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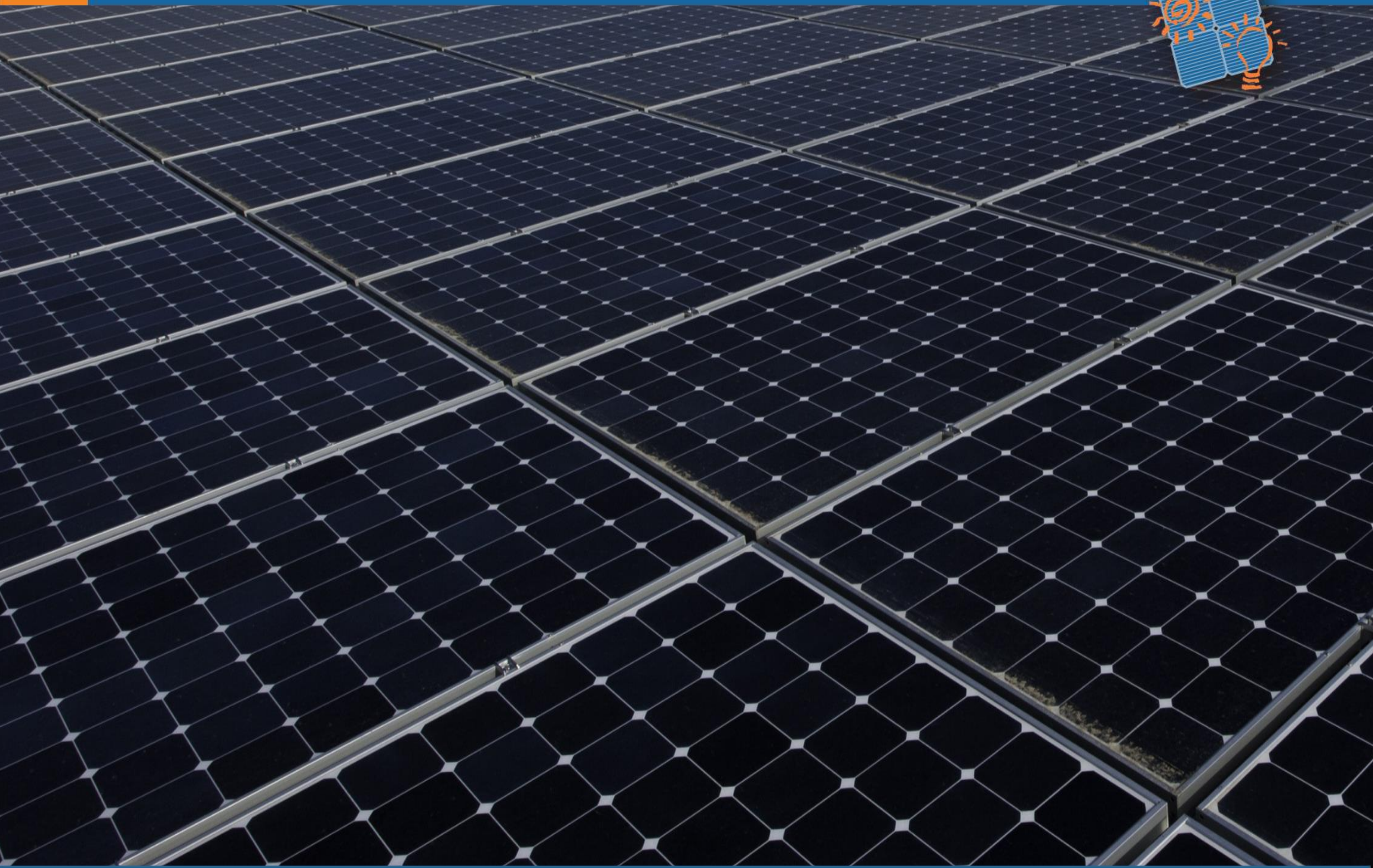

Task 1 Strategic PV Analysis and Outreach

National Survey Report of PV Power Applications in United States of America 2018

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY
SOLAR ENERGY TECHNOLOGIES OFFICE

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PHOTOVOLTAIC POWER SYSTEMS
TECHNOLOGY COLLABORATION PROGRAMME

PVPS

Cover picture: Photo by Dennis Schroeder, NREL 21292

WHAT IS IEA PVPS TCP

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The IEA carries out a comprehensive programme of energy cooperation among its 30 member countries and with the participation of the European Commission. The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the collaborative research and development agreements (technology collaboration programmes) within the IEA and was established in 1993. The mission of the programme is to "*enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems*."

In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas. This report has been prepared under Task 1, which deals with market and industry analysis, strategic research and facilitates the exchange and dissemination of information arising from the overall IEA PVPS Programme.

The IEA PVPS participating countries are Australia, Austria, Belgium, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, and the United States of America. The European Commission, Solar Power Europe, the Smart Electric Power Alliance (SEPA), the Solar Energy Industries Association and the Copper Alliance are also members.

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WHAT IS IEA PVPS task 1

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation. An important deliverable of Task 1 is the annual "Trends in photovoltaic applications" report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the country National Survey Report for the year 2018. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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1 INSTALLATION DATA

The PV power systems market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all installation and control components for modules, inverters and batteries. Other applications such as small mobile devices are not considered in this report.

For the purposes of this report, PV installations are included in the 2018 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2018, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

Growth in the United States' (U.S.) PV market has been propelled by grid-connected PV installations, with approximately 10 680 MW_{DC} of new grid-connected PV capacity added in 2018, bringing its cumulative total to approximately 62 498 MW_{DC}.[1] Because a reliable data source for off-grid systems is not available, new data presented here is for grid-connected systems only.

Grid-Connected PV: For the purposes of this report, distributed grid-connected PV systems are defined as residential and commercial applications, while centralized grid-connected PV systems are defined as utility applications. Distributed PV systems can be mounted on the ground near the facility, on the building roof, or integrated into the building roof, walls, or windows. Distributed generation is connected to the grid on the consumer side of the meter, usually at a facility or building that uses electricity and owns or leases the PV generation. By the end of 2018, there were nearly 2,0 million distributed PV systems interconnected across the United States.[2]

Centralized PV systems (utility applications) generate electricity that is fed directly to the grid, without serving an on-site load. This sector installed 6 196 MW_{DC} in 2018, approximately the same level as in 2017, which was 6 351 MW_{DC}.[3]

Community or shared solar projects, a process in which groups of individuals either jointly own, or jointly purchase electricity from large centralized PV arrays are also growing rapidly in parts the U.S. At the end of 2018, U.S. community solar projects had a cumulative capacity of 1 579 MW_{DC}.[4] The ownership structures of community solar projects can vary widely, and have been implemented by utilities, developers, and other organizations.

Off-Grid PV: Off-grid systems include storage (traditionally deep-cycle, lead-acid batteries, though lithium ion batteries are becoming more commonplace), charge controllers that extend battery life, and prevent the load from exceeding the battery discharge levels. Some off-grid systems are hybrids, with diesel or gasoline generators. Off-grid PV installations serve both the domestic and non-domestic market. Off-grid domestic PV systems are often used where utility-generated power is unavailable, or the customer requires back-up power and a second utility service is too costly. Applications also occur when the price of extending power lines costs more than a PV system. Off-grid domestic systems are ideal when only small amounts of power are needed, such as in residential applications in rural areas, boats, motor homes, travel trailers, vacation cottages, and farms. Most systems are rated at less than 1 kW, have several days of battery storage, and usually serve direct current (DC) loads. Some larger systems use stand-

[1] Wood Mackenzie Power and Renewables/SEIA: U.S. Solar Market Insight Q2 2019

[2] Ibid.

[3] Ibid.

[4] Ibid.

alone inverters to power alternating current (AC) loads and may include a diesel generator as backup.

Off-grid non-domestic PV systems are used in commercial, industrial, agricultural, and government activities. These include large PV and diesel hybrid power stations where grid connections are impractical. Telecommunications are often powered by PV for telephone, television, and secure communications, including remote repeaters and amplifiers for fibre optics. Additionally, off-grid PV systems supply power for data communication for weather and storm warnings and security phones on highways. In the United States, PV-powered lighting and signals are numerous along highways and in cities; they are used at bus stops, shelters, and traffic signals. Off-grid non-domestic PV is also used for pumping water into stock ponds and for irrigation control. The Energy Information Agency (EIA) estimates that as much as 274 megawatts of remote electricity generation with PV applications (i.e., off-grid power systems) were in service in 2013, plus an additional 573 megawatts in communications, transportation, and assorted other non-grid-connected, specialized applications.[5]

1.2 Total photovoltaic power installed

Deployment statistics are collected by the Solar Energy Industries Association (SEIA) and Wood Mackenzie Power & Renewables.[6] These organizations survey nearly 200 installers, manufacturers, utilities and state agencies to obtain granular installation data on installations in every state.

Table 1: Annual PV power installed during calendar year 2018.

		Installed PV capacity in 2018 [MW]	AC or DC
PV capacity	Off-grid	NA	NA
	Decentralized	4 485	DC
	Centralized	6 196	DC
	Total	10 680	DC

[5] Energy Information Administration. Annual Energy Outlook. September 2015. Washington, DC. U.S. Department of Energy.

