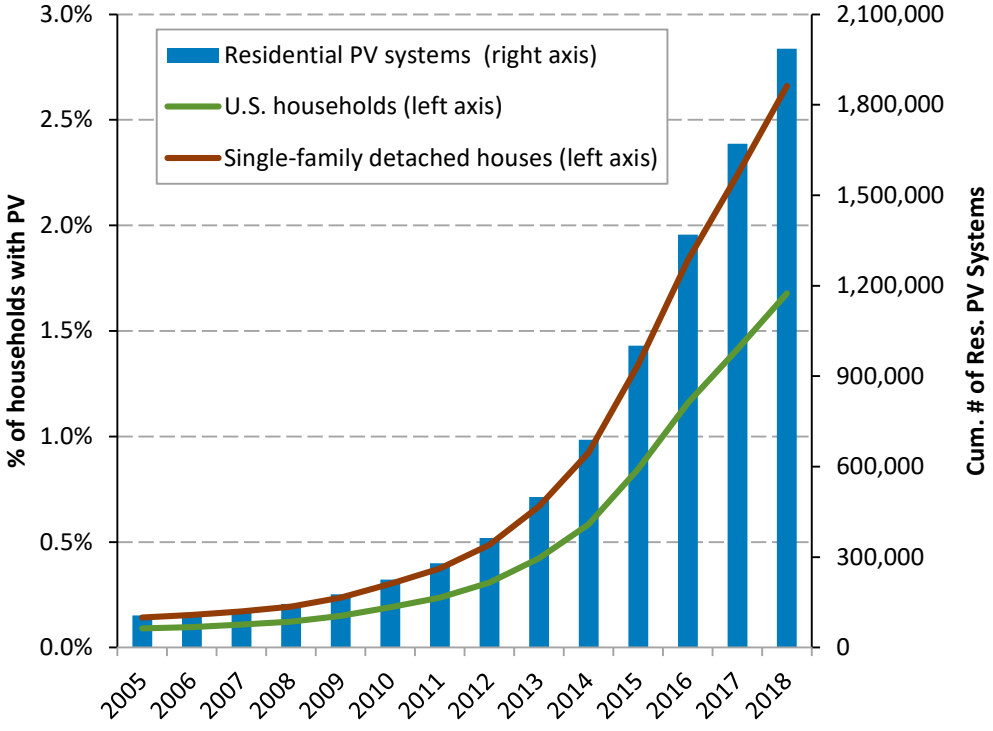
2018 Generation Mix of Largest Wholesale Markets/Balancing Authorities



- In 2018, 70% of U.S. electricity was generated in these eight balancing authorities/wholesale markets.
- Of these eight, CAISO generated the most (~29%) from wind and solar.
  - CAISO also generated 46% of its electricity from renewable sources.

Note: All numbers are approximate and only include U.S. generation. EIA monthly data for 2018 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. EIA-923 data does not include balancing authority classification for a significant portion of solar, and other, generating facilities designated as "State-Fuel Level Increment"; for these systems, we approximated the balancing authority using state designation. Balancing authorities do not strictly follow state lines, so best estimates were made in balancing authority designations for states. We also used these state categorizations to designate distributed PV generation to balancing authorities.
Sources: U.S. Energy Information Administration, EIA-923; distributed PV (EIA "Electric Power Monthly").

U.S. Residential PV Penetration



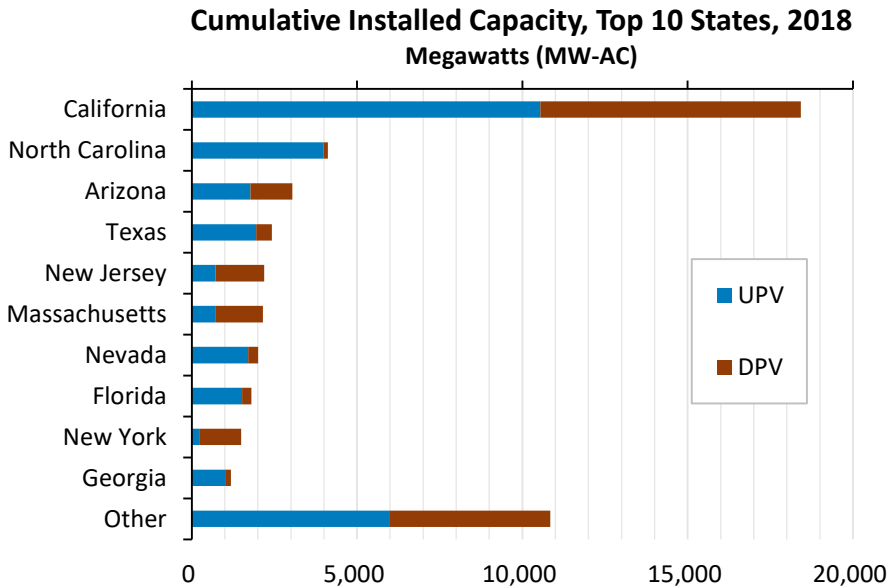
- Since 2005, when Congress passed the investment tax credit, the number of annually installed residential PV systems has grown by approximately 35% per year, or by about 46X.
- At the end of 2018, there were approximately 2.0 million residential PV systems in the United States.
  - Still, only 1.7% of households own or lease a PV system (or about 2.7% of households living in single-family detached structures).
  - However, solar penetration varies by location. Hawaii, California, and Arizona have residential systems on an estimated 31%, 13%, and 11% of households living in single-family detached structures.

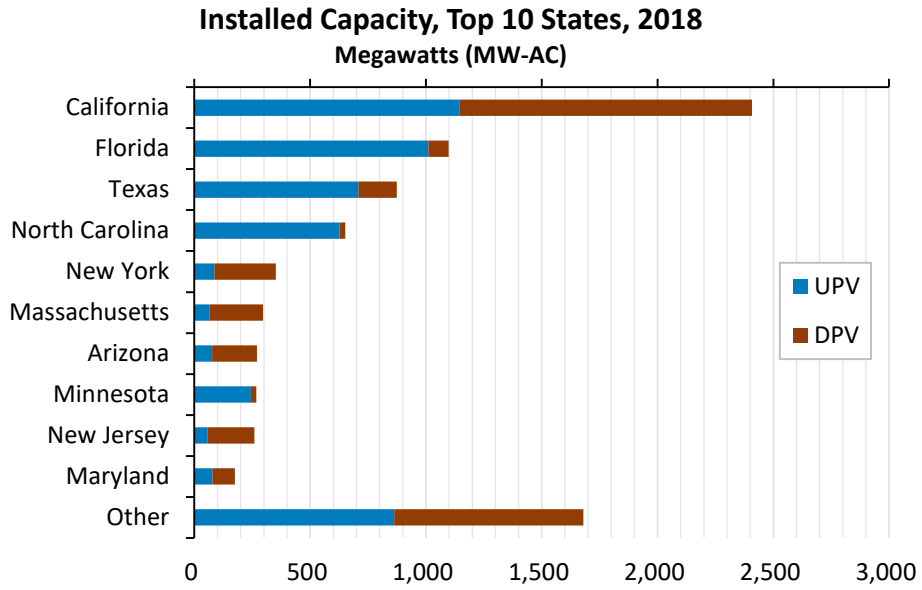
Sources: Res. PV Installations: 2000-2009, IREC 2010 Solar Market Trends Report; 2010-2018, SEIA/Wood Mackenzie Power & Renewables, Solar Market Insight 2018 Year-in-Review; U.S. Households U.S. Census Bureau, 2015 American Housing Survey; state percentages based on 2000 survey; Hawaii, California, and Arizona solar data from EIA form 861M.

U.S. Installation Breakdown by State

At the end of 2018, there were 49.7 GW-AC of solar systems in the United States, of which 30.2 GW were utility-scale PV and 19.5 GW were distributed PV.

In 2018, approximately 8.3 GW-AC of PV capacity was installed, of which 4.96 GW-AC were utility-scale PV and 3.37 GW-AC were distributed PV.



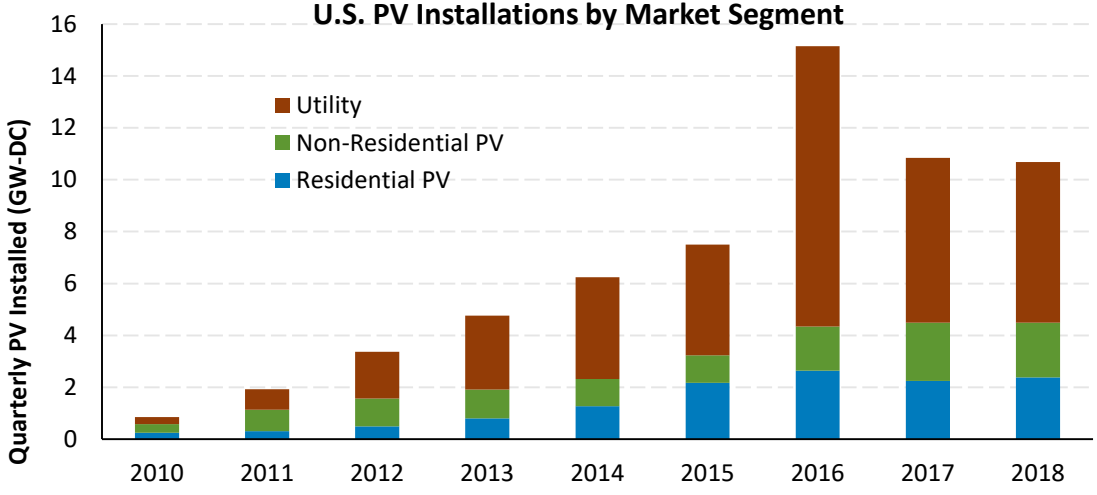


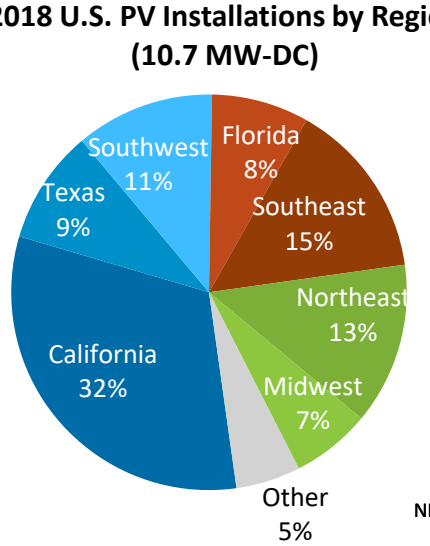
Note: EIA monthly data for 2018 are not final. Additionally, smaller utilities report information to EIA on a yearly basis, and therefore, a certain amount of solar data has not yet been reported. "Net Generation" includes DPV generation.
Sources: EIA, "Electric Power Monthly," forms EIA-023, EIA-826, and EIA-861 (December 2018).

U.S. Installation Breakdown

- The United States installed 10.7 GW-DC of PV in 2018, 4.2 GW-DC in Q4, and cumulative capacity reached 62.5 GW.
  - 2018 U.S. PV installations were down 2%, y/y, with the residential market growing 7%, but the nonresidential and utility-scale markets contracting 7% and 2% respectively.

- In 2018, new PV installations have had a fair geographic mix across the United States, though most capacity was installed in southern states.

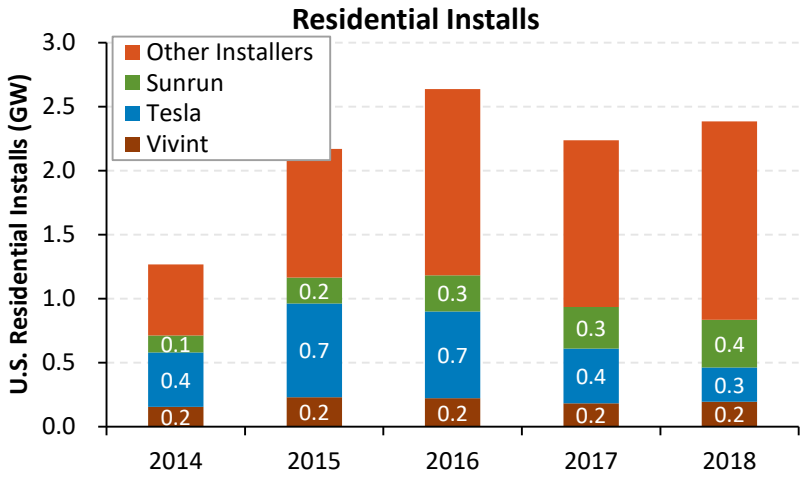


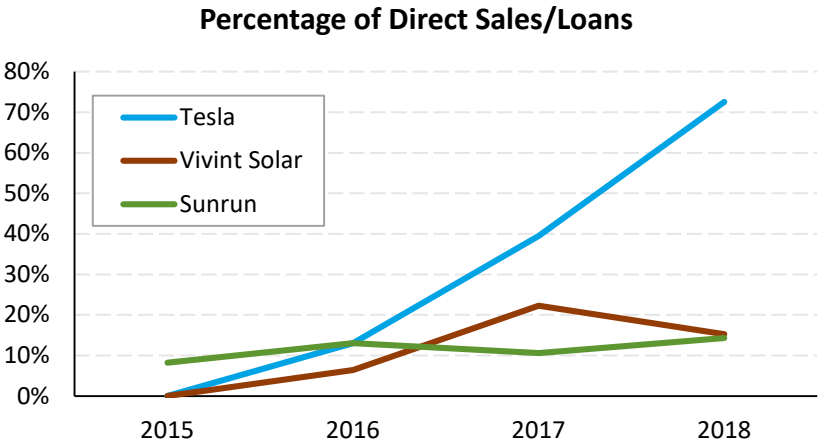


Sources: Wood Mackenzie Power & Renewables /SEIA: U.S. Solar Market Insight 2018 Year-in-Review.

