IEA INTERNATIONAL ENERGY AGENCY

National Survey Report of Photovoltaic Applications in United States of America 2017

PVPS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

Prepared by

Christopher Anderson, David Feldman, and Lenny Tinker

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Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its member countries.

The IEA Photovoltaic Power Systems Technology Collaboration Programme (IEA-PVPS) is one of the collaborative R & D agreements established within the IEA and, since 1993, its participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The participating countries and organisations can be found on the www.iea-pvps.org website.

The overall programme is headed by an Executive Committee composed of one representative from each participating country or organization, while the management of individual Tasks (research projects / activity areas) is the responsibility of Operating Agents. Information about the active and completed tasks can be found on the IEA-PVPS website www.iea-pvps.org.

Introduction

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 2017. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

The PVPS website www.iea-pvps.org also plays an important role in disseminating information arising from the programme, including national information.

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 2017 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2017, 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 10 681 MW_{DC} of new grid-connected PV capacity added in 2017, bringing its cumulative total to approximately 51 638 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 2017, there were more than 1,6 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 6 231 MW_{DC} in 2017, second only to 2016 installations which were 10 807 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 2017, U.S. community solar projects had a cumulative capacity of 856 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-alone inverters to power alternating current (AC) loads and may include a diesel generator as backup.

[1] "U.S. Solar Market Insight Report: Q2 2018." GTM Research/SEIA. June 2018.

[2] Ibid.

[3] Ibid.

[4] Ibid.

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 Green Tech Media Research (GTM Research).[6] These organizations survey nearly 200 installers manufacturers, utilities and state agencies to obtain granular installation data on installations in every state.

Table 1: PV power installed during calendar year 2017[7]

AC			**MW installed in 2017**	**MW installed in 2017**	**AC or DC**
Grid-connected	BAPV	Residential	4 450	2 248	DC
		Commercial			DC
		Industrial			DC
	BIPV (if a specific legislation exists)	Residential	N/A		
		Commercial			
		Industrial			
	Utility-scale	Ground-mounted	6 231	6 231	DC
		Floating			
		Agricultural			
Off-grid		Residential (SHS)	Not available		
		Other			
		Hybrid systems			
		Total	10 681		DC

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

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

[7] "U.S. Solar Market Insight Report: Q2 2018." GTM Research/SEIA. June 2018.

Table 2: 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 3: PV power and the broader national energy market.

MW-GW for capacities and GWh-TWh for energy	2017 numbers	2016 numbers
Total power generation capacities (all technologies)	1 101[8] GW_{AC}	1 093 GW_{AC}
Total power generation capacities (renewables including hydropower)	229,7 GW_{AC}	213 GW_{AC}
Total electricity demand (= consumption)	4 014 804 GWh	4 098 137 GWh
Total energy demand (= final consumption)		
New power generation capacities installed during the year (all technologies)	25,6[9] GW_{AC}	32,0 GW_{AC}
New power generation capacities installed during the year (renewables including hydropower)	14,6 GW_{AC}	20,1 GW_{AC}
Total PV electricity production in GWh-TWh	73 828 GWh	51 483 GWh
Total PV electricity production as a % of total electricity consumption	1,8%	1,3%

Table 4: Other information

	2017 Numbers
Number of PV systems in operation in your country (a split per market segment is interesting)	Residential: 1 584 524 Non-Residential: 75 280 Utility: 2 227

[8] EIA Electric Power Monthly, March 2018
https://www.eia.gov/electricity/monthly/archive/march2018.pdf

[9] : EIA "Preliminary Monthly Electric Generator Inventory" (December 2017). EIA, "Electric Power Monthly" Table 6.1; 2018

Capacity of decommissioned PV systems during the year in MW	0[10]
Total capacity connected to the low voltage distribution grid in MW	20 595 (includes all distributed PV) [11]
Total capacity connected to the medium voltage distribution grid in MW	Not available
Total capacity connected to the high voltage transmission grid in MW	Not available

Table 5: The cumulative installed PV power in 4 sub-markets (MWp).