[6] "U.S. Solar Market Insight Report" Wood Mackenzie/SEIA; more information on the reports methodology is available at: http://www.seia.org/research-resources/us-solar-market-insight/about

Table 2: PV power installed during calendar year 2018.

			MW installed in 2018 (mandatory)	MW installed in 2018	AC or DC
Grid-connected	BAPV	Residential	4 485	2 386	DC
		Commercial			DC
		Industrial			DC
	BIPV	Residential	N/A		
		Commercial			
		Industrial			
	Utility-scale	Ground-mounted	6 196		DC
		Floating			DC
		Agricultural			DC
Off-grid		Residential (SHS)	N/A		
		Other			
		Hybrid systems			
		Total	10 680		DC

Table 3: Data collection process.

If data are reported in AC, please mention a conversion coefficient to estimate DC installations.	N/A
Is the collection process done by an official body or a private company/Association?	Collaboration between official body (DOE and NREL) and Association (SEIA)
Link to official statistics (if this exists)	http://www.seia.org/research-resources/us-solar-market-insight; http://www.eia.gov/electricity/

Table 4: The cumulative installed PV power in 4 sub-markets.

Year	Off-grid (including large hybrids)	Grid-connected distributed (BAPV, BIPV)	Grid-connected centralized (Ground, floating, agricultural…)	Total
2004	NA	94	17	111
2005	NA	172	18	190
2006	NA	277	18	295
2007	NA	428	27	455
2008	NA	710	43	735
2009	NA	1 067	101	1 168
2010	NA	1 649	368	2 017
2011	NA	2 784	1 153	3 937
2012	NA	4 354	2 956	7 310
2013	NA	6 262	5 814	12 076
2014	NA	8 584	9 736	18 320
2015	NA	11 817	14 004	25 821
2016	NA	16 162	24 811	40 973
2017	NA	20 655	31 162	51 818
2018	NA	25 140	37 358	62 498

Table 5: Other PV market information.

	2017 Numbers	2018 Numbers
Number of PV systems in operation in your country	Residential: 1 584 524 Non-Residential: 75 280 Utility: 2 227	Residential: 1 897 710 Non-Residential: 85 530 Utility: 2 511
Capacity of decommissioned PV systems during the year in MW	41,7	42,5[7]
Total capacity connected to the low voltage distribution grid in MW	20 595	25 140[8]
Total capacity connected to the medium voltage distribution grid in MW	Not available	Not available
Total capacity connected to the high voltage transmission grid in MW	Not available	Not available

Table 6: PV power and the broader national energy market.[9]

MW-GW for capacities and GWh-TWh for energy	2016 numbers	2017 numbers	2018 numbers excluding small scale solar	2018 Numbers including small-scale solar
Total power generation capacities (all technologies)	1 093 GW_{AC}	1 101 GW	1 098 GWAC	1 117 GWAC
Total power generation capacities (renewables including hydropower)	213 GW_{AC}	227 GWAC	222 GWAC	242 GWAC
Total electricity demand (= consumption)	4 095 487 GWh	4 058 258 GWh	4 177 810 GWh	4 207 353 GWh
Total energy demand (= final consumption)				
New power generation capacities installed during the year (all technologies)	31,1 GW AC	25,9 GWAC	33,8 GWAC	37,2 GWAC
New power generation capacities installed during the year (renewables including hydropower) (GW)	20,1 GWAC	14,9 GWAC	11,8 GWAC	15,2 GWAC
	51 483 GWh	74 007 GWh	63 012 GWh	92 555 GWh

[7] EIA Form 860, 2018 Early Release

[8] "U.S. Solar Market Insight Report" Wood Mackenzie/SEIA; more information on the reports methodology is available at: http://www.seia.org/research-resources/us-solar-market-insight/about

[9] EIA Electric Power Monthly, February 2019 *and* EIA Form 860, 2018.

Estimated total PV electricity production (including self consumed PV electricity) in GWh-TWh				
Total PV electricity production as a % of total electricity consumption	1,3%	1,8%	1,6%	2,2%

1.3 Key enablers of PV development

Table 7: Information on key enablers.

	Description	Annual Volume	Total Volume	Source
Decentralized storage systems	Behind-the-meter battery storage systems, connected to the electric grid.	2018: 164 MW	332 MW (726 MWh)	Wood Mackenzie Power & Renewables and Energy Storage Association, "U.S. Energy Storage Monitor."
Residential Heat Pumps	Residential households (2017)	NA	12 100 000	https://www.eia.gov/todayinenergy/detail.php?id=30672
Electric cars [#]	Units	361 307	1 360 000 (est.)	https://insideevs.com/news/342513/january-2019-us-plug-in-ev-sales-report-card/
Electric buses and trucks [#]	Units		1600	https://www.sierraclub.org/articles/2019/02/for-us-transit-agencies-future-for-buses-electric
Other Centralized batteries		147 MW	772 MW (1 150 MWh)	Wood Mackenzie Power & Renewables and Energy Storage Association, "U.S. Energy Storage Monitor."

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices[10]

Table 8: Typical module prices for a number of years.

Year	Lowest price of a standard module crystalline silicon	Highest price of a standard module crystalline silicon	Typical price of a standard module crystalline silicon
2008	NA	NA	3,25
2009	NA	NA	2,18
2010	NA	NA	1,48
2011	0,35	2,30	1,37
2012	0,45	1,44	0,75
2013	0,40	1,97	0,81
2014	0,53	1,10	0,71
2015	0,50	1,00	0,72
2016	0,37	1,00	0,53
2017	0,28	0,72	0,45
2018	0,31	0,61	0,41

[10] Mints, Paula. "Photovoltaic Manufacturer Capacity, Shipments, Price & Revenues 2018/2019." SPV Market Research. April 2019.

2.2 System prices

Installed system prices continue to fall in the United States, driven by three primary factors: 1) falling hardware prices 2) the shift toward larger systems and 3) improved installation practices. While average system prices are still higher than those seen in other developed countries[11], the trend is clearly downward in all sectors and utility scale prices in 2018 approached 1,00 USD/Wp. This downward trend is somewhat masked for distributed PV systems by the popularity of third-party ownership in the U.S., as systems deployed under these lease or power purchase agreement structures tend to report higher installed prices that reflect higher financing transaction costs and services.

Table 9: Turnkey PV system prices of different typical PV systems.

Category/Size	**Typical applications and brief details**	**Current prices [currency/W]**
Off-grid 1-5 kW	A stand-alone PV system is a system that is installed to generate electricity to a device or a household that is not connected to the public grid.	N/A
Residential BAPV 5-10 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected households. Typically roof-mounted systems on villas and single-family homes.	2,70
Residential BIPV 5-10 kW	Grid-connected, building integrated, distributed PV systems installed to produce electricity to grid-connected households. Typically, on villas and single-family homes.	N/A
Small commercial BAPV 10-100 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	1,95
Small commercial BIPV 10-100 kW	Grid-connected, building integrated, distributed PV systems installed to produce electricity to grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	N/A
Large commercial BAPV 100-250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected large commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	1,83
Large commercial BIPV 100-250 kW	Grid-connected, building integrated, distributed PV systems installed to produce electricity to grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc.	N/A
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected industrial buildings, warehouses, etc.	1,72
Small centralized PV 1-20 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	1,25
Large centralized PV >20 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale.	1,06

[11] Barbose, G.; Darghouth, N. "Tracking the Sun X: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States." Berkeley, CA: Lawrence Berkeley National Laboratory.

Other categories existing in your country. Examples could be: **Hybrid diesel-PV** **Floating Centralized PV** **Agricultural PV** **Industrial BIPV**		N/A

Table 10: National trends in system prices for different applications

Year	**Residential BAPV** Grid-connected, roof-mounted, distributed PV system 5-10 kW **[USD/W]**	**Small commercial BAPV** Grid-connected, roof-mounted, distributed PV systems 10-100 kW **[USD/W]**	**Large commercial BAPV** Grid-connected, roof-mounted, distributed PV systems 100-250 kW **[USD/W]**	**Large centralized PV** Grid-connected, ground-mounted, centralized PV systems >20 MW **[USD/W]**
2010	7,34	N/A	5,43	4,63
2011	6,44	N/A	5,04	3,97
2012	4,55	N/A	3,47	2,70
2013	3,97	N/A	2,82	2,07
2014	3,49	N/A	2,80	1,91
2015	3,23	2,42	2,30	1,85
2016	3,02	2,40	2,20	1,47
2017	2,84	2,08	1,88	1,04
2018	2,70	1,95	1,83	1,06

2.3 Cost breakdown of PV installations

The cost breakdown of a typical 5-10 kW roof-mounted, grid-connect, distributed PV system on a residential single-family house and a typical >10 MW Grid-connected, ground-mounted, centralized PV systems at the end of 2018 is presented in **Error! Reference source not found.** and Table 12, respectively.