Tesla, Vivint Solar, and Sunrun Residential Market Share

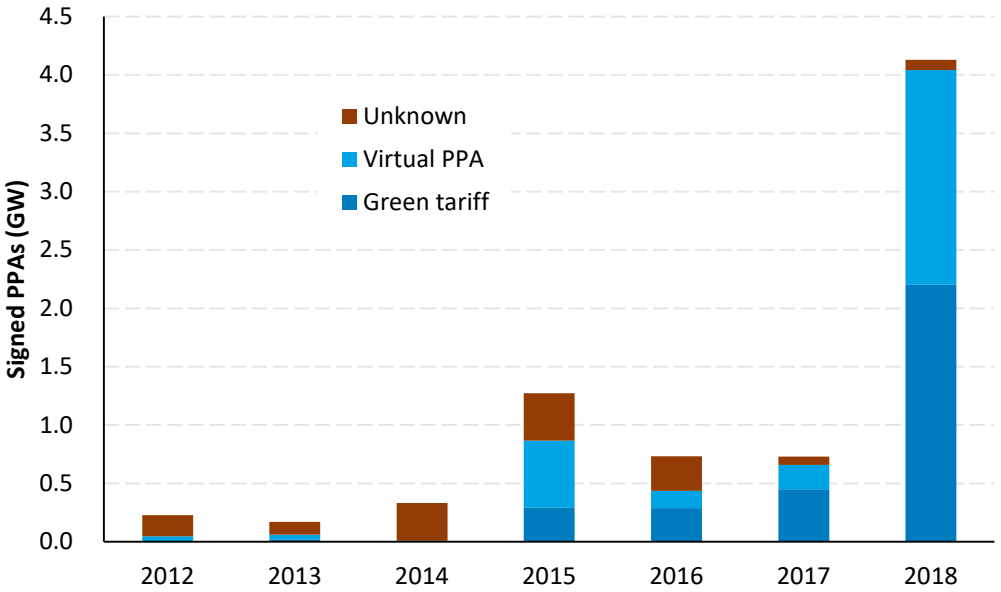
- In 2018, U.S. residential installations increased 7%, y/y, while Tesla installs contracted 38%.
  - Tesla's cash and loan sales increased 14%, y/y.
  - Tesla also announced plans in April to cut its prices to between $2.5/W and $2.85/W to regain market share.
    - To cut costs, it is simplifying the design by only offering systems in 4-kW increments, and it is transitioning its sales channels, requiring all orders to be placed online.
    - Tesla will also ask customers to do certain tasks typically performed by installers, such as photographing their electric meter, circuit breaker boxes, and other equipment, and send them to Tesla, reducing the need for site visits.





Source: Corporate filing, SEIA / Wood Mackenzie Power & Renewables "Solar Market Insight 2018 Year-in Review," NYTimes (04/30/19).

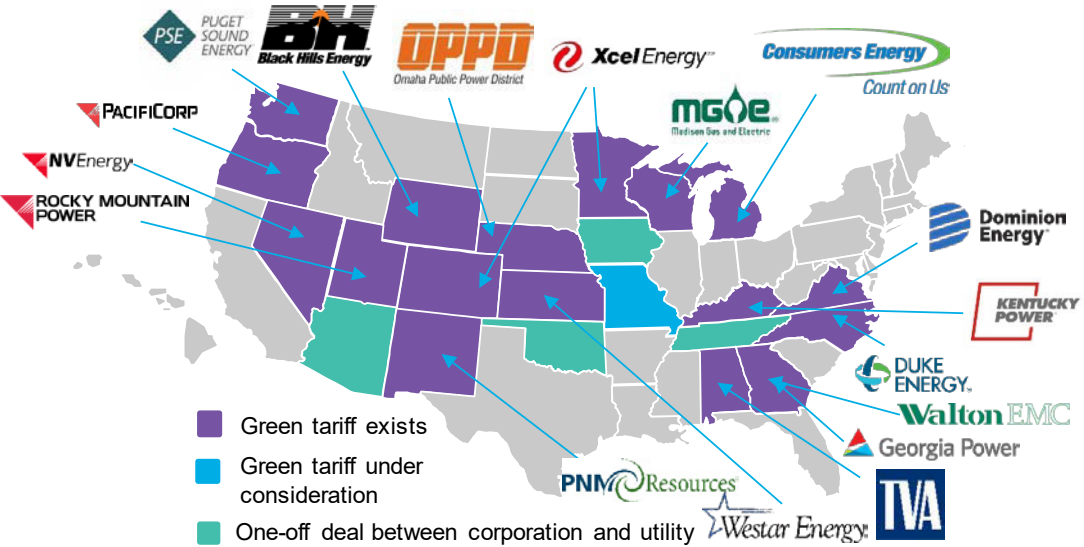
U.S. Off-Site Corporate Solar PPAs



- In 2018, U.S. offsite corporate PPA signatures grew 5X, y/y—more than all previous year's combined.
  - BNEF reports that total U.S. corporate PPAs, including wind (4.1 GW) and on-site solar (0.3 GW), were 8.5 GW.
- Corporations are moving to manage operational, production, and shape risk.
  - In October 2018, Google said it would prioritize storage and complimentary technologies to smooth intermittency in order to achieve 24x7 hourly matching of clean energy. Microsoft also announced financial products it was purchasing to transfer operation and shape risk.
- In July 2018, 20 U.S. cities with 5.7 TWh of demand (including Boston, Chicago and Los Angeles) issued an RFI to obtain competitive pricing on large-scale clean energy purchases.

Sources: BNEF, "Corporate PPA Deal Tracker," as of April 2, 2019, database of "Corporate PPAs," accessed 04/09/19.

U.S. Green Tariff Availability, 2018

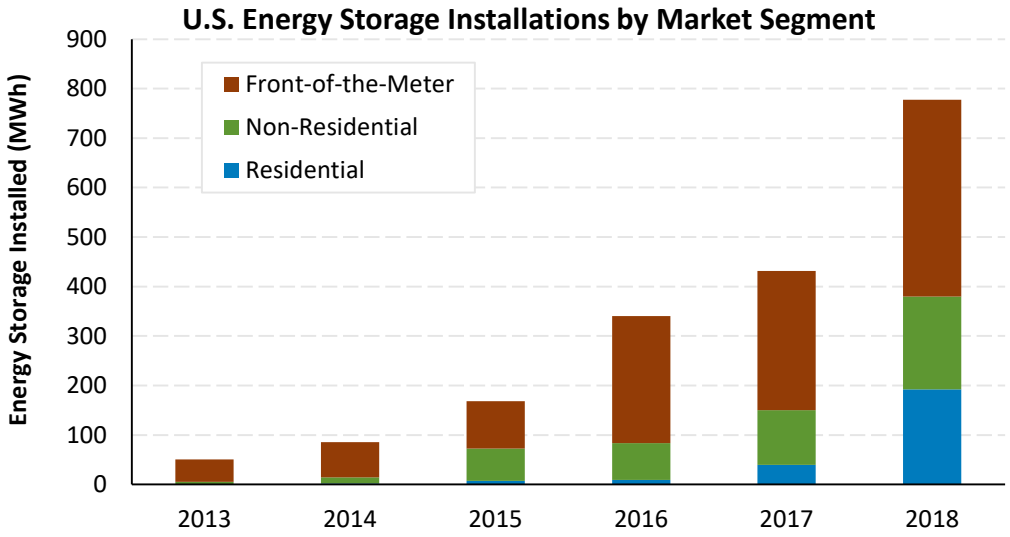


- In 2018, 17 utilities in 17 states offered programs for corporations to buy clean energy at a large scale.
  - These programs typically replace the "fuel cost" portion of a corporation's electricity bill with a charge structured around the cost of renewable energy and the utility's avoided cost.
  - In 2018, there was more activity in regulated states because there was a drop in wholesale pricing in unregulated states.

Sources: BNEF, "1H 2019 Corporate Energy Market Outlook."

U.S. Energy Storage Installations by Market Segment

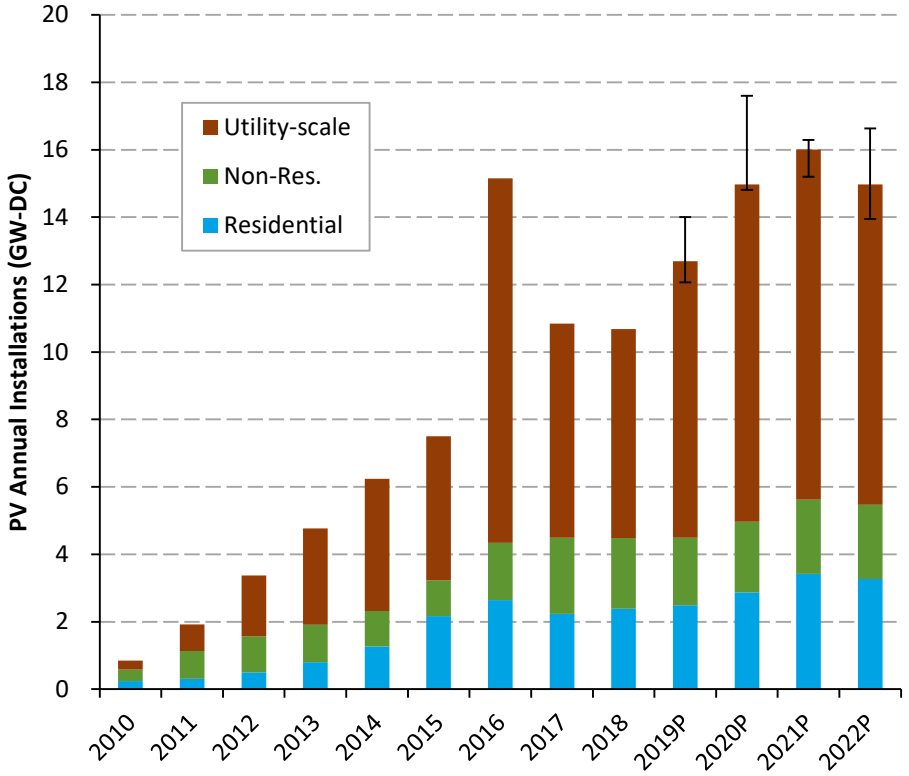
- The United States installed approximately 777 MWh (310 MW) of energy storage onto the electric grid in 2018—up 80% y/y, and 15X annual installations in 2013.



- The residential market grew the most, y/y, at 3.8X, with California (50%), Hawaii (17%), and Arizona (6%) representing the largest markets.
- Hawaii (25%), California (13%), and Arizona (12%) also represented the largest front-of-the-meter markets, but they represented a small portion of the total market.
  - The premium in solar PPA pricing with storage continued to contract in 2018, with some projects in Colorado and Nevada offering PPAs between $30/MWh and $40/MWh.
- Almost all nonresidential, behind-the-meter storage occurred in California; however more diversification is expected with storage programs beginning in Massachusetts and New York.

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

Annual U.S. PV Demand Projections

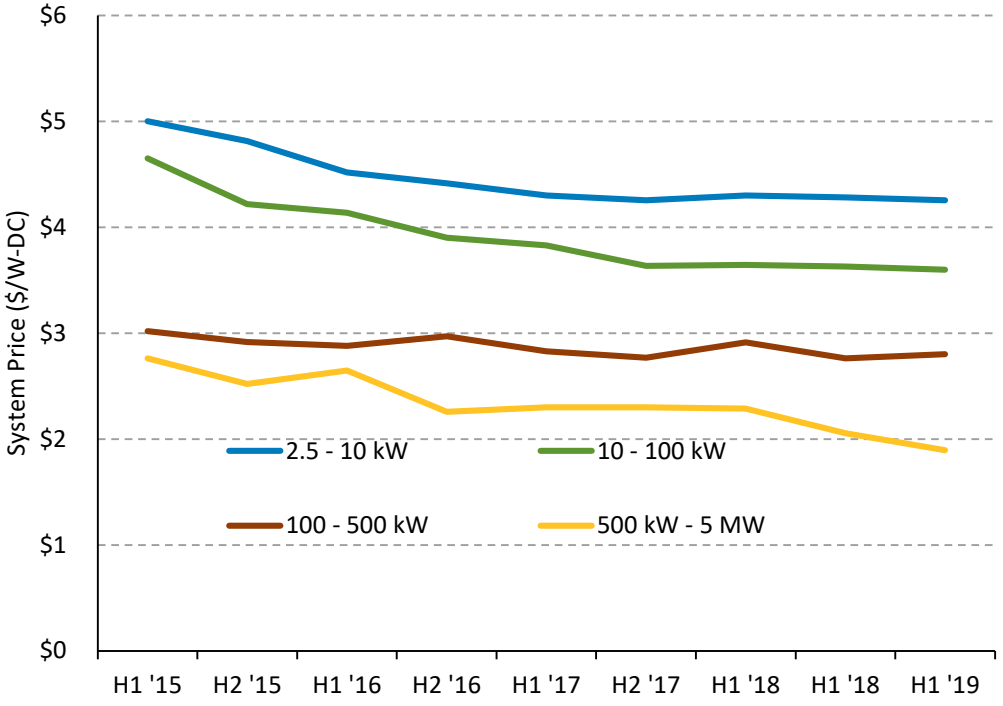


- Analysts estimate U.S. solar installations in 2019 will be between 12 GW and 14 GW—a significant increase over 2017–2018.
  - Most of the growth is expected to come from the utility-scale sector.
- The median analyst projection predicts that 59 GW of PV will be installed between 2019 and 2022 in the United States, which is close to the same amount installed cumulatively at the end of 2018.

Note: P = projection. Bar represents median projection. Error bars represent high and low projections.
Sources: BNEF (December 2018); Goldman Sachs (03/13/19); Wood Mackenzie Power & Renewables (March 2019).