The cost structure presented is from the customer's point of view. I.e., it does not reflect the installer companies' overall costs and revenues. The “average” category in **Error! Reference source not found.** and Table 12 represents the average cost for each cost category and is the average of the typical cost structure. The average cost is taking the whole system into account and summarizes the average end price to customer. The “low” and “high” categories are the lowest and highest cost that has been reported within each segment. These costs are individual posts, i.e., summarizing these costs do not give an accurate system price.

Data provided by the National Renewable Energy Laboratory’s (NREL) Strategic Energy Analysis Center. NREL uses a bottom-up methodology based on tracked wholesale pricing of major solar components and data collected from major installers, with national average pricing supplemented by data collected from utility and state programs.

Table 11: Cost breakdown for a grid-connected roof-mounted, distributed residential PV system of 5-10 kW[12]

Cost category	Average [USD/W]	Low [USD/W]	High [USD/W]
Hardware			
Module	0,47		
Inverter	0,21		
Mounting material	0,31		
Other electronics (cables, etc.)			
Subtotal Hardware	**0,99**		
Soft costs			
Planning			
Installation work	0,27		
Shipping and travel expenses to customer	1,45		
Permits and commissioning (i.e. cost for electrician, etc.)			
Project margin			
Subtotal Soft costs	**1,71**		
Total (excluding VAT)	**2,70**		
Average VAT			
Total (including VAT)			

Table 12: Cost breakdown for a grid-connected, ground-mounted, centralized PV systems of >20 MW[13]

Cost category	Average [USD/W]	Low [USD/W]	High [USD/W]
Hardware			
Module	0,47		
Inverter	0,04		
Mounting material	0,17		
Other electronics (cables, etc.)			
Subtotal Hardware	**0,69**		
Soft costs			
Planning			
Installation work	0,11		
Shipping and travel expenses to customer	0,27		
Permits and commissioning (i.e. cost for electrician, etc.)			
Project margin			
Subtotal Soft costs	**0,37**		
Total (excluding VAT)	**1,06**		
Average VAT			

[12] NREL. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018. Ran Fu, David Feldman, and Robert Margolis

[13] Id.

Total (including VAT)		

2.4 Financial Parameters and specific financing programs

30 states and the District of Columbia have enabled Property Assessed Clean Energy (PACE) programs which allow energy efficiency or renewable energy improvements to be financed through property taxes. Programs exist for both residential and commercial properties and the debt is tied to the property as opposed to the property owner. In turn, the repayment obligation may transfer with property ownership if the buyer agrees to assume the PACE obligation and the new first mortgage holder allows the PACE obligation to remain on the property. This can address a key disincentive to investing in solar because many property owners are hesitant to make property improvements if they think they may not stay in the property long enough for the resulting savings to cover the upfront costs.[14]

Table 13: PV financing information in 2018.

Different market segments	Loan rate [%]
Average rate of loans – residential installations	Non-Subsidized APR, Top-Tier Credit, for Residential Solar Loans: 6.1-7.1%[15]
Average rate of loans – commercial installations	Weighted average cost of capital for a portfolio of rooftop installations: 5.6-10.4%[16]
Average cost of capital – industrial and ground-mounted installations	Weighted average cost of capital for a portfolio of rooftop installations: 5.1-7.5%[17]

2.5 Specific investments programs

Table 14: Summary of existing investment schemes.

Investment Schemes	Introduced in USA
Third party ownership (no investment)	The up-front capital requirements of PV installations often deter PV adoption. As a result, innovative third-party financing schemes that address high up front capital requirements, such as solar leases and power purchase agreements (PPA), have become popular. In 2018, third party owned systems accounted for 33% of residential installations. However, third party ownership is declining in many markets due to a combination of declining system costs, and new loan products entering the market.[18]

[14] https://www.energy.gov/eere/slsc/property-assessed-clean-energy-programs

[15] Feldman, D; Schwabe, P. (2018). "PV Project Finance in the United States, 2018." National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy19osti/72037.pdf

[16] Ibid

[17] Ibid

[18] Mond, A. 2018. *U.S. Residential Solar Finance Update, H1 2019*. Wood Mackenzie Power & Renewables.

Renting	NA
Leasing	Leasing remains a popular model for procuring solar energy, especially in states that do not allow residential PPAs. Many solar installers that provide PPA products also have solar lease products.
Financing through utilities	On Bill Financing, a process by which energy efficiency upgrades are financed through utility bills, is being explored by some utilities. 12 states currently have enabling legislation for On Bill Financing, and at least one state (New York) has a state-wide on bill financing program for solar.[19]
Investment in PV plants against free electricity	
Crowd funding (investment in PV plants)	A number of platforms exist to facilitate the crowdfunding of solar projects. More generally, the Securities and Exchange Commission provides general guidance and annual limits for crowdfunded investments.[20]
Community solar	Community Solar, or Shared Solar, allow multiple participants to benefit directly from the energy produced by one solar array. Shared solar participants typically benefit by owning or leasing a portion of a system, or by purchasing kilowatt-hour blocks of renewable energy generation.[21] As of April 2019, 20 states and Washington D.C. had adopted community solar policies, with Connecticut and New Jersey enacting legislation in 2018 and Utah enacting legislation in 2019.[22] At the end of 2018, seventy-seven percent of the cumulative installed community solar capacity was in the leading five states, with Minnesota representing 39%.
International organization financing	N/A
Other (Virtual PPA)	Virtual PPAs (also known as "financial PPAs," "synthetic PPAs," "contracts for differences," or "fixed for floating swaps") do not involve the direct purchase of energy as do onsite PPA contracts or Direct PPAs with virtual net metering. Virtual PPAs, by contrast, require the ability to sell electricity into a wholesale electricity market. In a virtual PPA, the developer or sponsor does not actually deliver the power to the customer (i.e., the corporate purchaser). Instead, the corporation and developer agree to exchange the difference between the price at which the renewable energy is sold into the wholesale electricity market from the developer and the set contract price (or the virtual PPA rate) between the developer and corporate purchaser. If the renewable energy is sold into the wholesale market at a rate higher than the set contract price, the developer pays the corporate purchaser the difference in value; if on the other hand, the renewable energy is sold in the wholesale

[19] National Conference of State Legislatures. "On-Bill Financing: Cost-Free Energy Efficiency Improvements." April 7, 2015. http://www.ncsl.org/research/energy/on-bill-financing-cost-free-energy-efficiency-improvements.aspx, accessed June 26, 2017.

[20] Securities and Exchange Commission "Investor Bulletin: Crowdfunding for Investors." February 16, 2016. https://www.sec.gov/oiea/investor-alerts-bulletins/ib_crowdfunding-.html, accessed May 23, 2016.

[21] https://www.energy.gov/eere/solar/community-and-shared-solar

[22] Feldman, D.; R. Margolis. 2019. "Q1/Q2 2019 Solar Industry Update." https://www.nrel.gov/docs/fy19osti/74585.pdf

	market at a lower price, the corporate purchaser pays the developer the difference in value. At the same time, the corporation likely continues to purchase energy from its local utility (or utilities), ideally in the same power market.[23]

2.6 Additional Country information

Table 15: Country information.

<table>
<tr><td>Retail electricity prices for a household [USD/kWh]</td><td colspan="4">Average: 0,13 USD. Range 0,09 USD (Mississippi) – 0,32USD (Hawaii) / KWh[24]</td></tr>
<tr><td>Retail electricity prices for a commercial company [USD/kWh]</td><td colspan="4">Average: 0,11 USD. Range 0,08 USD (Arkansas) –0,30 USD (Hawaii) / KWh[25]</td></tr>
<tr><td>Retail electricity prices for an industrial company [USD/kWh]</td><td colspan="4">Average: 0,07 USD. Range 0,05 USD (Washington) – 0,26 USD (Hawaii) / KWh[26]</td></tr>
<tr><td>Population at the end of 2018</td><td colspan="4">327,167,434 [27]</td></tr>
<tr><td>Country size [km^2]</td><td colspan="4">9 833 517[28]</td></tr>
<tr><td>Average PV yield in [kWh/kW]</td><td colspan="4">Ground-mount: 1 726 (1 309 to 2 329)
Residential rooftop: 1 421 (1 103 to 1 824)</td></tr>
<tr><td rowspan="6">Name and market share of major electric utilities (2017)</td><td></td><td>Electricity production [%]</td><td>Share of grid Subscribers [%]</td><td>Number of retail customers [%]</td></tr>
<tr><td>Florida Power & Light</td><td>3.4%</td><td>N/A</td><td>3.5%</td></tr>
<tr><td>Georgia Power</td><td>2.6%</td><td>N/A</td><td>1.8%</td></tr>
<tr><td>Virginia Electric</td><td>2.4%</td><td>N/A</td><td>1.8%</td></tr>
<tr><td>Southern California Edison</td><td>2.3%</td><td>N/A</td><td>3.6%</td></tr>
<tr><td>Pacific Gas & Electric</td><td>2.0%</td><td>N/A</td><td>3.3%</td></tr>
</table>

3 POLICY FRAMEWORK

This chapter describes the support policies aiming directly or indirectly to drive the development of PV. Direct support policies have a direct influence on PV development by incentivizing or simplifying or defining adequate policies. Indirect support policies change the regulatory environment in a way that can push PV development.

[23] Schwabe, P.; D. Feldman; J. Fields; E. Settle. 2016. “Wind Energy Finance in the United States: Current Practice and Opportunities.” NREL/TP-6A20-68227.
[24] Data, as of 2018, from EIA, forms EIA-861- schedules 4A-D, EIA-861S and EIA-861U. http://www.eia.gov/electricity/data/browser, accessed August 26, 2019.
[25] Ibid.
[26] Ibid.

[27] Annual Estimates of the Resident Population for the United States, States, Counties, and Puerto Rico Commonwealth and Municipals: as of July 1, 2018. Source: U.S. Census Bureau, Population Division. Release Date: December 2018. Census.gov, accessed August 26, 2019.

[28] Data from the CIA World Factbook, as of June 15, 2016. https://www.cia.gov/library/publications/the-world-factbook/geos/us.html, accessed June 26, 2017.

Table 16: Summary of PV support measures.

	On-going measures in 2018 – Residential	Measures introduced in 2018 – Residential	On-going measures in 2018 – Commercial + Industrial	Measures introduced in 2018 – Commercial + Industrial	On-going measures in 2018 – Centralized	Measures introduced in 2018 – Centralized
Feed-in tariffs	5 states currently have FiT programs.	-	6 states currently have FiT programs.	-	-	-
Feed-in premium (above market price)	Performance based incentive programs for PV systems in the residential sector exist in 17 states.	-	Performance based incentive programs for PV systems in the non-residential sector exist in 20 states.	-	Performance based incentives in Nevada and Oregon.	-
Capital subsidies	Grant programs for PV systems in the residential sector exist in 7 states and through the USDA.		Grant programs for PV systems in the non-residential sector exist in 13 states and through the USDA.	-	-	-
Green certificates	Many states with RPS requirements also allow the trading of renewable electricity credits, and at least 10 states allow for the trading of solar renewable energy credits.	In May 2018, Missouri PSC published a draft ruling, stating that net metering customers were entitled to their generated RECs, unless they received a rebate. In May 2018, New Jersey passed legislation that would transition the state	Many states with RPS requirements also allow the trading of renewable electricity credits, and at least 10 states allow for the trading of solar renewable energy credits.	In May 2018, Missouri PSC published a draft ruling, stating that net metering customers were entitled to their generated RECs, unless they received a rebate. In May 2018, New Jersey passed legislation that would transition the state	Many states with RPS requirements also allow the trading of renewable electricity credits, and at least 10 states allow for the trading of solar renewable energy credits.	-

		away from RECs.		away from RECs.		
Renewable portfolio standards (RPS) with/without PV requirements	29 states plus the District of Columbia, Guam, Puerto Rico, and Virgin Islands, have an RPS.	Several states, counties and cities increased their RPS targets, with California and Washington DC mandating carbon free electricity by 2040 and 2032, respectively.	29 states plus the District of Columbia, Guam, Puerto Rico, and Virgin Islands, have an RPS.	Several states, counties and cities increased their RPS targets, with California and Washington DC mandating carbon free electricity by 2040 and 2032, respectively.	29 states plus the District of Columbia, Guam, Puerto Rico, and Virgin Islands, have an RPS.	-
Income tax credits	Federal: federal investment tax credit of 30 % for residential, commercial, and utility systems. State: 10 states offer personal tax credits for solar projects.	-	Federal: federal investment tax credit of 30 % for residential, commercial, and utility systems. State: 8 states offer corporate tax credits for solar projects.	-	Federal: federal investment tax credit of 30 % for residential, commercial, and utility systems. State: 8 states offer corporate tax credits for solar projects.	-
Self-consumption	Most states use net metering as a process for compensating self-consumption. However, some states have recently moved to other systems for self-consumption as distributed solar has become a	-	Most states use net metering as a process for compensating self-consumption. However, some states have recently moved to other systems for self-consumption as distributed solar has become a	-	-	-

	more sizeable portion of their load.		more sizeable portion of their load.			
Net-metering	As of January 2019, 35 states plus DC have mandatory net metering rules.	-	As of January 2019, 35 states plus DC have mandatory net metering rules.	-	-	-
Net-billing	10 states have or are in transition to other statewide distributed generation compensation rules.	2 states adopted net metering successors to traditional net metering.[29]	10 states have or are in transition to other statewide distributed generation compensation rules.	2 states adopted net metering successors to traditional net metering.[30]	-	-
Collective self-consumption and virtual net-metering	17 States have virtual net metering or community solar policies.	-	17 States have virtual net metering or community solar policies.	-	-	-
Commercial bank activities e.g. green mortgages promoting PV	Green banks have been created in California, Connecticut, Hawaii, Maryland, Massachusetts, Nevada, New York, Pennsylvania, and Vermont.	-	Green banks have been created in California, Connecticut, Hawaii, Maryland, Massachusetts, Nevada, New York, Pennsylvania, and Vermont.	-	Green banks have been created in California, Connecticut, Hawaii, Maryland, Massachusetts, Nevada, New York, Pennsylvania, and Vermont.	-
Activities of electricity utility businesses	Several electricity utilities have begun engaging	-	Several electricity utilities have begun engaging	-	Several electricity utilities have begun engaging	-

[29] North Carolina Clean Energy Technology Center & Meister Consultants Group, *The 50 States of Solar: 2018 Annual Review and Q4 Quarterly Report*, January 2019.

[30] North Carolina Clean Energy Technology Center & Meister Consultants Group, *The 50 States of Solar: 2018 Annual Review and Q4 Quarterly Report*, January 2019.

	with PV development, either through direct ownership of centralized and distributed PV assets, community solar programs, partial ownership in PV development companies, or joint marketing agreements.		with PV development, either through direct ownership of centralized and distributed PV assets, community solar programs, partial ownership in PV development companies, or joint marketing agreements.		with PV development, either through direct ownership of centralized and distributed PV assets, community solar programs, partial ownership in PV development companies, or joint marketing agreements.	
Sustainable building requirements	Federal: No federal codes exist, but DOE produces best-practices guides for sustainable building for both residential and commercial buildings.	-	Federal: No federal codes exist, but DOE produces best-practices guides for sustainable building for both residential and commercial buildings.	-	-	-
BIPV incentives	-	-	-	-	-	-
Other	-	-	-	-	-	-

3.1 National targets for PV

There are currently no national targets for PV.

3.2 Direct support policies for PV installations

3.2.1 Climate change Commitments

In June of 2017, the President of the United States stated that the U.S. would “cease all implementation” of the COP21 accord. A number of states and territories subsequently pledged to uphold the agreement within their borders, including California, Colorado, Connecticut, Delaware, Hawaii, Maryland, Massachusetts, Minnesota, New Jersey, New

York, North Carolina, Oregon, Puerto Rico, Rhode Island, Vermont, Virginia, and Washington. These states collectively account for 45,4% of U.S. GDP.[31]

3.2.2 Net Metering

Most PV in the U.S. is tied to the grid. The process for valuing solar energy sold to the grid is regulated by state and local governments. Net metering is the most popular process for selling distributed solar energy to the grid and 38 states plus the District of Columbia and Puerto Rico have net metering policies.[32] Recently some jurisdictions have seen disputes between utilities and solar advocates over net metering, and several jurisdictions have approached, or are approaching the maximum allowed capacity for net metering programs. Some states have successfully raised these caps; however, others have modified their net metering policies, decreasing the value of energy put onto the grid by PV systems, or moving to alternative rate structures such as time of use. Areas without net metering may employ different practices to value solar energy while some do not compensate for grid-pared solar.

3.2.3 Renewable Portfolio Standards

State-level Renewable Portfolio Standard (RPS) policies are a significant driver of solar development in the U.S., especially in areas with good solar resources. An RPS requires electric utilities or load-serving entities to source a percentage of their electric load from renewable generation. These targets are typically expressed as a percentage of total electricity consumption and range from approximately 2% in Iowa to 10% in California and Hawaii. As of June 2019, 29 states, Washington DC, and Puerto Rico have mandatory RPS policies.[33]

In 2018, several states, counties, and cities increased their renewable energy targets. Most notably, California increased the state's RPS to 60% by 2030 and joined Hawaii in establishing a 100% clean energy target to be met by 2045. Additionally, the DC City Council approved a bill calling for 100% renewable energy by 2032; Connecticut increased the state's RPS to 40% by 2030; and New Jersey enacted a 50% RPS by 2030.[34] By the end of 2018, a total of 104 American cities, 11 counties, and 51 companies in the United States had made 100% clean power commitments.[35]

3.2.4 BIPV development measures

Although there are no current development measures specific to BIPV, DOE's Office of Energy Efficiency and Renewable Energy funds BIPV research and research into BIPV-supporting technology areas (E.g., organic PV).

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[31] https://www.bea.gov/newsreleases/regional/gdp_state/qgdpstate_newsrelease.htm

[32] Two other states have no state-wide mandatory rules, but some utilities allow net metering. Six other states offer distributed generation compensation rules other than net metering. Data from the Database of State Incentives for Renewables and Efficiency. http://www.dsireusa.org/, accessed August 26, 2019.