- **From 2017 to 2018, the median reported PV system price in California, Massachusetts, and New York was relatively flat, or fell only slightly, across system sizes; however, significant price variation remains.**
- **For H2 2017 to H2 2018, EnergySage reported a 3% reduction in the average gross costs of a residential system, down to $3.05/W.**
- **In Q4 2018, totals costs for Vivint- and Sunrun-built systems were approximately $3/W.**
- **In 2018, the capacity-weighted average price of a utility-scale PV systems owned by regulated utilities, was $1.48/W-AC (or ~$1.14/W-DC) —representing a y/y price reduction of 31%.**

System Pricing from Select States



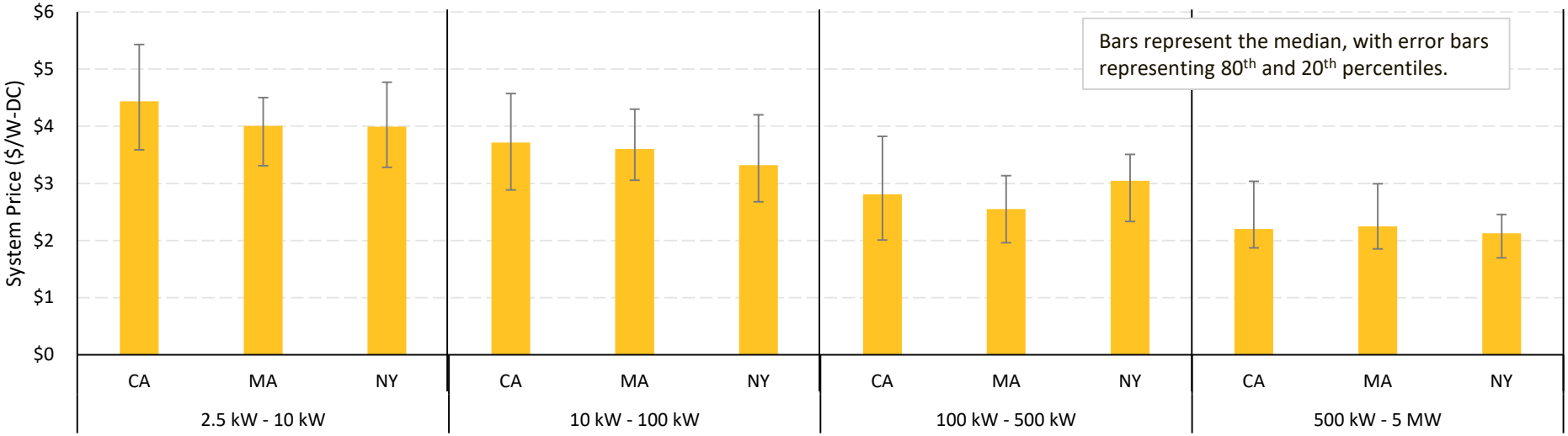
Preliminary 2018 MW: CA (657), MA (218), NY (256)
Note: System prices above $10/W and below $1/W were removed from the data set.
Sources: CA NEM database (10/31/18); MA SREC program (12/12/18); NYSERDA (11/30/18).

- From 2017 to 2018, the median reported PV system price in California, Massachusetts, and New York:
  - Remained flat at $4.29/W for systems from 2.5 kW to 10 kW
  - Fell 3% to $3.63/W for systems from 10 kW to 100 kW
  - Increased 2% to $2.86/W for systems from 100 kW to 500 kW
  - Fell 4% to $2.220/W for systems from 500 kW to 5 MW.
- Based on preliminary Q1 2019 data, the median reported PV system price in California, Massachusetts, and New York remained relatively flat, with the exception of systems above 500 kW, which dipped below $2/W.

System Pricing from Select States, 2018

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

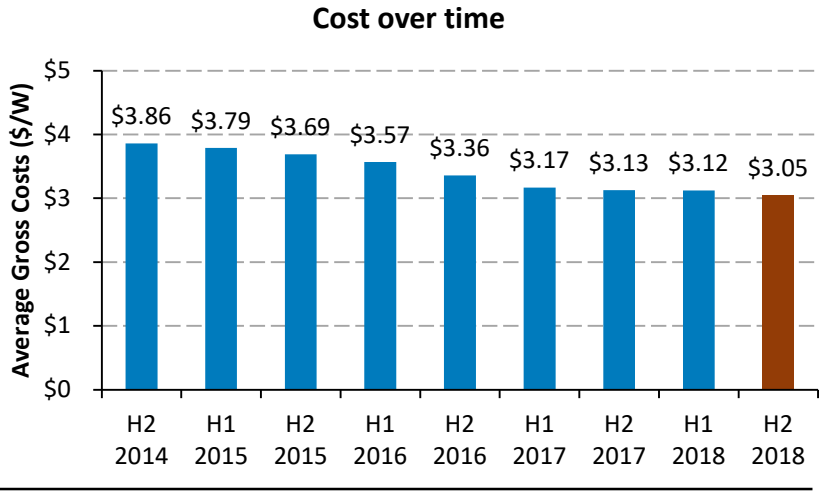
- The median price of a small system in New York was about 10% less than the median price in California.
- In 2018, the 20th and 80th percentile preliminary prices in California for a small system were $3.59/W and $5.43/W respectively.

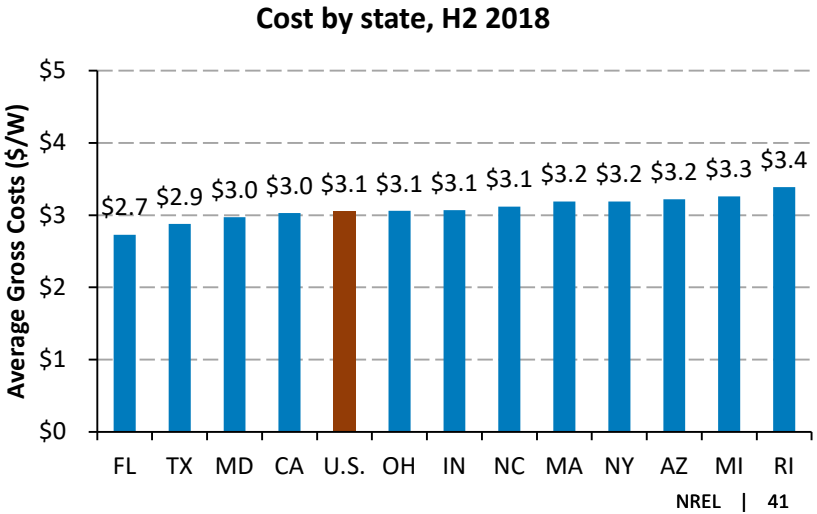


2018 MW: CA (684), MA (273), NY (278)
Note: System prices above $10/W and below $1/W were removed from the data set.
Sources: CA NEM database (02/28/19); MA SREC program (03/04/19); NYSERDA (03/31/19).

Residential System Costs Reported by EnergySage, H2 2018

- For H2 2017 to H2 2018, EnergySage reported a 3% reduction in the average gross costs of a residential system.
  - Part of the reduction in price was due to an increase in average system size, from 8.7 kW to 9.6 kW, with an average usage offset of 94%.
- EnergySage quotes also reported an average system payback period of 7.8 years.
- Residential system quotes varied by state. In H2 2018, the average gross cost of a residential system in Rhode Island was 24% higher than the average gross cost of a residential system in Florida.

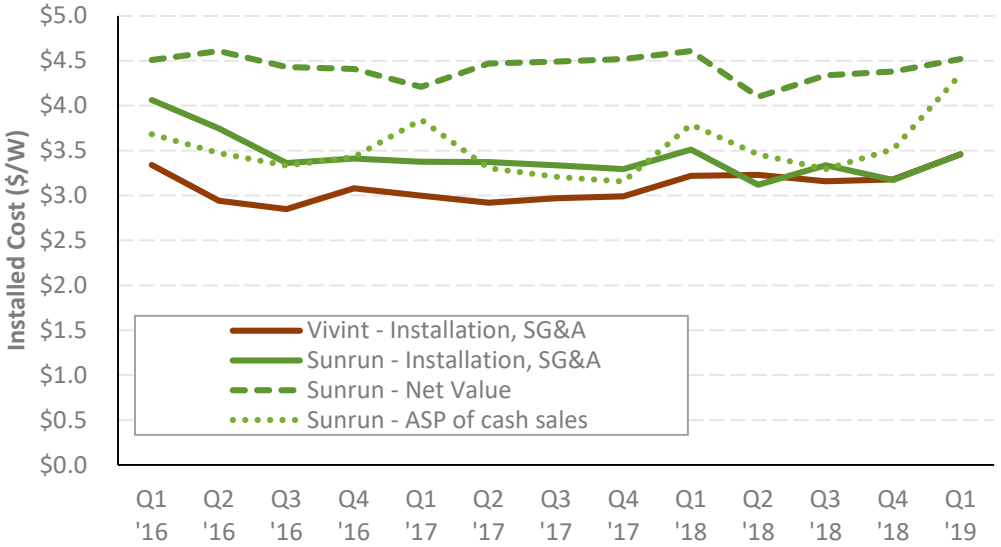




Source: EnergySage, "Solar Market place Intel Report H1 2018 – H2 2018."

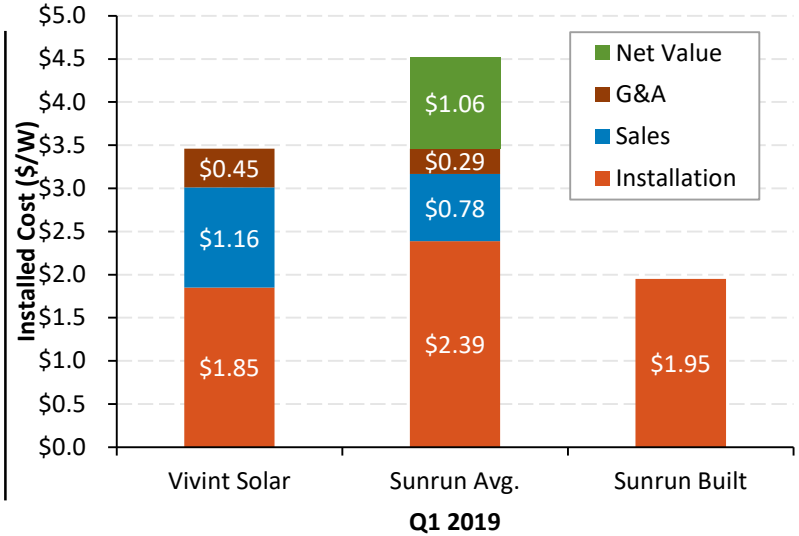
Vivint Solar and Sunrun Cost and Value

- For the past two years, Vivint Solar and Sunrun total system costs remained relatively flat.
  - The average price of Sunrun's cash sales is approximately the same as their costs.

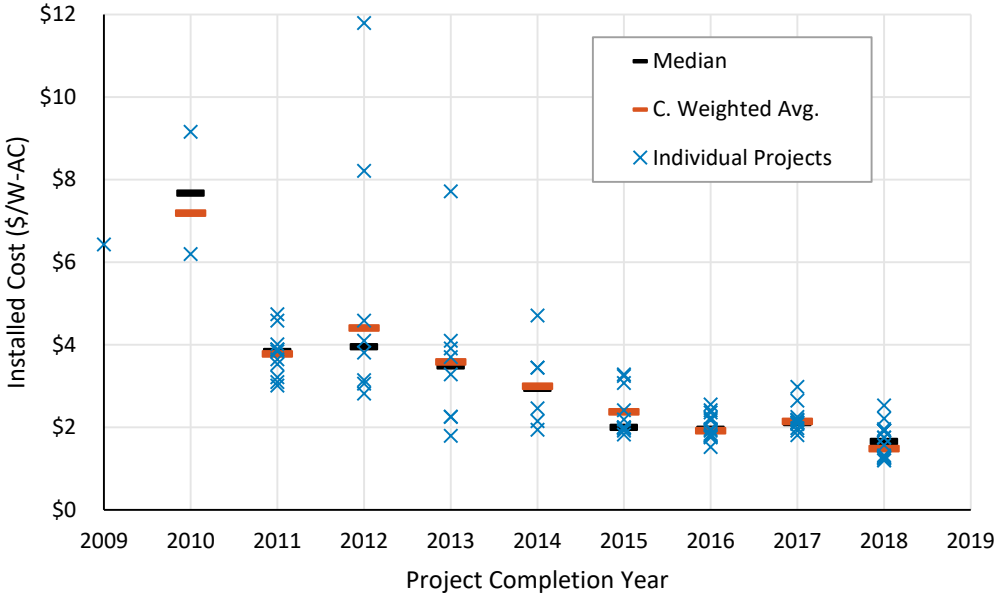


Sources: Corporate filings.

- In Q1 2019, totals costs for Vivint- and Sunrun-built systems were approximately $3.5/W.
- Sunrun still reports a PV system net value of approximately $4.5/W.



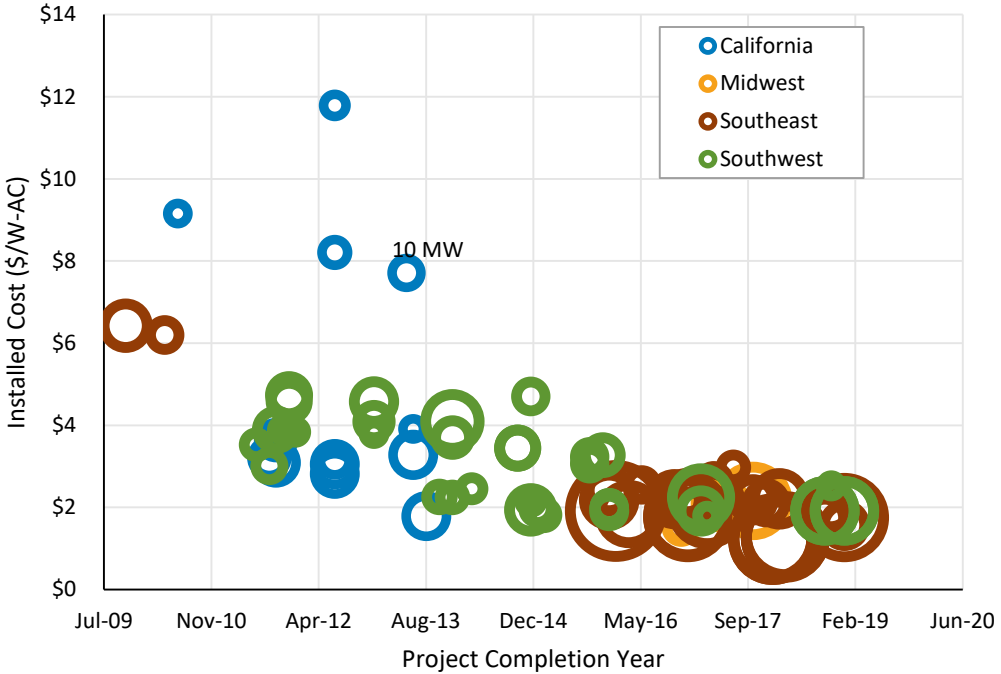
Utility-Owned PV Pricing (>5 MW)



- In a select data set of utility-scale PV systems (92 projects totaling 2.4 GW-AC) owned by 19 regulated utilities, the median system price in 2018 was $1.66/W-AC, and the capacity-weighted average price was $1.48/W – representing y/y price reductions of 22% and 31% respectively.
  - Assuming an inverter loading ratio of 1.3, the 2018 capacity-weighted average price in this data set was $1.14/W-DC.
  - The lowest and highest reported prices in 2018 were $1.19/W-AC and $2.53/W-AC (or $0.92/W-DC and $1.94/W-DC, assuming an ILR of 1.3).
  - From 2010 through 2018, system prices in this data set fell 18% per year on average, with the largest drop coming in 2010 and 2011.