[33] https://www.dsireusa.org/resources/detailed-summary-maps/

[34] North Carolina Clean Energy Technology Center & Meister Consultants Group, *The 50 States of Solar: 2018 Annual Review and Q4 Quarterly Report*, January 2019.

[35] Feldman et al. (2019). "Q3/Q42018 Solar Industry Update." https://www.nrel.gov/docs/fy19osti/73234.pdf

3.3 Self-consumption measures

Table 17: Summary of self-consumption regulations for small private PV systems in 2018

PV self-consumption	1	Right to self-consume	Yes
	2	Revenues from self-consumed PV	Savings on electricity bill
	3	Charges to finance Transmission, Distribution grids & Renewable Levies	In some states.
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	Retail electricity prices in most states, solar specific tariffs and Time of Use (ToU) rates in others, up to the point of annual electricity consumption (or some other pre-determined timeframe). Excess PV electricity beyond consumption is often credited at wholesale rates.
	5	Maximum timeframe for compensation of fluxes	Varies by state.
	6	Geographical compensation (virtual self-consumption or metering)	On-site; at least 20 states have community solar or virtual net metering policies[36]
Other characteristics	7	Regulatory scheme duration	Unlimited
	8	Third party ownership accepted	Yes, at least 28 states + Washington DC and Puerto Rico[37]
	9	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	Some states have implemented minimum bills for Net Energy Metering (NEM) customers
	10	Regulations on enablers of self-consumption (storage, DSM…)	ToU Tariffs in some states. Hawaii provides easier interconnection procedures.
	11	PV system size limitations	Most states restrict the size of the system of the amount of load a PV system can offset
	12	Electricity system limitations	In some states
	13	Additional features	Multiple other policies depending on the state or at federal level

3.3.1 Time-of-use rate structures

The increased use of rooftop solar systems, storage, and demand response, and the addition of electric vehicles and other major new electricity-consuming end uses are anticipated to significantly alter the load shape of many utility systems in the future.[38] Time-of-use (TOU) retail energy rates price electricity differently by the time of day, thereby communicating to consumers the costs of supplying electricity throughout the day. As a successor to volumetric

[36] Feldman, D.; R. Margolis. 2019. "Q1/Q2 2019 Solar Industry Update." https://www.nrel.gov/docs/fy19osti/74585.pdf

[37] https://www.dsireusa.org/resources/detailed-summary-maps/

[38] Natalie Mims Frick, Tom Eckman, Charles A Goldman. 2017. "Time-varying value of electric energy efficiency." LBNL-2001033. http://eta-publications.lbl.gov/sites/default/files/lbnl-1005704.pdf

rates, TOU rates are part of a broader movement to modernize demand-side loads. In 2015, the California Public Utility Commission announced reforms to better align costs of electricity supply and demand. Most prominently, Decision D.15.07-001 initiated a transition to TOU tariffs for all residential customers, to begin implementation in 2019. An impact of the transition is the change in the value of distributed wind and solar generation, based on the correlation of each technology's generation with retail prices. In part, this relative change in value under TOU could be considered an implication of the "duck curve"— as solar penetration in California increases, it depresses the price of midday generation and increases prices during afternoon peak load.[39] Several other states and utilities with increased solar penetration are also considering a switch to TOU residential rates.

3.3.2 *Solar-Plus-Storage Net Metering*

A growing number of states are considering the net metering eligibility of solar facilities paired with energy storage. In 2018, New York approved a tariff with multiple compensation options for systems paired with energy storage, and a proposed decision in California establishes equipment requirements for larger solar-plus-storage facilities to participate in net metering. Legislation enacted in Colorado also permits solar-plus-storage projects to net meter, and the Massachusetts Department of Public Utilities is currently considering the issue.

3.4 Collective self-consumption, community solar and similar measures

As of April 2019, 20 states and Washington D.C. had adopted community solar policies, with Connecticut and New Jersey enacting legislation in 2018 and Utah enacting legislation in 2019.[40] Community solar is also available in states without distinct policies, but often require utility participation. Forty-three states have at least one community solar project online, with SEIA reporting 1 387 cumulative megawatts$_{DC}$ installed through 2018.[41]

3.4.1 *State Policies and Incentives for Shared Solar*[42]

State	Legislation or Incentive	Description	Geographic Limitations	Capacity Limit
California	Virtual Net Energy Metering at Multitenant Buildings[43]	In 2009, California enabled virtual net metering in investor-owned utility territories for on-site renewable energy systems benefiting multiple tenants in affordable housing developments. This legislation was utilized by the Multifamily Affordable Solar Housing (MASH) program and the New Solar Homes Partnership (NSHP), which provided incentives for solar on existing and new properties, respectively. In 2011, the legislation was broadened to all multitenant properties (including commercial tenants) in the state with customer accounts served by the same Service Delivery Point (SDP) as the generation source. The single SDP requirement was removed for affordable housing developments.	• Applies within the SDG&E, PG&E, and SCE utility territories. • Affordable housing customers must be located within the same property development. • All others must be on the same Service Delivery Point (SDP).	• Subject to state net metering cap of 1 MW and 5% of aggregate customer peak demand.

[39] Ashwin Ramdas, Kevin McCabe, Paritosh Das, and Benjamin Sigrin. 2019. "California Time-of-Use (TOU) Transition: Effects on Distributed Wind and Solar Economic Potential." NREL/TP-6A20-73147. https://www.nrel.gov/docs/fy19osti/73147.pdf

[40] SEPA:"2019 Utility Solar Market Snapshot"

[41] Wood Mackenzie Power and Renewables/SEIA: U.S. Solar Market Insight Q2 2019.

[42] David Feldman, Anna M. Brockway, Elaine Ulrich, and Robert Margolis. 2015. "Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation." NREL/TP-6A20-63892.

[43] http://www.sfenvironment.org/download/virtual-net-energy-metering-at-multitenant-buildings.

		Renewable energy customers are credited at the retail rate. A minimum of 2 participants are required per facility.		
	Green Tariff Shared Renewables Program (SB 43)[44]	Mandates the installation of 600 MW of new renewable energy that will be available to ratepayers who are unable to access the benefits of onsite generation, including renters, businesses, and institutional customers such as universities, local governments, and the military. A minimum of 100 MW is reserved for residential customers, 100 MW for economically disadvantaged communities, and 20 MW for the City of Davis. Subscriptions are limited to 100% of a customer's electricity demand. Customers will be compensated at the retail rate plus a time-of-delivery adjustment, but will have to pay a renewable generation rate to cover administrative and other program costs.	• Applies within the SDG&E, PG&E, and SCE utility territories. • Customers must be located within the same utility territory as the renewable facility.	• Statewide limit: 600 MW. • Individual projects cannot exceed 20 MW or 1 MW if located in disadvantaged communities.
Colorado	Community Solar Gardens Act (HB 1342)[45] Enacted: 2010	Enables the development of Community Solar Gardens, shared solar facilities with a minimum of 10 participants. Subscriptions are limited to 120% of a customer's average annual electricity demand. Subscribers will be compensated at the retail rate minus a reasonable fee for electricity delivery, integration, and program administration. Community Solar Gardens must be operated by a for- or non-profit Subscriber Organization whose sole purpose is to beneficially own and operate the facility.	• Applies to investor owned utilities. • Customers must be located within the same municipality or county as the solar garden with some exceptions.	• IOU purchase requirement: 6 MW/year from 2011-2013. • Projects are limited to 2 MW each.
Connecticut	Virtual Net Metering[46]	Enables virtual net metering for state, municipal, and agricultural customers. Renewable energy systems may serve the electricity needs of the host customer and additional state, municipal, and agricultural facilities. Critical facilities connected to microgrids may also participate in some circumstances.	• Applies to investor owned utilities. • All facilities must be in the same electric distribution company's service territory.	• Projects are limited to 3 MW each.
District of Columbia	Community Renewables Energy Act[47] Enacted: 2013	Enables the deployment of Community Energy Generating Facilities, shared solar facilities with a minimum of 2 subscribers. Subscriptions are limited to 120% of a customer's energy consumption over the previous 12 months. Participants will be compensated via net metering at a standard offer service rate. Facilities must be owned or operated by a for- or non-profit Subscriber Organization. New subscribers may be added monthly.	• Customers must be located within the same utility service territory as the shared renewable energy facility.	• Projects are limited to 5 MW each.
Delaware	Community Net Metering Provisions (Order 7946)[48] Enacted: 2010	Modified the existing net metering law to allow virtual net metering. Renewable energy generating facilities may be located as stand-alone or behind the meter of a subscriber. Customers on the same distribution feeder as the facility are compensated at the full retail rate. Customers not on the same distribution feeder are compensated at a lower rate.	• Customers must be located within the same utility service territory as the shared renewable energy facility.	Subject to state net metering caps: • 2 MW for Delaware Power and Light • 500 kW for municipal utilities • 5% of electric supplier's aggregated customer monthly peak demand

44 http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB43.

45 http://www.leg.state.co.us/CLICS/CLICS2010A/csl.nsf/fsbillcont3/490C49EE6BEA3295872576A80026BC4B?Open&file=1342_enr.pdf.