Sources: FERC Form 1 filings from the from the following utilities: Alabama Power, Allete, Arizona Public Service, Avangrid, DTE, Duke Energy, El Paso Electric, Florida Power and Light, Georgia Power, Indiana Michigan Power, Kentucky Utilities, Nevada Power, Pacific Gas and Electric, Public Service of New Mexico, Southern California Edison, Tampa Electric, Tucson Electric, United Illuminating, UNS Electric, Virginia Electric.

Utility-Owned PV Pricing (>5 MW)



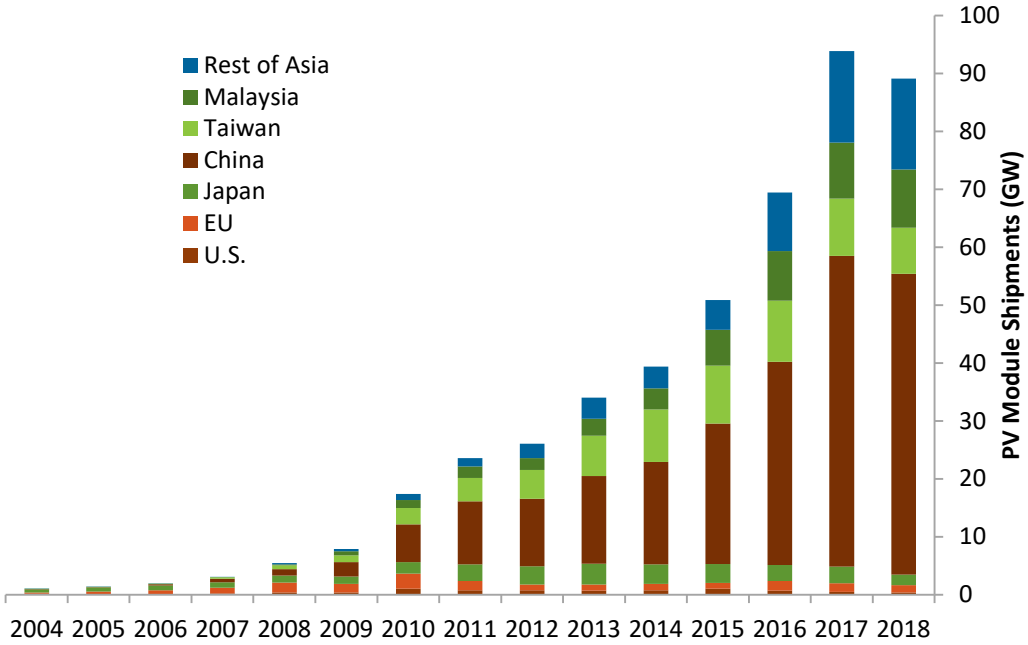
- In a select data set of utility-scale PV systems (92 projects totaling 2.4 GW-AC) owned by 19 regulated utilities, the average system size has trended upwards as system pricing has trended downwards.
  - The average system size in this data set was 8 MW in 2010 and 51 MW in 2018.
- Some of the reductions in price may be explained by a change in geographical focus over time.
  - Of the systems in this data set, 64% by capacity, are in the Southeast, with most installations happening after 2015.
  - However, virtually all areas of the country show a significant reduction in price over time.

Sources: FERC Form 1 filings from the from the following utilities: Alabama Power, Allete, Arizona Public Service, Avangrid, DTE, Duke Energy, El Paso Electric, Florida Power and Light, Georgia Power, Indiana Michigan Power, Kentucky Utilities, Nevada Power, Pacific Gas and Electric, Public Service of New Mexico, Southern California Edison, Tampa Electric, Tucson Electric, United Illuminating, UNS Electric, Virginia Electric.

- **In 2018, global PV shipments were approximately 89 GW—a decrease of 5% from 2017.**
  - **96% of 2018 PV shipments used c-Si technology.**
  - **98% of the PV shipments came from Asian countries, with China supplying 57%.**
- **It is estimated that PV manufacturers spent approximately $1 billion dollars on R&D in 2018.**
- **At the end of Q1 2019, the United States had approximately 6 GW of PV module assembly, up from 2.5 GW in 2017. An additional 3 GW of manufacturing capacity is expected to be added in the near future.**
- **In 2018, the United States produced approximately 1 GW of c-Si modules and 0.4 GW of thin film.**
- **In 2018. U.S.-produced polysilicon was 30% lower than in 2017 and 55% lower than in 2014.**

Global Annual PV Shipments by Region*

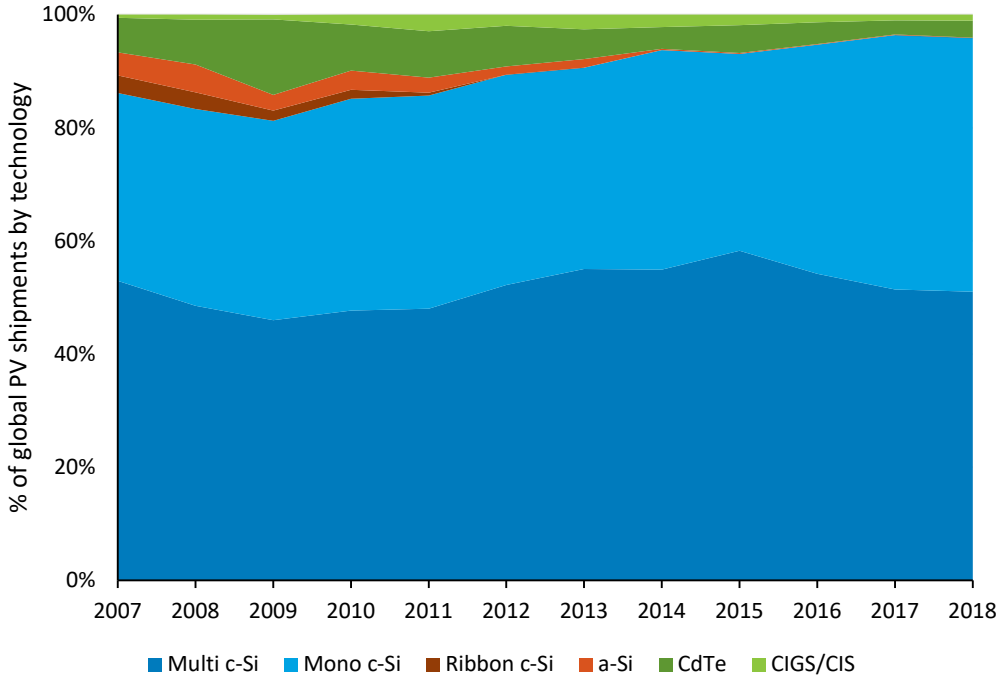
- In 2018, global PV shipments were approximately 89 GW—a decrease of 5% from 2017.



***Note:** Excludes inventory sales and outsourcing.
Source: 2004-2018: Paula Mints. "Photovoltaic Manufacturer Capacity, Shipments, Price & Revenues 2018/2019." SPV Market Research. Report SPV-Supply6. April 2019.

- 2018 is the first time since before 1976 that PV shipments declined, y/y, caused by Chinese pullback in demand.
  - Because China represents approximately 50% of supply and demand, the market is far more susceptible to shocks.
- 98% of the PV shipments came from Asian countries, with China supplying 57%.
- The pullback was not uniform across all markets, as Chinese shipments only shrank 3% and Malaysian shipments actually grew 4%.
  - Japan produced fewer PV modules and cells in 2018 than it did before the FiT, with a 35% reduction y/y due to price pressure.
  - Europe is also producing less, due in part to the elimination of the minimum pricing agreement with China.
  - U.S. market share was 0.41% in 2018, its lowest level to date; however, it is expected to bounce back in 2019.

Global Annual PV Shipments by Technology*



- Technologies have gained and lost market share over time as companies and researchers push forward new PV technologies.
- Mono c-Si had a global PV market share of approximately 90% in 1981 before declining to a low of around 31% by 2006. By 2018, it had grown again to 45%.
  - Mono manufacturers have continued to adopt P-type PERC.
- Thin-film technologies market share was flat, y/y, at 4% in 2018.
  - Thin-film technologies peaked in the 1980s due to the consumer indoor market (e.g., calculators) and again in 2009 during a period of silicon shortage.

***Note:** Excludes inventory sales and outsourcing.
Sources: 2007-2018: Paula Mints. "Photovoltaic Manufacturer Capacity, Shipments, Price & Revenues 2018/2019." SPV Market Research. Report SPV-Supply6. April 2019.

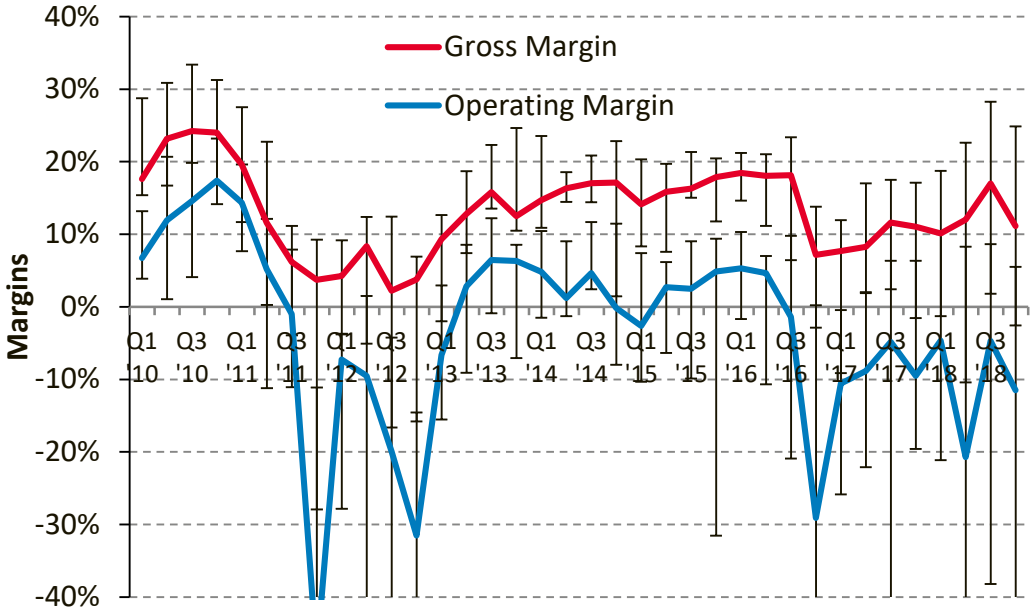
Global Leading PV Manufacturers, by Shipments

Rank	Manufacturer (2018)	Shipments (GW)	Manufacturer (2017)	Shipments (GW)	Manufacturer (2007)	Shipments (GW)
1	Jinko Solar	6.7	JA Solar	6.5	Sharp	0.4
2	LONGi	5.7	Canadian Solar	5.4	Q-Cells	0.3
3	Canadian Solar	5.7	Zhongli Talesun	5.0	Suntech	0.3
4	JA Solar	5.2	Jinko Solar	4.9	Kyocera	0.2
5	Trina Solar	4.8	Trina Solar	4.8	First Solar	0.2
6	Tongwei	4.8	LONGi	4.5	Motech	0.2
7	UREC	4.1	Hanwha	4.2	Sanyo	0.2
8	Hanwha	3.9	Tongwei	3.8	SolarWorld	0.1
9	Suntech	3.3	Motech	3.2	Mitsubishi	0.1
10	Aiko	3.3	Aiko	3.1	SunPower	0.1
Other		41.5		45.5		1.0
Total		**89.1**		**91.9**		**3.0**

- In 2007, there was significant geographic diversity of manufacturers.
- Since then, Asian manufacturers have significantly scaled operations; however, many of the leading manufacturers in 2018 have scaled-up faster than many of the top Asian manufacturers from a few years ago.
- Each of the top 10 PV manufacturers shipped more in 2018 than the entire industry did in 2007.
- At the end of 2018, there was 144 GW of global module assembly—31 GW more capacity than cell manufacturing, indicating price pressure on module assemblers.

***Note:** Excludes inventory sales and outsourcing.
Source: 2007-2018: Paula Mints. "Photovoltaic Manufacturer Capacity, Shipments, Price & Revenues 2018/2019." SPV Market Research. Report SPV-Supply6. April 2019.

PV Manufacturers' Margins



Line represents the median, with error bars representing 80th and 20th percentiles for the following companies in Q4 2018: Canadian Solar, First Solar, Hareon Solar, HT-SAAE, Jinko Solar, LONGi, Motech Industries, Neo Solar Power, ReneSola, and SunPower. Margin data from Hanwha Q Cells, JA Solar, Trina, and Yingli are also included from Q1 2010 to Q3 2018 where available.

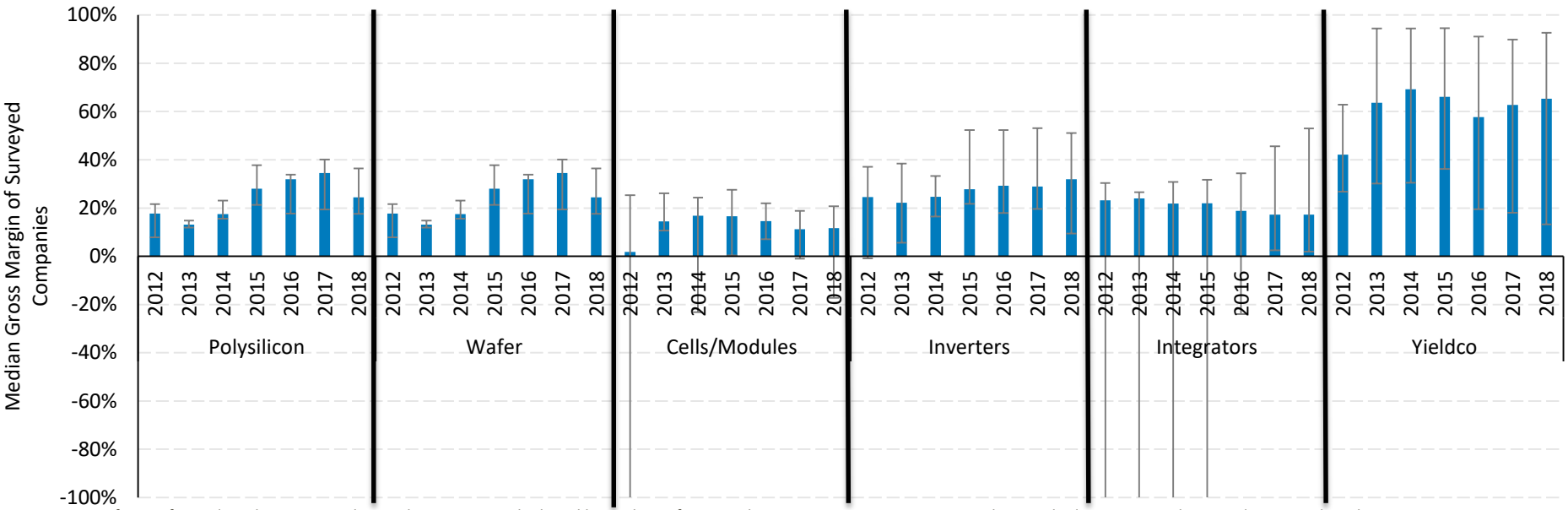
Performance of solar companies declined, on average, in Q4 2018, as ASP of modules and cells fell.

Sources: Company figures based on data from Bloomberg Terminal and SEC filings by the respective companies.

Gross Margin across Supply Chain

- Polysilicon and wafer manufacturers generally had lower gross margins between 2017 and 2018, while module and cell manufacturers' gross margins were relatively flat, y/y, after falling from 2014 to 2017.

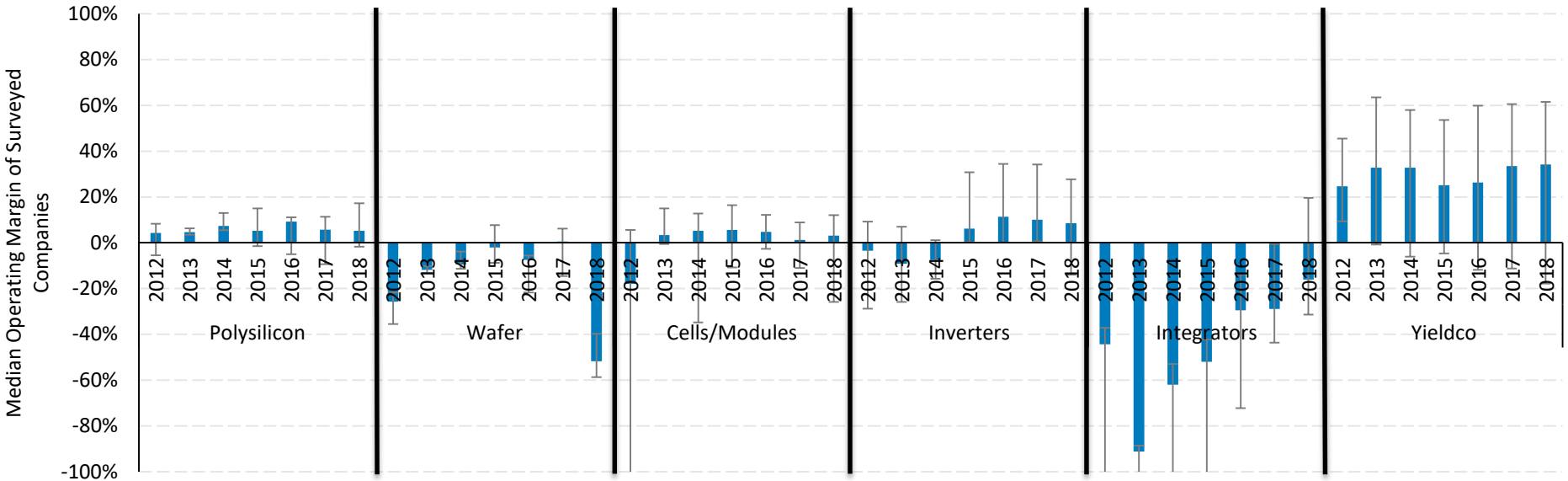
- In 2018, gross margins were mixed in the PV industry, with variations by sector and within each sector.



Sources: Company figures from Bloomberg Terminal. Error bars represent high and low values of surveyed companies. Companies surveyed are: Polysilicon – GCL Poly, REC Silicon, Wacker Chemie, Ferroglobe; Wafers - ReneSola, Wafer Works Corp, Danen Technology Group, Green Energy Technology Inc; Cells/Modules, Gintech, Motech, First Solar, JA Solar, Yingli, Trina Solar, Canadian Solar, PV Crystalox Solar, Hanwha Solar One, Jinko Solar, SunPower; Inverters – SolarEdge; Enphase; SMA Solar; Advanced Energy Industries; Integrators - Real Goods Solar; SolarCity (through 2015); Vivint Solar; Sunrun; Sunworks; Enlight Renewable Energy; IPP/Yieldco - Brookfield Renewable Partners; Algonquin Power & Utilities Corp; NextEra Energy Partners' Northland Power; Pattern Energy; Terraform Power; TransAlta Renewables.

Operating Margin across Supply Chain

- Despite a competitive environment for manufacturers, many made money operating in 2018, notably in the polysilicon, cell, module, and inverter sectors.
- While integrators continue to lose money, they continue to move toward profitability.
- Operating margin is not necessarily an indicator of corporate profitability, though with strong margins, companies should eventually find a way to profitability.



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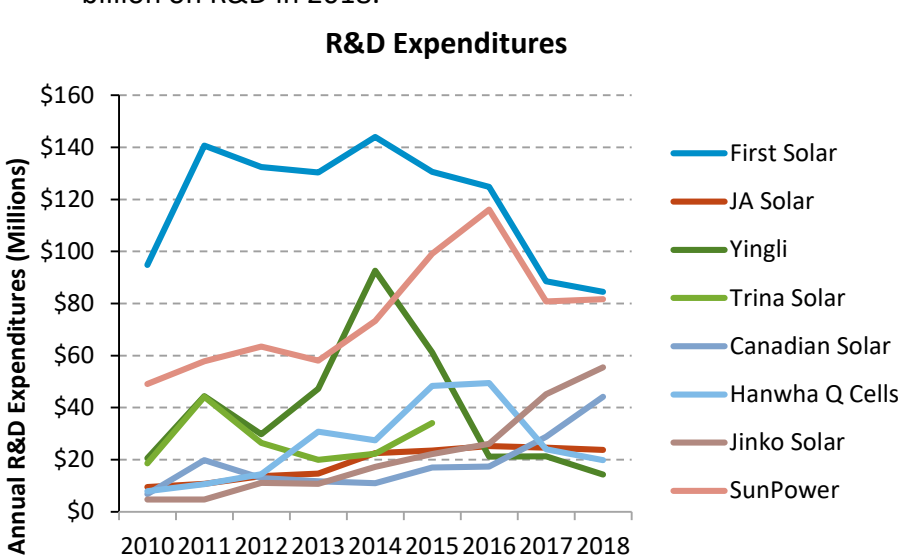
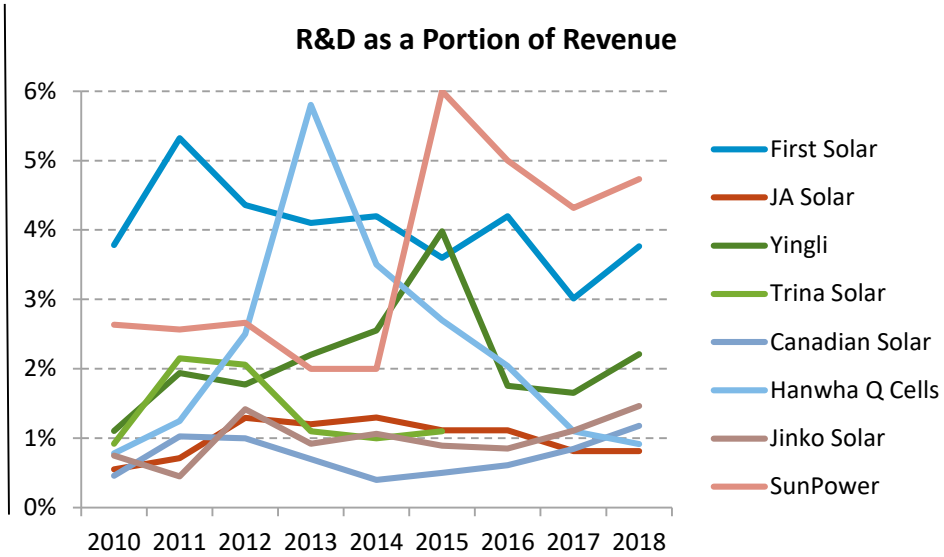
Research and Development

- R&D among the tracked companies increased 3% to $324 million in 2018.
  - The tracked companies shipped approximately 26 GW in 2018—approximately 29% of global shipments. If the rest of the industry spent similar levels in R&D, PV manufacturers would have spent $1 billion on R&D in 2018.

- First Solar continues to lead in R&D spending, although SunPower is a close second. Both companies' 2018 R&D funding are significantly below that of their peak years.
- Canadian Solar and Jinko Solar have significantly increased their R&D budgets, growing 3X and 4X from 2013 to 2018.



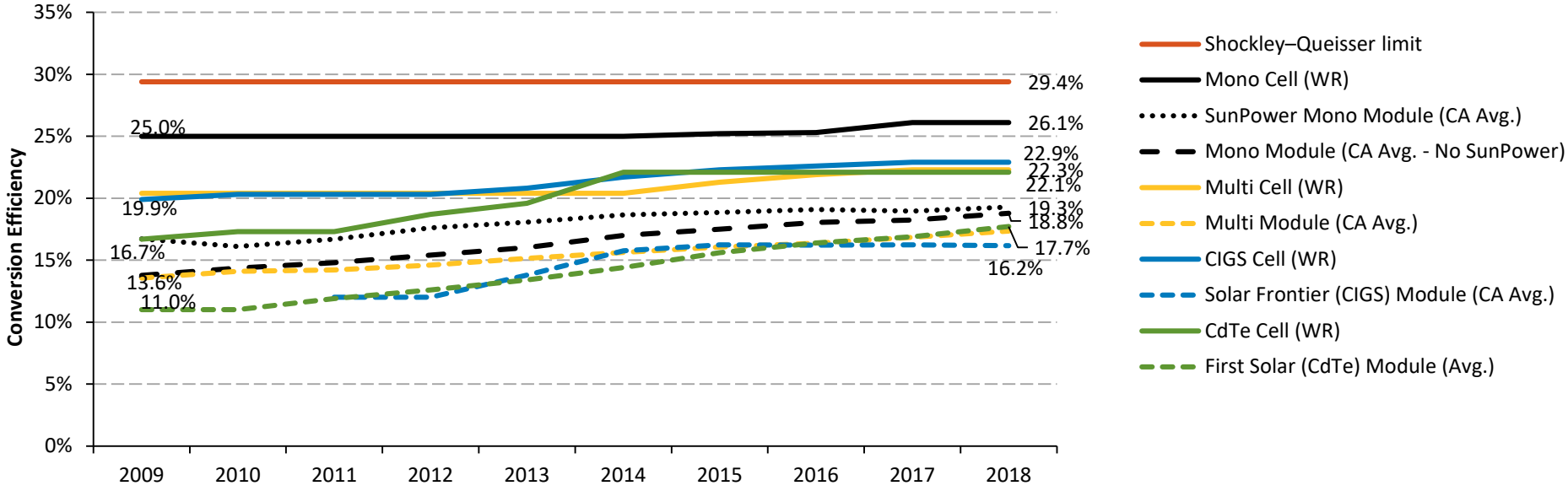


Sources: Company figures based on Q4 2018 (and previous) SEC filings by the respective companies.

PV Efficiency Improvements

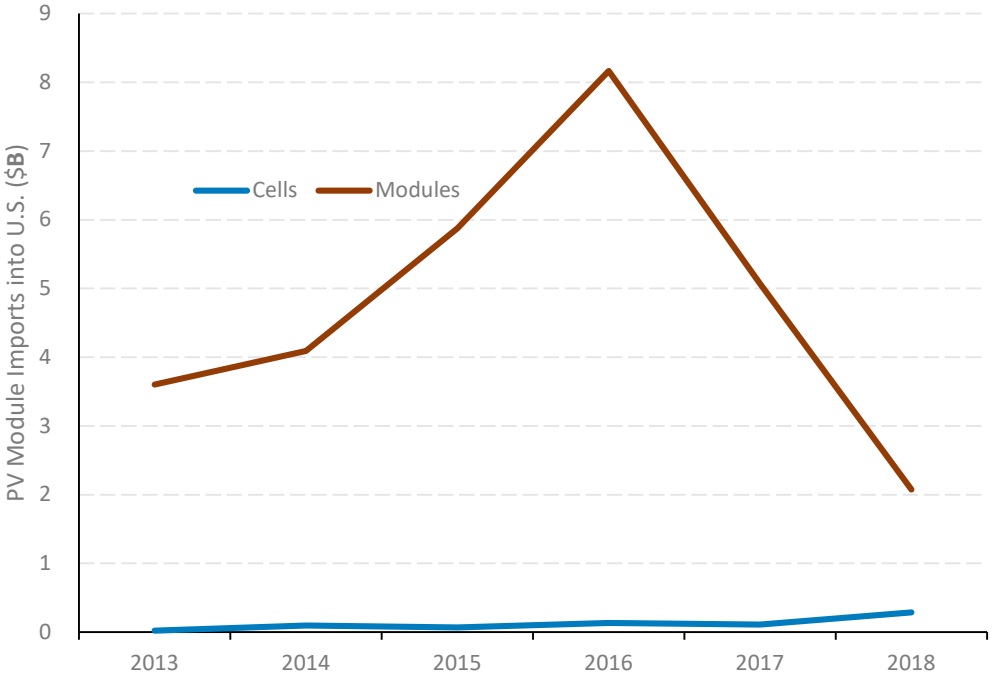
- While no world records were achieved for mono c-Si, multi c-Si, CIGS, or CdTe cells, average module efficiencies deployed for most technologies continue to improve.
  - Despite Solar Frontier's world record achievement for CIGS, the company continues to sell modules well below the efficiency of other products.