46 http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=CT01R&re=0&ee=0.

47 http://dcclims1.dccouncil.us/lims/legislation.aspx?LegNo=B20-0057.

48 http://regulations.delaware.gov/AdminCode/title26/3000/3001.shtml#TopOfPage.

Massachusetts	Massachusetts Green Communities Act (SB 2768)[49]	Enacted Virtual Net Metering, enabling customers to transfer generation credits to other customers. Participants are compensated at the full retail rate. All customer classes are eligible.	• Applies to investor-owned utilities. • Municipal utilities may choose to offer net metering. • Customers must be located within the same utility service territory and ISO load zone as the facility.	• Projects are limited to 2 MW each, 10 MW for government-owned systems. • All net metering is capped at 6% of the utility's peak load (3% for government-owned systems, 3% for non-government-owned).
	Neighbourhood Net Metering (SB 2395)[50]	Enables the deployment of neighbourhood net metering facilities with a minimum of 10 residential customers. Other customer classes are also permitted to participate. Participants are compensated at the retail rate minus default service, transmission, and transmission service charges.	• Customers must be located within the same municipality and service territory.	• Subject to state net metering cap of 2 MW. • All net metering is capped at 6% of the utility's peak load (3% for government-owned systems, 3% for non-government-owned).
Maine	Net Energy Billing to Allow Shared Ownership[51]	Enables shared ownership of renewable energy facilities through virtual net metering for a maximum of 10 participants. Participants are required to have an ownership stake in the facility and are compensated at the retail rate. An eligible facility must be used primarily to offset all or part of the customers' electricity requirements.	• Applies to investor-owned utilities. • Municipal and cooperative utilities may choose to participate.	Projects are limited to: • 660 kW in IOU territories. • 100 kW in municipal and cooperative utility territories, up to 660 kW at the utility's discretion.
Minnesota	Solar Energy Jobs Act (HF 729)	Required Xcel Energy to submit a plan for a community solar gardens program to the state public utility commission. Participants will be credited at a retail rate, with option for a future value-of-solar rate. Each facility must have at least 5 participants, each of whom subscribes to at least 200 watts of the system's generating capacity.	• Applies to investor-owned utilities. • All customers must be located in the same utility service territory.	• Projects are limited to 1 MW.
New Hampshire	Group Net Metering (SB 98)[52] Enacted: 2013	Enables a customer with behind-the-meter renewable generation to become a group host for a group of other customers who wish to offset their electricity demand. The group host is responsible for any costs incurred by a utility to accommodate the required billing arrangements.	• All customers must be located in the service territory of the same electric distribution utility as the host.	• Projects are limited to 1 MW each.
Vermont	Group Net Metering[53]	Enables energy consumers to link their electricity usage accounts to one renewable facility. Vermont does not require programs to be administered by a utility or a third-party administrator. Participants receive credits at the retail rate.	• All participants must be located in the same utility service territory.	• Projects are limited to 500 kW each (2.2 MW on military property) • Subject to state net metering cap of 4% of utility's 1996 peak demand or the previous year's peak demand, whichever is greater.

[49] www.malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169.

[50] https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXXII/Chapter164/Section140.

[51] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME02R.

[52] http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=NH01R.

[53] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=VT02R.

Washington	Community Renewables Enabling Act	Shared renewables projects must be located on community-owned property, such as schools, parks, or government buildings. All participants are credited $0.30/kWh for their participation.	• All participants must be located in the same utility service territory as the renewable facility.	• Projects are limited to 75 kW each. • Subject to state net metering cap of 0.5% of a utility's peak demand in 1996. (Limit was 0.25% prior to 2014.)

3.5 Tenders, auctions & similar schemes

U.S. PV project developers and utilities use a variety of different processes to create PPAs for PV systems. There is no compulsory nation-wide process for granting PPAs.

3.6 Other utility-scale measures including floating and agricultural PV

3.6.1 Public Utilities Regulatory Policies Act

The Public Utilities Regulatory Policies Act (PURPA), passed in 1978, requires utilities to purchase energy from qualifying facilities that meet certain size and generation requirements at no less than the utility's "avoided cost." As solar project costs become competitive with avoided costs in some states, standard PURPA contracts have been a main driver behind utility-scale PV deployment. Each state determines how it follows PURPA, determining the avoided cost, the length of the contract, and the maximum size of the system. Some states which have achieved rapid solar deployment through PURPA have altered some of these standards in an effort to limit further solar deployment.

3.7 Social Policies

Seven of the 20 states with community solar policies have provisions that incentivize low- and moderate-income participation. Much of the community solar activity occurring in 2018 focused on expanding opportunities for low-income customers to participate in these programs. New community solar rules in Connecticut and New Jersey include provisions to encourage low-income participation, while states with existing programs, such as Colorado and New York, considered changes to increase the number of low-income subscribers.[54]

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[54] North Carolina Clean Energy Technology Center & Meister Consultants Group, *The 50 States of Solar: 2018 Annual Review and Q4 Quarterly Report*, January 2019.

Low Income Community Solar Provisions[55]

3.8 Retrospective measures applied to PV

Connecticut	10% of program capacity and 10% of each project's capacity are reserved for low-income customers or service organizations
Illinois	Additional 6 to 13 cents/kWh for low-income projects
Maryland	60 MW of program capacity reserved for low-income projects
Massachusetts	SMART Program offers an additional 6 cents/kWh for projects serving low-income customers
Minnesota	Pilot program combines community solar subscriptions with energy efficiency improvements for certain low-income customers
New Jersey	40 % of program capacity reserved for low-income customers
New York	Low-income bill discount may be applied to community solar

3.8.1 Fixed charges and minimum bills

To gain more revenue from customers who adopt solar, many utilities across the U.S. have attempted, and in many cases succeeded, in increasing the fixed charges for electric utility customers or establishing a minimum dollar amount for each bill. By having less revenue from variable charges (i.e., USD per kWh used) and more from fixed charges, the electricity generated by distributed PV systems under a net energy metering system is devalued. In Q4 2018, the median fixed charge increase requested was $4.05/billing cycle, representing a median percentage increase in fixed charges of 47% (average of 90%). Proposals ranged from an increase of $1.50 to $19.94.[56]

3.9 Indirect policy issues

3.9.1 Rural electrification measures

Nearly 99 % of Americans have access to electricity.[57] The Rural Utility Service (RUS) offers loans and loan guarantees to finance energy efficiency and renewable distributed energy improvements to Americans without access to electricity.

3.9.2 Support for electricity storage and demand response measures

In May 2018, New Jersey became the seventh state with an energy storage mandate, requiring 2 GW of storage by 2030. Other leading states include California, with a 1.8 GW

[55] SEPA:"2019 Utility Solar Market Snapshot"

[56] North Carolina Clean Energy Technology Center & Meister Consultants Group, *The 50 States of Solar: 2018 Annual Review and Q4 Quarterly Report*, January 2019.

[57] Data from the World Bank. http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS, accessed June 27, 2017.

target (1.3 GW by 2025) and New York (1.5 GW by 2025). Nearly 60% of the total demand response came from 25 utilities in 17 states.[58]

3.9.3 Support for electric vehicles (and VIPV)

The federal government and a number of states offer financial incentives, including tax credits, for lowering the up-front costs of plug-in electric vehicles. The federal Internal Revenue Service (IRS) tax credit is $2,500 to $7,500 per new EV purchased for use in the U.S. The size of the tax credit depends on the size of the vehicle and its battery capacity.

3.9.4 Curtailment policies

Existing PPA structures generally address curtailment in one of three ways: 1) Take-or-pay: the offtaker agrees to buy all output—delivered and curtailed—at the settled PPA rate. 2) Reduced take-or-pay: the PPA contract terms include separate rates for delivered PV output and curtailed PV output, with the curtailed rate being lower than the delivered rate. Alternatively, the offtaker may only compensate for curtailment under certain conditions (e.g., for economic curtailment but not for exceptional dispatches). 3) Non-compensable curtailment: The offtaker only pays for delivered energy; the generator bears the full risk of curtailment.

New PPA structures are being explored that would impact the distribution of curtailment risk between the offtaker and the generator, including: capacity plus energy PPA, in which the offtaker pays the generator a fixed capacity ($/MW) rate in addition to the standard volumetric ($/MWh) rate; or a fixed lease, in which the offtaker pays a fixed monthly lease rate to fully control the generator.

Curtailment has been increasing in the Midwest (for wind) and California and Hawaii (for PV). The implementation of curtailment varies in these three regions, varying between economic and manual curtailment.

Midwest: curtailment is managed by the Midwest System Operator (MISO). Starting in 2011, MISO requires wind farms to offer energy into the real-time market and participate in security-constrained economic dispatch, which requires them to curtail for economic reasons for all but extreme circumstances.

California: curtailment is managed by the California Independent System Operator (CAISO). In the event of a need for curtailment, CAISO first attempts to curtail through low or negative pricing. It may also accept offers from generators to curtail at some level of compensation, known as decremental bids. These economic measures resolve the issue in most cases. In rare events, CAISO manually curtails generators through an "exceptional dispatch." However, most renewable energy procurement in CAISO is managed by its three IOUs, which have an incentive to optimize their own portfolios.