- CdTe now has virtually the same module efficiency as multi c-Si in the marketplace.
- Standard p-type mono modules still have a ~1% efficiency advantage over multi and CdTe.
- SunPower's advantage over other mono products has significantly shrunk over time.



Note: WR denotes "World Record."
Sources: California Interconnection Dataset (02/28/19); Corporate press releases and public filings, NREL World Records.

Module and Cell Import Data

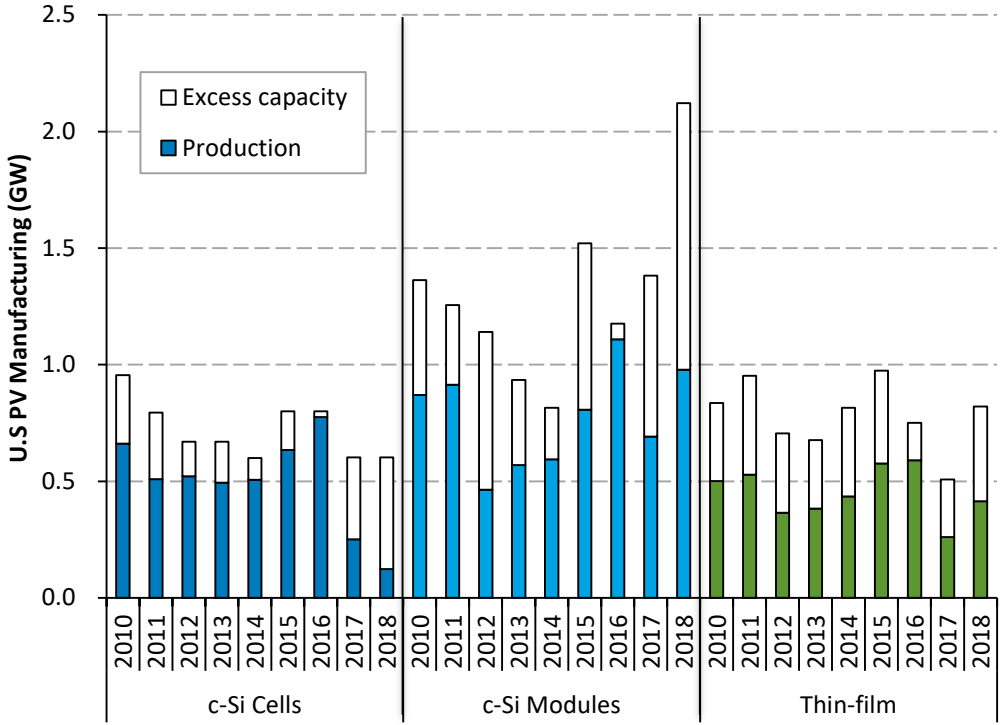


While module and cell imports into the United States fluctuate over time, PV module import value has dropped to a historically low level since the implementation of the Section 201 tariffs; PV cell value has been increasing.

- In 2018, the United States imported $2.1 billion in PV modules (5.2 GW, assuming $0.4/W modules) and $285 million in PV cells (1.4 GW, assuming $0.2/W cells).
- The top four countries that the United States imported PV modules from in 2018 were Malaysia ($686 million), South Korea ($514 million), Vietnam ($324 million), and Mexico ($300 million).
- The top four countries that the United States imported PV cells from in 2018 were South Korea ($98 million), Malaysia ($50 million), Japan ($47 million), and Philippines ($32 million).

Sources: Imports, by value: U.S. International Trade Commission, 2018.

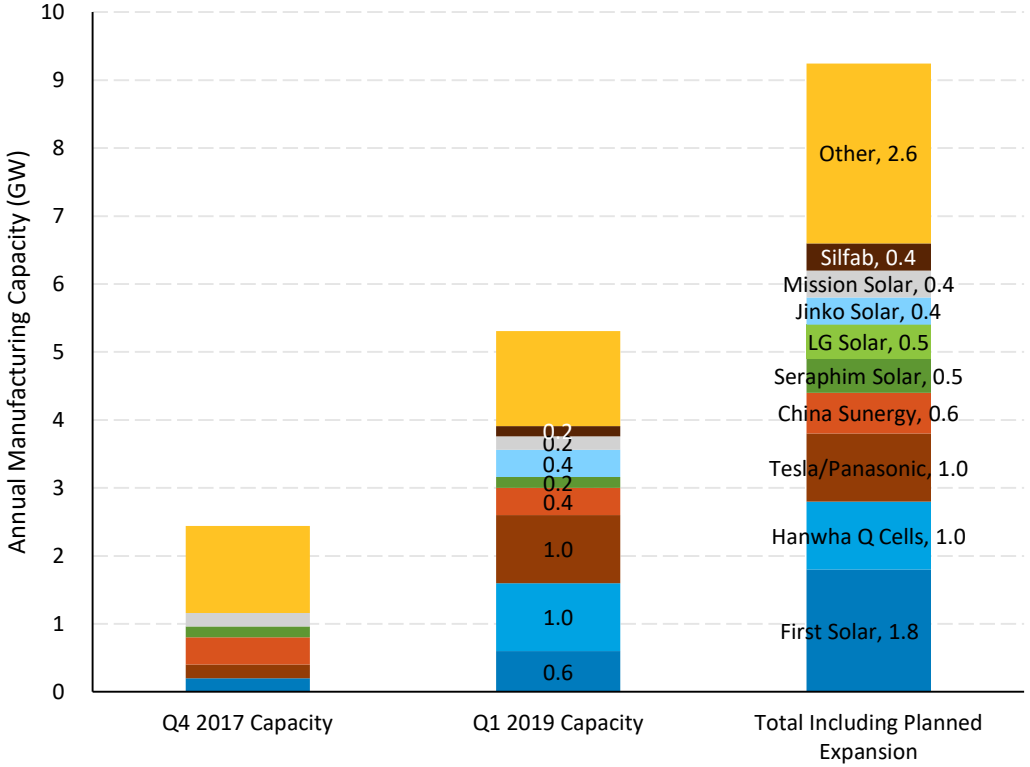
U.S. Module and Cell Manufacturing



Source: Wood Mackenzie Power & Renewables & SEIA, "U.S. Solar Market Insight" (2014–2018).

- In 2018, U.S thin-film and c-Si module production rebounded from 2017 declines, and c-Si module manufacturing capacity reached record levels.
  - Module manufacturing in 2019 should reach record levels, with more c-Si module assembly capacity and First Solar CdTe panel manufacturing, coming online.
- C-Si cell capacity was flat between 2017 and 2018, but production declined 51%.
  - There are no plans to bring on new c-Si capacity.

U.S. PV Manufacturing Expansion

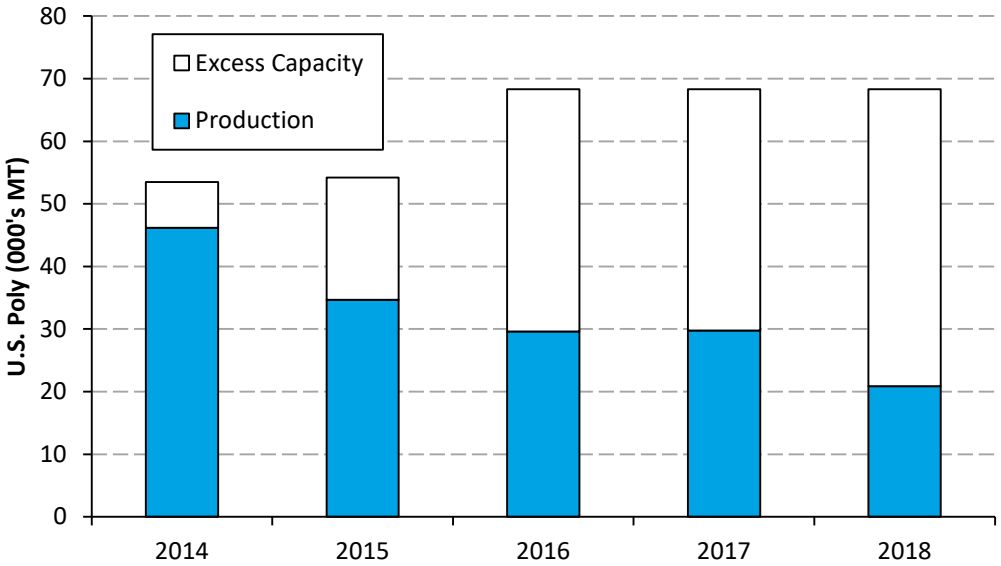


- Since the end of 2017, the United States has increased its module assembly capacity to more than 5 GW, as reported by Solar Power World.
  - The largest addition was the 1-GW Hanwha Q Cells factory in Georgia.
- Another 4 GW of additional U.S. capacity is planned, which would bring total U.S module assembly to just under 9 GW, from more than 25 firms.

Sources: Solar Power World (May 2019); Wood Mackenzie Power & Renewables "PV Pulse July 2018;" NREL.

U.S. Polysilicon Manufacturing

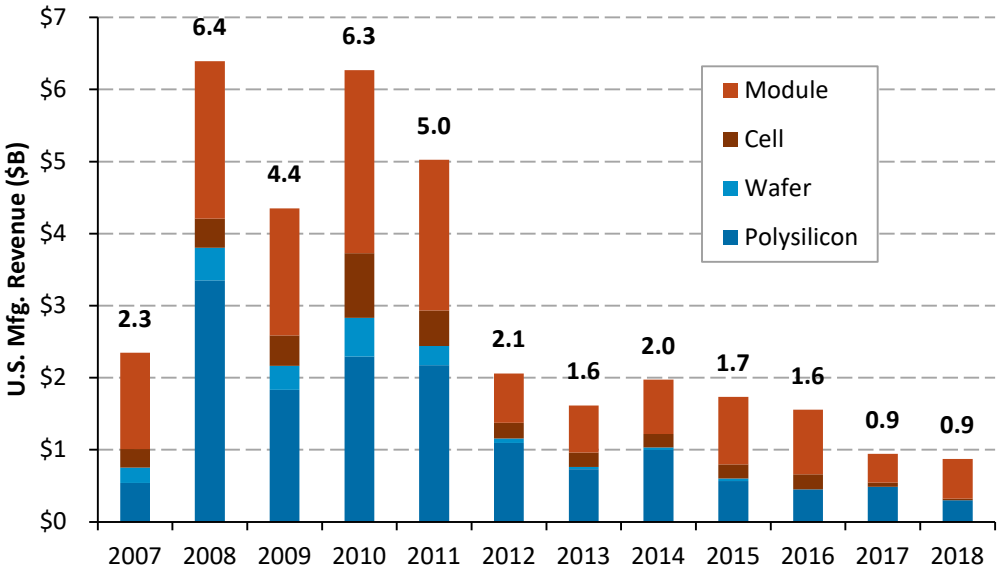
- Almost all U.S.-produced polysilicon is manufactured by Hemlock, REC Silicon, and Wacker.



- In January 2014, China began applying a 57% tariff on U.S.-produced polysilicon, significantly hindering U.S. manufacturers, given the limited market outside China.
  - In 2018, U.S.-produced polysilicon was 30% lower than in 2017 and 55% lower than in 2014.
  - Wacker's Tennessee facility had to stop production for eight months beginning in September 2017 because of an explosion. And a fire was also reported at the site in May 2019.

Source: Wood Mackenzie Power & Renewables & SEIA, "U.S. Solar Market Insight" (2014–2018).

Estimated U.S. PV Manufacturing Revenue

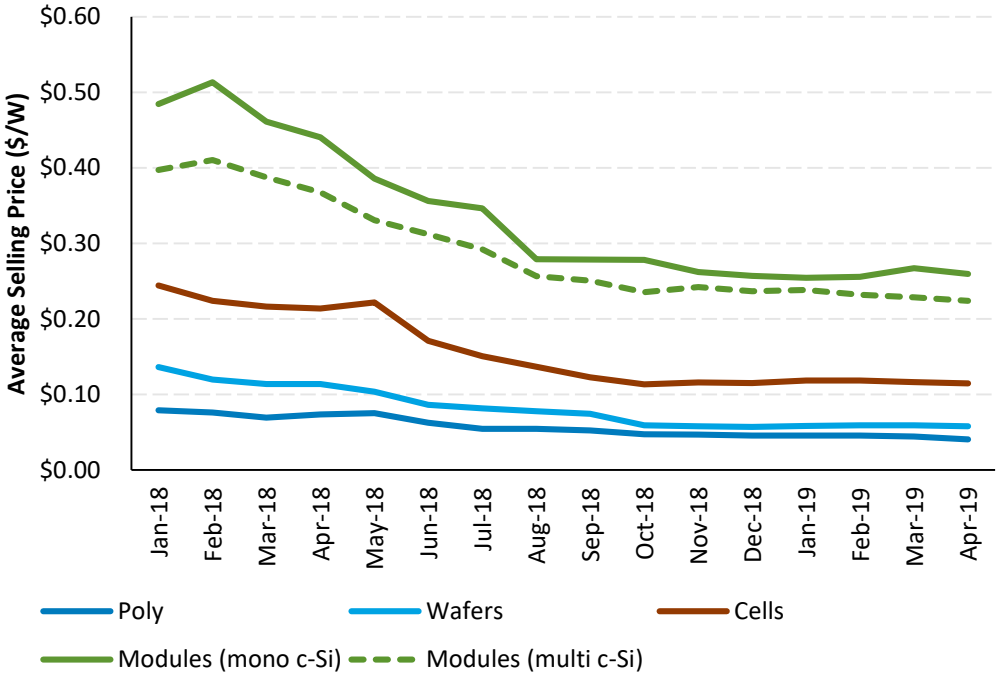


- In 2018, U.S. manufacturers of polysilicon, cell, and modules had estimated revenues of approximately $0.9 billion, $0.7 billion less than in 2016 and $5.5 billion less than their peak in 2008.
  - The largest decrease in revenues, year-on-year, came from the U.S. PV cell sector, which dropped ~66%, followed by revenues from U.S.-produced polysilicon, which dropped 38% y/y. Revenues from U.S.-produced modules increased 38% from 2017 to 2018.
- These values do not incorporate all revenues from companies that manufacture PV products in the United States; other parts of the U.S. PV supply chain include racking, encapsulants, and backsheets.

Note: measured by U.S. production x average component price.
Source: production of wafer/cell/module 2007-15: Wood Mackenzie Power & Renewables "Wafer Cell Module Database". February 2017. Polysilicon 2007-11: IEA, U.S. NSR, 2007-2011. Wafer/cell/module/poly 2016-17 (production) : Wood Mackenzie Power & Renewables /SEIA “U.S. Solar Market Year-in-Review” (2017, 2018). Price, 2007-11: Photon Consulting, "Solar Annual 2012" & "Solar Annual 2009“; 2012-2017 (price): Wood Mackenzie Power & Renewables /SEIA “U.S. Solar Market Insight Year-in-Review” (2013-2018).

- **While global module and module-component prices were relatively flat in Q4 2018, they began falling again in Q1 2019, with mono c-Si modules down 4% to 0.26/W, multi c-Si modules down 8% to $0.22/W and poly down 11% to $8.6/kg.**
- **Modules sold in the United States in Q4 2018 were 25% lower in price than modules sold in the United States in Q4 2017 but 61% higher in price than the global average.**

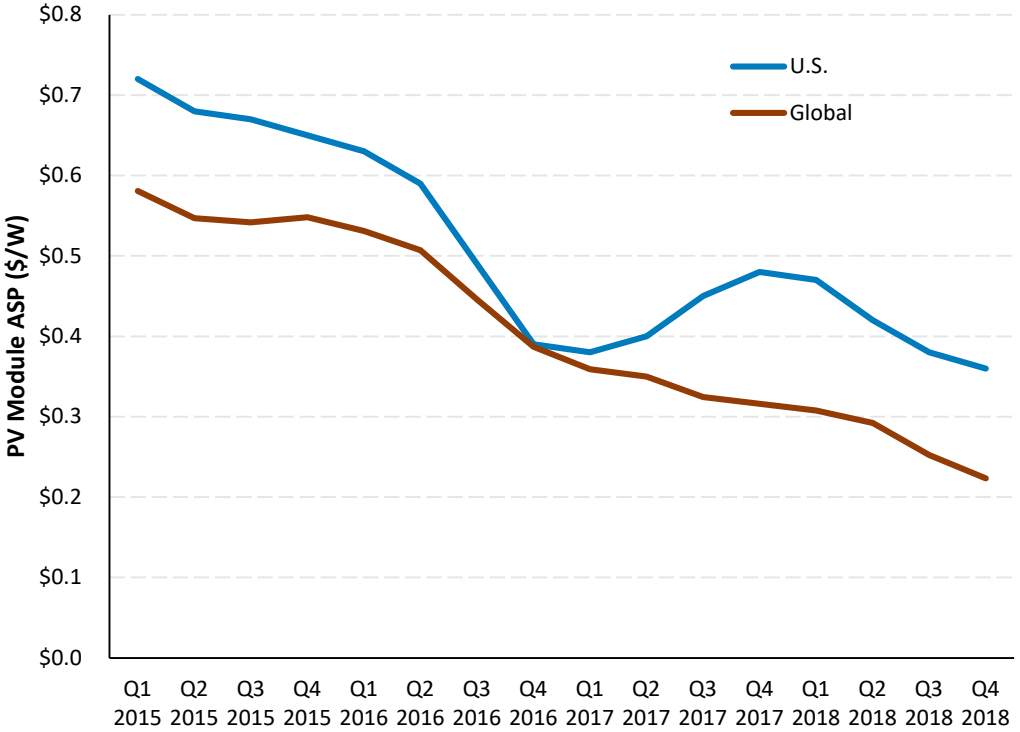
PV Value Chain Spot Pricing



While global module and module-component prices were relatively flat in Q4 2018, they began falling again in Q1 2019, with mono c-Si modules down 4% to 0.26/W, multi c-Si modules down 8% to $0.22/W and poly down 11% to $8.6/kg.

Source:. BNEF Solar Spot Price Index (04/29/19).
Kilogram to Watt conversion: 4.78 grams per watt (2016); 4.73 grams per watt (2017, 2018, 2019), from Cowen & Co. (05/11/17); Deutsche Bank (07/19/17).

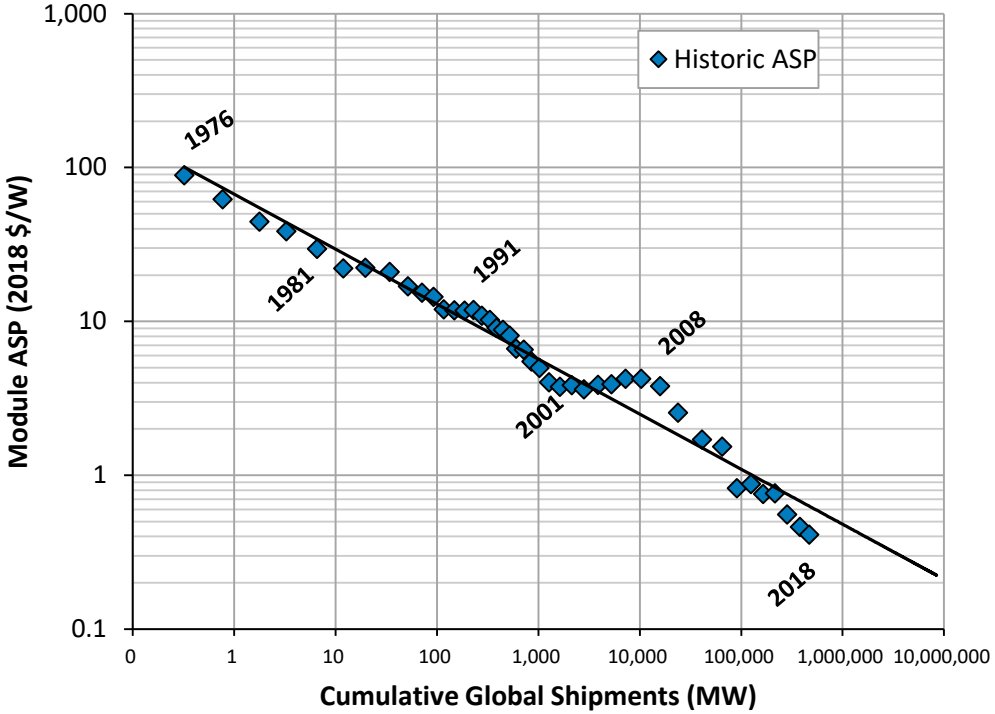
Module Average Selling Price: Global versus United States



- In Q4 2018, U.S. module prices continued to fall, dropping to their lowest recorded levels, but they were still trading at a significant premium over global module ASP.
  - Modules sold in the United States in Q4 2018 were 25% lower in price than modules sold in the United States in Q4 2017 but were 61% higher in price than the global average.

Sources. U.S. (Wood Mackenzie Power & Renewables / SEIA); Global (PVinsights/Mercom).

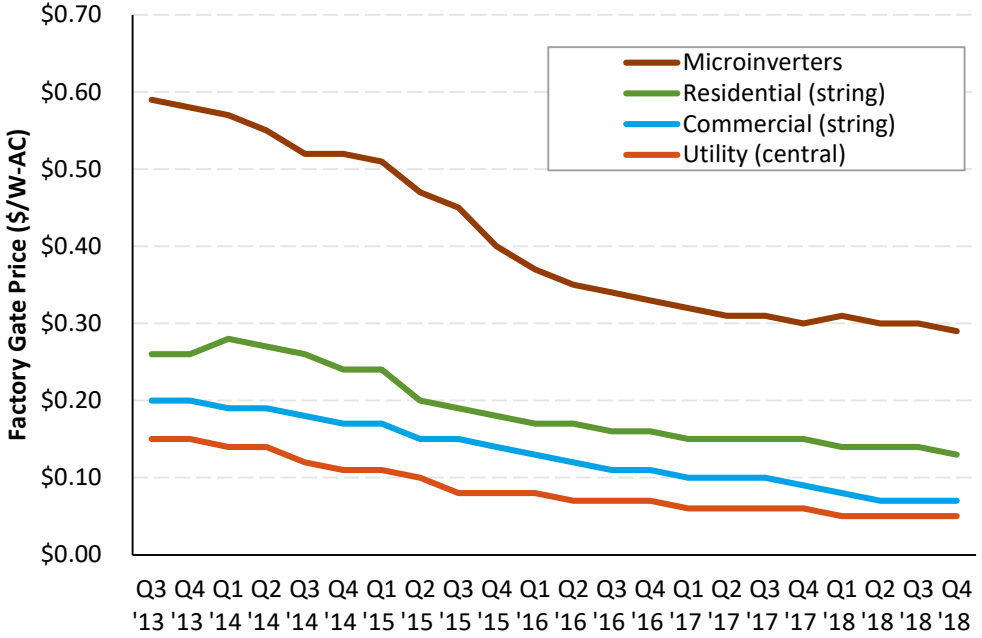
PV Experience Curve



- This experience curve displays the relationship, in logarithmic form, between the average selling price of a PV module and the cumulative global shipments of PV modules. As shown, for every doubling of cumulative PV shipments, there is on average a corresponding ~22% reduction in PV module price.
  - In 2010, the experience rate was 20%
- Since 2012, module ASP has been below the historical experience curve.
- Analysts project that by 2022 ASP will be approximately $0.2/W and globally we will have shipped a terawatt.

Source: 1976-2018: Paula Mints. "Photovoltaic Manufacturer Capacity, Shipments, Price & Revenues 2018/2019." SPV Market Research. Report SPV-Supply6. April 2019.

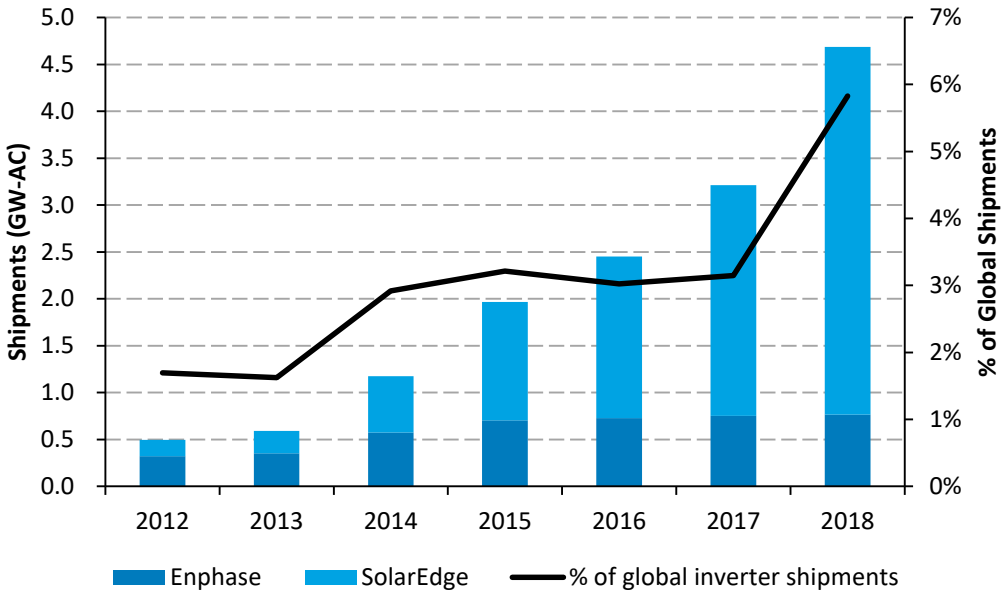
Inverter Pricing



- U.S. inverter pricing fell 13% (residential) to 22% (commercial) in 2018.
  - In Q4 2018, residential string inverters fell 7%, while microinverters fell 3%.

Source. Wood Mackenzie Power & Renewables/SEIA.

Enphase Microinverters and SolarEdge DC-Optimized Inverter Systems



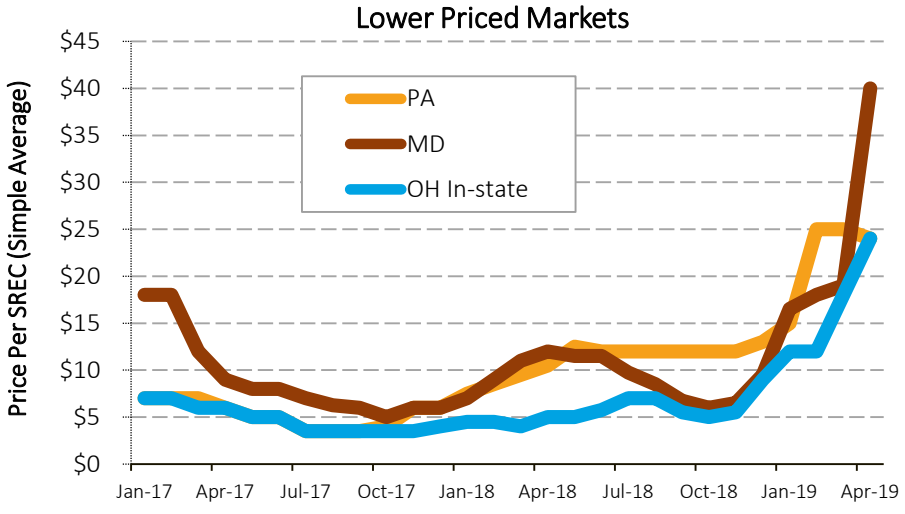
- Enphase and SolarEdge shipped more than 4.5 GW-AC of MLPE combined in 2018.
  - Since 2015, Enphase shipments have been relatively flat and SolarEdge shipments have grown 46% per year.
  - In Q4 2018, SolarEdge's MLPE product was approximately $0.15/W less than Enphase's product.
- Enphase and SolarEdge represented approximately 6% of all inverter shipments in 2018.
  - Wood Mackenzie reports that these companies represented approximately 71% of U.S. residential PV system inverters installed in 2018—up from 65% in 2017.