Hawaii: curtailment is managed by the Hawaiian Electric Company (HECO) based on system needs. HECO curtails generators in reverse chronological order (i.e., newer generators are curtailed before older generators).

3.9.5 Other support measures

In August 2015, the U.S. Environmental Protection Agency (EPA) announced the Clean Power Plan, which stated that beginning in 2020, each state must have a goal establishing their carbon intensity and a plan to achieve emission reductions. While each state can decide how to accomplish its goal, one of the major building blocks to reaching their target is, "expanding zero-

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[58] GTM Research. "The U.S. Utility Demand Response Landscape: Programs, Case Studies and Economics." May 2017.

and low-carbon power sources," which can include solar.[59] The Clean Power Plan includes a Clean Energy Incentive Program (CEIP) designed to reward investment in renewable energy and demand-side energy efficiency, prior to the intended start of the Clean Power Plan. In 2016, 27 states petitioned the U.S. Court of Appeals for the District of Columbia Circuit for an emergency stay of the Clean Power Plan and the U.S. Supreme Court ordered the EPA to halt enforcement until the case was heard by the lower Court of Appeals. In March 2017 the President of the United States signed the Executive Order on Energy Independence (E.O. 13783), which calls for a review of the Clean Power Plan. In October 2017, the EPA Administrator signed a proposal to repeal to Clean Power Plan. The repeal process, if successful, may take several years.

State governments have collaborated to develop carbon trading schemes. The Regional Greenhouse Gas Initiative (RGGI), which includes 8 states in the Northeastern U.S., is a mandatory market based trading program designed to cap carbon emissions through the issuance of carbon allowances through quarterly actions. California has a similar cap and trade program that trades with the Western Climate Initiative in Canada.

3.10 Financing and cost of support measures

Financial incentives for U.S. solar projects are provided by the federal government, state and local governments, and some local utilities. Historically, federal incentives have been provided primarily through the U.S. tax code, in the form of an investment tax credit (ITC) and accelerated 5-year tax depreciation (which applies to all commercial and utility-scale installations and to third-party owned residential, government, or non-profit installations). For commercial installations, the present value to an investor of the combination of these two incentives—which can be used only by tax-paying entities—amounts to about 56 % of the installed cost of a solar project.[60]

Many solar project developers are not in a financial position to absorb tax incentives themselves (due to lack of sufficient taxable income to offset deductions and credits), and so they have had to rely on a small cadre of third-party "tax equity investors" who invest in tax-advantaged projects to shield the income they receive from their core business activities (e.g., banking). In doing so, tax-equity investors monetize the tax incentives that otherwise could not be efficiently used by project developers and other common owners of the renewable energy plants.

Federal benefits can be used in combination with state and local incentives, which come in many forms, including—but not limited to—up-front rebates, performance-based incentives, state tax credits, renewable energy certificate (REC) payments, property tax exemptions, and low-interest loans. Incentives at both the federal and state levels vary by sector and by whether or not the systems are utility scale or distributed.

In most cases, solar project developers combine several of these federal, state, and local incentives to make projects economically viable. Given the complexity of capturing some of these incentives—particularly in combination— solar financiers have adopted (and in some cases, modified) complex ownership structures previously used to invest in other tax-advantaged sectors in the United States, such as low-income housing, historical buildings, and commercial wind projects.

Ordinarily, utility-scale projects are owned by independent power producers (in conjunction with tax equity investors), who sell the power to utilities under a long-term PPA. However, a considerable amount of utility-scale PV installed in 2018 was owned by utilities, mostly in Florida

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[59] EPA. Fact Sheet: Clean Power Plan Framework. http://www2.epa.gov/carbon-pollution-standards/fact-sheet-clean-power-plan-framework, accessed May 23, 2016.

[60] DOE (U.S. Department of Energy). (2012). *SunShot Vision Study*. DOE/GO-102012-3037. Washington, DC: U.S. Department of Energy. http://www1.eere.energy.gov/solar/pdfs/47927.pdf.

and Virginia. This was caused by rule changes recently made in Florida and Virginia that improve the economics for owning solar by a regulated utility. Distributed PV systems are either self-financed, financed through a loan, or are third-party financed. Approximately 33% of U.S. residential systems installed in 2018 used third-party financing arrangements.[61] At least 28 states, the District of Columbia, and Puerto Rico allow for third party financing of solar systems such as PPAs or solar leases (7 states apparently disallow the process or have legal barriers).[62] Additionally, 36 states and the District of Columbia have enabled Property Assessed Clean Energy (PACE) programs which allow energy efficiency or renewable energy improvements to be financed through property taxes.[63]

[61] Mond, A. 2018. *U.S. Residential Solar Finance Update, H1 2018*. Boston: GTM Research.

[62] https://www.dsireusa.org/resources/detailed-summary-maps/

[63] https://pacenation.us/pace-programs/

4 INDUSTRY

4.1 Production of feedstocks, ingots and wafers (crystalline silicon industry)

Table 18: Silicon feedstock, ingot and wafer producer's production information for 2018.

Manufacturers	Process & technology	Total Production	Product destination	Price
SunEdison, REC Silicon, Hemlock	Silicon feedstock [Tonnes]	20 866	N/A	$14.5/kg
Nation	sc-Si ingots. [Tonnes]	0	0	N/A
Nation	mc-Si ingots [Tonnes]	0	0	N/A
Nation	sc-Si wafers [MW]	0	0	N/A
Nation	mc-Si wafers [MW]	0	0	N/A

U.S. based wafer producer 1366 Technologies has partnered with Hanwha Q Cells to build a Malaysian plant, producing 1366 Technologies direct wafer technology. The plant is scheduled to be operational in 2019.

4.2 Production of photovoltaic cells and modules (including TF and CPV)

Module manufacturing is defined as the industry where the process of the production of PV modules (the encapsulation) is done. A company may also be involved in the production of ingots, wafers or the processing of cells, in addition to fabricating the modules with frames, junction boxes etc. The manufacturing of modules may only be counted to a country if the encapsulation takes place in that country.

Total PV cell and module manufacture together with production capacity information is summarised in Table below.

Table 19: PV cell and module production and production capacity information for 2018.[64]

Cell/Module manufacturer	Technology	Total Production [MW]		Maximum production capacity [MW/yr]	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
Total National	c-Si	124	979	602	2 122
Thin film manufacturers					
Total National	CdTe		331		610
Total National	CIGS		84		210
Cells for concentration					

[64] Wood Mackenzie / SEIA. "U.S. Solar Market Insight: 2018 year-in-review." March 2019.

N/A					
Totals		**124**	**1 394**	**602**	**2 940**

Tables 18 and 19 summarize the production of PV products within the United States, however the two largest U.S. based PV module manufacturers (First Solar, SunPower) have a majority of their manufacturing operations located abroad. In 2018 First Solar produced 2,7 GW of PV modules and SunPower produced approximately 1,2 GW of PV modules.[65] In January 2018 the President of the United States placed a tariff[66] for a period of four years on imported cells and modules. The tariff is set at 30% in the first year, and will be reduced by five percent in each of the next three years. The first 2,5 GW of cells imported each year are excluded. Partially in response, in 2018 some U.S. solar manufacturers started to significantly increase their c-Si module assembly capacity, though the majority of the new facilities became operational in 2019. These facilities mostly rely on imported c-Si cells. In 2018, 85% of these cells came from South Korea, Malaysia, Japan, the Philippines, and Vietnam.[67]

[65] Data from corporate public filings from First Solar and SunPower.

[66] Tariffs resulted from a case brought by two U.S. based PV manufacturers to the U.S. International Trade Commission under Section 201, Trade Act of 1974, accusing foreign governments of implementing policies supporting their domestic manufacturing in violation of WTO rules and the GATT agreement.

[67] U.S. import value. https://dataweb.usitc.gov/

4.3 Manufacturers and suppliers of other components

Companies continue to produce some PV inverters in the U.S. The supporting structures (racking and mounting hardware) for U.S. systems are primarily domestically manufactured. Battery implementation represents a small but growing portion of the overall U.S. PV deployment market; companies offering integrated solar and battery packages continue to grow in the US, with many companies exploring partnerships or other mergers and acquisitions activity to offer solar plus storage packages. Additionally, micro-inverters and DC optimizers represent a growing portion of the U.S. market.

5 PV IN THE ECONOMY

This chapter aims to provide information on the benefits of PV for the economy.

5.1 Labour places

Table 20: Estimated PV-related full-time labour places in 2018[68]

Market category	Number of full-time labour places
Research and development (not including companies)	The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy, DOE's Office of Science and ARPA-E, the National Science Foundation, the Department of Defense, the National Aeronautics and Space Administration, and states such as California, New York, Florida and Hawaii.
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	33 726
Distributors of PV products	29 243
System and installation companies	155 157
Electricity utility businesses and government	NA
Other	24 217
Total	**242 343**

5.2 Business value

Table 21: Rough estimation of the value of the PV business in 2018 (VAT is excluded).