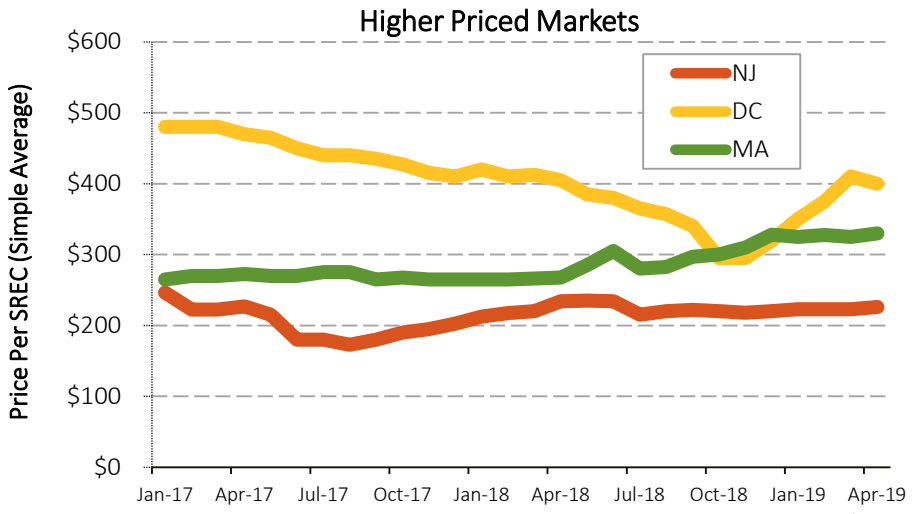
Sources: Corporate filings; Wood Mackenzie Power & Renewables "The Global PV Inverter and MLPE Landscape H2 2018: Prices, Forecasts, Market Shares and Vendor Profiles." October 2018; "U.S. PV Leaderboard: Q1 2019."

- **SREC pricing continued to rise in all markets in the beginning of 2019, buoyed in some cases by proposed or enacted legislation, raising RPSs.**
- **In the first four months of 2019, solar stocks recovered dramatically, wiping away the 2018 losses.**

SREC Pricing

- SREC pricing continued to rise in all markets in the beginning of 2019.
  - Some of these markets are in undersupply, but many have been buoyed by proposed or enacted legislation, raising RPSs.
- The largest increases in pricing occurred in Maryland and Pennsylvania.
  - In April, Maryland doubled its RPS to 50%, and increased the solar carve out to 5.5% in 2019 and 14.5% to 2028.
  - In November, the Pennsylvania Department of Environmental Protection released strategies to get 10% of its electricity from solar by 2030; in April, the governor announced his support of a senate bill to do the same.

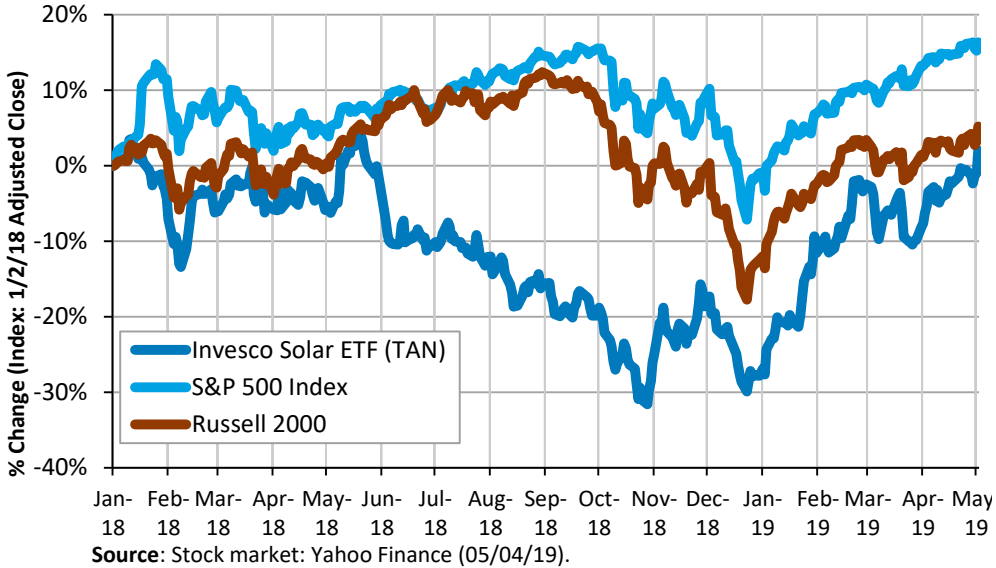




Sources: SRECTrade, https://www.srectrade.com/, accessed 10/25/18.

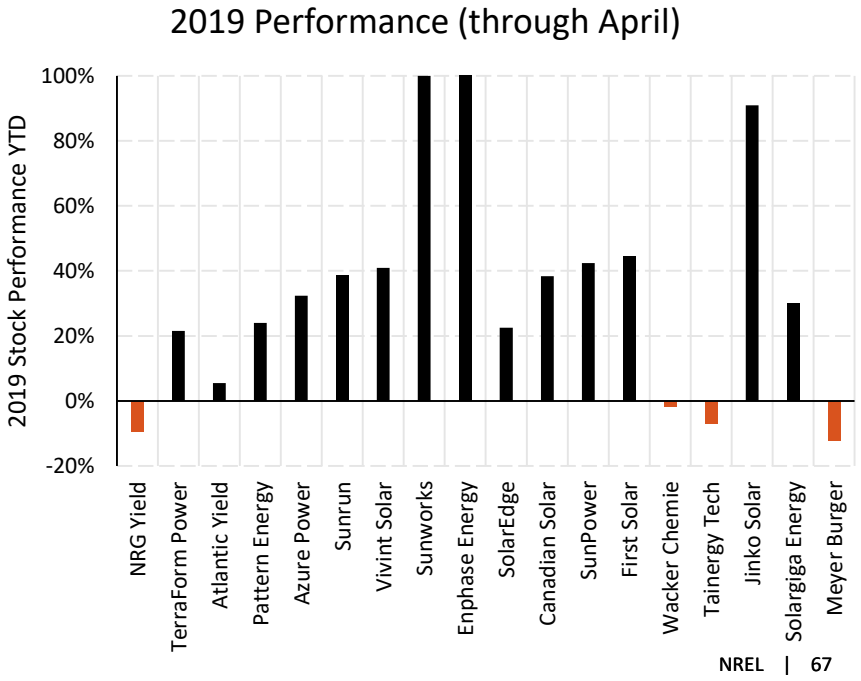
Stock Market Activity

- In 2018, many solar stock prices plummeted after the Chinese announcement in late May of a decrease in subsidies, causing an oversupply of PV modules and cells in the marketplace.
- However, in the first four months of 2019, they recovered dramatically, wiping away a 30% loss.



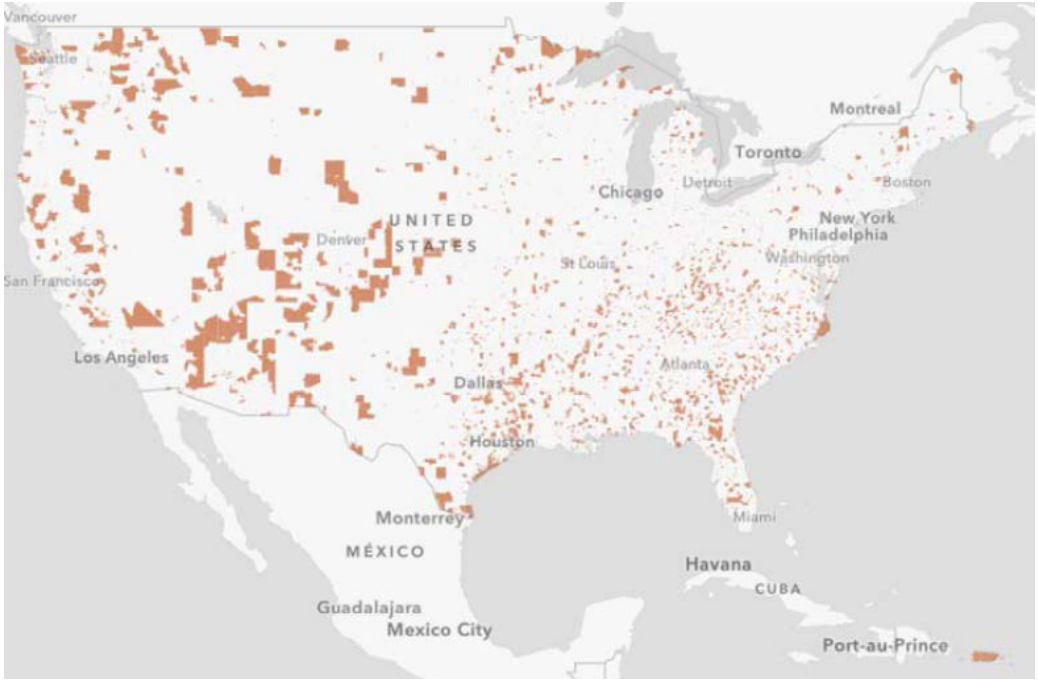
Source: Stock market: Yahoo Finance (05/04/19).

- Many solar stocks gained 20%–40%, while some did considerably better and others lost value.



- **Opportunity zones are economically distressed communities where new investments, under certain conditions, may be eligible for preferential tax treatment.**
- **There are some challenges to making an investment in a solar asset and using these tax treatments; however, opportunity zones could potentially create an additional driver to further PV deployment.**

Opportunity Zones



- "An Opportunity Zone is an economically-distressed community where new investments, under certain conditions, may be eligible for preferential tax treatment"
- Qualified Opportunity Zones (QOZs) were created by the Tax Cuts and Jobs Act on December 22, 2017.
  - In 2018, states nominated low-income communities, which were then designated as opportunity zones by the treasury.
  - There are QOFs in all 50 states (and territories); they are home to 35 million people, and are in rural, suburban, and urban areas.

Sources: https://www.irs.gov/newsroom/opportunity-zones-frequently-asked-questions, https://eig.org/news/opportunity-zones-map-comes-focus; map from: https://eig.org/opportunityzones

Tax Benefits of Investing in an Opportunity Zone

- **Deferral of Capital Gains**: Investors can take proceeds from the sale of capital, invest in a qualified investment in an opportunity zone, and not pay capital gains from that sale until the *earlier* of (1) the date the investment is sold or (2) December 31, 2026.
- **Step-Up in Basis** (i.e., partial "haircut" to amount of income taxed): If the qualified investment is held for five years, 10% of investment is excluded from capital gains; if it is held for seven years, 15% is excluded from capital gains.
  - Due to the 2026 deadline, investors must invest capital gains before 2020 to be eligible to receive the 15% exclusion (i.e., seven years)
  - Capital gains are further reduced if the FMV of the investment (when taxes are owed) is less than the initial investment of capital gains.
- **Additional Gain is Not Taxed**: If an investor holds their investment for 10 years, they are not required to pay taxes on any additional capital gains (beyond those paid December 31, 2026), no matter how much the asset appreciates.

Tax Benefits of Investing in an Opportunity Zone

Example

- Five-year deferral and 10% step-up in basis reduces the capital gains tax, in real terms, by 29%.
- Seven-year deferral and 15% step-up in basis reduces the capital gains tax, in real terms, by 40%.
  - $0 tax basis could also mean a reduction in value of solar depreciation expense by 7%.
    - The percentages may not be of equivalent value based on the equity contribution versus the total cost of the project.

Year 0

- Sale of $1 million asset, invest within 180 days—no taxes owed
- Tax basis: $0

Year 5

- 10% increase in basis ($100,000)
- Taxed on $900,000 (or FMV if lower) if sold

Year 7

- 5% increase in basis ($150,000)
- Taxed on $850,000 (or FMV if lower)
- Capital gains accrued on or before December 31, 2026 (sale or no sale)

Year 10

- Taxpayer sells asset for $2 million.
- Basis in the investment is deemed to be FMV; no *federal* taxes owed

Held for 5 Years

Held for 7 Years

Held for 10 Years

Notes: Assumes a capital gains tax rate of 20%, a combined corporate tax rate of 27.3% (state and federal), a discount rate of 6%, assumes depreciation is taken when the step-up in basis occurs, and that the first year of depreciation and the ITC flow to the tax equity investor.

Solar Investment Challenges and Opportunities

- Investors may be worried their investments will not qualify for tax benefits because the opportunity zone law is unclear in places and current regulations do not cover everything.
- There is a time pressure because investments must be made by the end of 2019 in order to take advantage of 15% step-up in basis.
- A typical equity investment in a solar project has challenges for a QOF.
  - Tax basis begins at zero, so it can be challenging to take advantage of depreciation expense.
  - Individual investors can only take advantage of ITC or depreciation expense against passive gains (i.e., passive activity loss rules).
- Part of the benefit of opportunity zone investments is that "additional gain is not taxed" after 10 years; however, solar assets typically go down in value over time (as the facility ages).
  - While solar assets' value typically goes down over time, transactions may be structured so that a specific investor's equity value may increase.
- The complexity in structuring a transaction could make ideal QOF size $50 million to $200 million.
- Most large-scale opportunity zone projects will have more to do with city planning than individual developer priorities.
  - Cities encourage certain investments based on their priorities, such as affordable housing and clean energy deployment.
  - Project development is tied to permitting; a city could require all projects include renewable energy and energy efficiency in their plans before it would issue a permit.

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Thank You

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List of Acronyms and Abbreviations

AC	alternating current
ASP	average selling price
BNEF	Bloomberg New Energy Finance
CAISO	California Independent System Operator
CdTe	cadmium telluride
CIGS	copper indium gallium selenide
C-Si	crystalline silicon
CSP	concentrating solar power
DC	direct current
EIA	U.S. Energy Information Administration
ERCOT	Electric Reliability Council of Texas
ETF	exchange traded fund
FiT	feed-in-tariff
FMV	fair market value
GW	gigawatt
ILR	inverter loading ratio
ITC	investment tax credit
kg	kilogram
kW	kilowatt
kWh	kilowatt-hour
MLPE	module-level power electronics
MW	megawatt
MWh	megawatt-hour
NERC	North American Electric Reliability Corporation
NEM	net energy metering
PERC	passive emitter rear cell
PPA	power purchase agreement
PV	photovoltaic
R&D	research and development
Q	quarter
QOF	qualified opportunity fund
QOZ	qualified opportunity zone
REC	renewable energy certificate
RPS	renewable portfolio standards
S&P	Standard and Poor's
SEIA	Solar Energy Industries Association
SPP	Southwest Power Pool
SREC	solar renewable energy certificate
SWPP	Southwest Power Pool
TAN	Invesco Solar ETF
TPO	third-party owner
TW	terawatt
TWh	terawatt-hour
UAE	United Arab Emirates
W	watt
WECC	Western Electricity Coordinating Council
y/y	year over year
YTD	year to date