Sub-market	Capacity installed in 2018 [MW]	Average price [USD/W]	Value	Sub-market
Off-grid	*not available*	*not available*		
Grid-connected distributed	**2 386 (residential)** **2 099 (non-residential)**	**2,70 (residential)** **1,83 (non-residential)**	*BUSD 6,4* *BUSD 3,8*	*BUSD 10,3*

[68] Jobs numbers in table are from Solar Foundation. (2019). National Solar Jobs Census 2018. Washington, DC: The Solar Foundation

Grid-connected centralized	**6 196**	**1,06**	*BUSD 6,6*	*BUSD 6,6*
Value of PV business in 2018				***BUSD 16,9***

6 INTEREST FROM ELECTRICITY STAKEHOLDERS

6.1 Structure of the electricity system

The U.S. has a diverse deregulated utility landscape in which roughly 68% of consumers are served by an investor owned utility and the remaining customers are served by municipal utilities or cooperatives. Utilities are regulated at the local, state, and federal level by PUCs, ratepayer groups and federal agencies such as the Federal Energy Regulatory Commission (FERC) to ensure they provide fair and reliable service to their customers. Transmission is regulated by Independent System Operators (ISO) or Regional Transmission Organizations, depending on region.

6.2 Interest from electricity utility businesses

Electricity utility interest in solar continues to increase in the United States. As utility scale solar has become increasingly competitive with retail generation, four broad categories of utility solar business models have emerged in the United States: utility ownership of assets, utility financing of assets, development of customer programs, and utility purchase of solar output.[69]

Utility ownership of assets allows the utility to take advantage of the tax policy benefits and earn a rate of return on the asset (for investor-owned utilities), while providing control over planning, siting, operating, and maintaining the solar facilities. The variety of ownership explored in the United States is:

- Rate basing solar on non-residential customer sites
- Rate basing solar at substations and utility facilities
- Owning community solar equipment
- Owning inverters on customer sites
- Acquiring existing or new solar projects from developers in the present or future:
    - turnkey acquisition, or purchase and sale agreement
    - power purchase agreement with buy-out option
    - acquisition of sites for development
    - “flip” transactions that can take various forms

The issues related to utility ownership include:

- Some state restructuring rules that do not allow generation utilities to own distributed generation
- State or commission policy or guidelines that prohibit or specifically limit utility ownership to specific conditions
- Regulatory or stakeholder concern about the rate impacts, utilities’ costs relative to private market pricing and capabilities, ensuring that the utility operates in a fair and competitive environment, and related issues.

[69] The Smart Electric Power Alliance (formally the Solar Electric Power Association) has continued to define, research, and track utility solar business models since early 2008. These business models are differentiated from general market activity by the short- or long-term economic value (or future potential) they bring the utility and its ratepayers, relative to traditional market activity that often has negative utility value.

Utility Financing of Solar Assets is a solar business option for utilities that do not choose to own solar assets for tax, cost, regulatory, or competitive considerations. To be successful, regulators treat the financing and lost revenue costs associated with a solar project as assets, allowing the utility to earn a rate of return on "investment". Some of the options for this solar business model include:

- Rate basing solar loans and recovering lost revenues
- Supporting turnkey installations and rate basing shareholder loans
- Supporting a feed-in tariff (FIT) with solar revenue streams and rate based shareholder loans.

Development of Customer Programs refers to utility programs that are designed to increase access to solar energy by lowering costs, for both the utility and the customer, compared to a traditional customer-sited photovoltaic system. Community solar programs involve a community or centralized 0,1 MW to 20 MW PV system. Specific classes of participating customers can be allocated a proportional share of the output from the system to directly offset their electric consumption bill (remote net metering) or the customers are offered a fixed-rate tariff (that is competitive with retail rates or will be in the near future as electric prices increase).

Utility Purchase of Solar Output is a business model often applied by publicly owned utilities (POUs) to create value to their communities through local solar development. Some POUs have developed a FIT to purchase solar power. Solar power purchases through a FIT are often made available instead of net metering, thus mitigating revenue erosion while providing a clear contractual understanding for purchase that supports financial viability for solar developers.

6.3 Interest from municipalities and local governments

Electric cooperatives and municipal utilities accounted for 15% of solar capacity interconnected to the grid in 2018.[70] Deployment in these sectors is mostly driven by a few key states, with Hawaii and Texas accounting for 40% of solar capacity deployed by cooperatives, and Texas accounting for 50% of municipal solar interconnected to the grid in 2018. Within Texas, two municipal utilities accounted for over 68% of the total solar capacity added throughout the entire state. [71]

Being more flexible and responsive to customer demand provides municipal utilities and cooperatives a unique opportunity within the community solar market. Some of the first community solar projects in the nation were initiated by municipal utilities. Sacramento Municipal Utility District (SMUD) in California, for example, launched its SolarShares program in 2008 with a 1-MW installation.[72] In states without community solar enabling legislation, many cooperative and municipalities have started programs within their territories.

Community choice aggregation (CCA) has emerged as an alternative energy procurement strategy for municipalities/regions with state-enabling legislation. CCA allows local governments to aggregate electricity demand and procure electricity from alternative suppliers on behalf of residential and, in some cases, commercial customers. Local utilities remain responsible for transmission, distribution, and billing services. The “choice” component of the term CCA reflects a key feature of aggregation: CCAs can choose the electric resources that supply their community and may choose to offer more renewable energy than the incumbent utility. NREL

[70] SEPA:”2019 Utility Solar Market Snapshot.”

[71] Ibid.

[72] NREL. “Lessons Learned: Community Solar for Municipal Utilities” https://www.nrel.gov/docs/fy17osti/67442.pdf

estimates that in 2017 CCAs procured about 8.9 million MWh of voluntary green power in the U.S., representing about 21% of all CCA sales, on behalf of about 2.7 million customers.[73]

[73] Eric O'Shaughnessy, Jenny Heeter, Julien Gattaciecca, Jenny Sauer, Kelly Trumbull, and Emily Chen. "Community Choice Aggregation: Challenges, Opportunities, and Impacts on Renewable Energy Markets." NREL/TP-6A20-72195. https://www.nrel.gov/docs/fy19osti/72195.pdf.

7 HIGHLIGHTS AND PROSPECTS

7.1 Highlights

In 2018, the U.S. market installed approximately 10,7 GW of PV, flat from 2017.[74] Much of the recent growth came from utility-scale installations, though the distributed market has also increased in size. PV capacity continues to be concentrated in certain states, such with 20% of the states accounting for 78% of the market. However, this trend continues to change as 36 states currently have 100 MW or more of PV capacity and 20 states each have more than 500 MW.[75] The U.S. started to significantly increase its c-Si module assembly capacity in 2018, though the majority of the new facilities became operational in 2019. It also quadrupled its CdTe PV module capacity in 2018.

7.2 Prospects

Annual PV installations are expected to increase significantly in 2019, in part to qualify for the full 30% federal tax credit, which steps down to 26% in 2020. U.S. PV installation is projected to remain robust at least until 2024 when the tax credit fully sunsets to 10% for businesses.[76] Though some incentive programs in the U.S. have expired or been reduced, many projects currently under construction have already qualified to receive funding. In addition, due to the continued reduction in system pricing as well as the availability of new loan products and third-party ownership arrangement with lower financing costs, most PV in 2018 was installed outside of state RPS requirements. As more PV is installed in the U.S., a growing percentage of distributed and utility-scale systems are expected to co-locate with energy storage systems. Lawrence Berkeley Laboratory reported that PPAs with solar-plus-storage have been signed at a premium over PV-standalone projects of USD 5/kWh to USD 15/kWh, while offering significantly more value.[77] Additionally, Wood Mackenzie and SEIA estimated that solar-plus-storage will grow from 7% of the distributed PV market in 2019 to 24% by 2024.[78] Utility-scale and commercial PV systems are also expected to shift to using a large share of bifacial modules, which generate electricity from light reaching both sides of the PV panel. This shift can be attributed to the reduction in production costs, expansion of manufacturing, and an exemption for bifacial panels by the U.S. government from tariffs on imported PV modules. These tariffs have also contributed to the expansion of U.S. module assembly capacity, which grew to approximately 6 GW by the end of H1 2019, up from 2.5 GW in 2017. An additional 3 GW of manufacturing capacity has been announced for the near future.[79]

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[74] Wood Mackenzie Power and Renewables/SEIA: U.S. Solar Market Insight Q2 2019.

[75] Wood Mackenzie Power and Renewables/SEIA: U.S. Solar Market Insight Q2 2019.

[76] EIA, Annual Energy Outlook (February 2018). https://www.eia.gov/outlooks/aeo/pdf/AEO2018.pdf

[77] Bolinger, M. and J. Seel. 2018,*Utility-Scale Solar 2017: An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States*. Berkeley, CA: Lawrence Berkeley National Laboratory.

[78] Wood Mackenzie Power and Renewables/SEIA: U.S. Solar Market Insight Q2 2019.

[79] Feldman, D.; R. Margolis. 2019. “Q4 2018/Q1 2019 Solar Industry Update.” https://www.nrel.gov/docs/fy19osti/73992.pdf