Year	Off-grid (including large hybrids)	Grid-connected distributed (BAPV, BIPV)	Grid-connected centralized (Ground, floating, agricultural…)	Other uses (VIPV, wearables…)	Total
2004	NA	94	17	NA	111
2005	NA	172	18	NA	190
2006	NA	277	18	NA	295
2007	NA	428	27	NA	455
2008	NA	710	43	NA	753
2009	NA	1 087	101	NA	1 188
2010	NA	1 649	368	NA	2 017
2011	NA	2 784	1 153	NA	3 937
2012	NA	4 174	2 956	NA	7 130
2013	NA	6 262	5 814	NA	12 076
2014	NA	8 585	9 736	NA	18 321
2015	NA	11 817	14 004	NA	25 821
2016	NA	16 145	24 811	NA	40 956
2017	NA	20 596	31 042[12]	NA	51 638

[10] United States Energy Information Administration, "Electric Power Monthly: Table 6.1. Electric Generating Summer Capacity Changes (MW), November 2017 to December 2017."

[11] GTM USSMI Q2 2018

[12] Ibid.

1.3 Key enablers of PV development

Table 6: information on key enablers

	Description	Annual Volume (Units)	Total Volume (Units)	Source
Decentralized storage systems	85 MW of total distributed batteries (approximately 69 MW installed in 2017)	Approximately 2 165 in 2017	2 309 total net-metered storage customer	https://www.eia.gov/electricity/data/eia861m/
Residential Heat Pumps		NA	NA	
Electric cars (and light weight)	Units	199 826	1 000 000 (estimate)	https://insideevs.com/december-2017-plugin-electric-vehicle-sales-report-card/
Electric buses/trucks	Units		300	https://www.reuters.com/article/us-transportation-buses-electric-analysi/u-s-transit-agencies-cautious-on-electric-buses-despite-bold-forecasts-idUSKBN1E60GS
Other Centralized batteries	708 MW total (145 MW in 2017)			EIA “Preliminary Monthly Electric Generator Inventory” (December 2017)

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Table 7: Typical module prices for a number of years

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Standard module crystalline silicon price(s): Typical[13]	3,25	2,18	1,48	1,37	0,75	0,81	0,71	0,72	0,53	0,49
Lowest prices[14]	NA	NA	NA	0,35	0,45	0,40	0,53	0,50	0,37	0,28
Highest prices[15]	NA	NA	NA	2,30	1,44	1,97	1,10	1,00	1,00	0,72

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[16], the trend is clearly downward in all sectors and utility scale prices are beginning to drop below 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 8: **Turnkey Prices of Typical Applications – local currency**

Category/Size	Typical applications and brief details	Current prices per W
OFF-GRID Up to 1 kW (SHS)	N/A	
OFF-GRID > MW scale	N/A	
Grid-connected Rooftop up to 5-10 kW (residential BAPV) [17]	Modeled 5-10 kW system with standard crystalline silicon modules, blended string, microinverter and DC optimizer (Q3 2017)	2,88

[13] Mints, Paula. "Photovoltaic Manufacturer Capacity, Shipments, Price & Revenues 2017/2018." SPV Market Research. April 2017.

[14] Bloomberg New Energy Finance. Solar Spot Price Index. Accessed July 12, 2018.

[15] Ibid.

[16] 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.

[17] GTM Research SEIA, Q4 2017: U.S. Solar Market Insight. December 2017.

Grid-connected Rooftop 300 kW (commercial BAPV) [18]	Modeled 300 kW flat roof system with standard modules, ballasted mounting, and string inverters (Q3 2017)	1,55
Grid-connected Ground-mounted above 10 MW[19]	Modeled 10 MW, standard multicrystalline silicon modules, 1.3 DC-to-AC ratio, steel-based fixed-tilt with pile-driven foundations.	0,98
Other category (hybrid diesel-PV, hybrid with battery…)	NA	
Floating PV	NA	
Agricultural PV	NA	
Residential BIPV (tiles, or complete roof).	NA	
Industrial BIPV	NA	

Table 9: National trends in system prices (current) for different applications – 2017 USD

Price/Wp	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	H1 2017
Residential PV systems < 5-10 KW	9,42	9,01	8,56	7,24	6,45	5,45	4,76	4,33	4,12	4,06	3,76
Non-Residential ≤500 kW	9,23	8,84	8,58	6,94	5,90	5,14	4,27	3,82	3,55	3,44	3,01
Non-Residential >500 kW	7,33	7,72	7,42	5,86	4,91	4,49	3,48	2,76	2,52	2,32	2,17
Ground-mounted > 10 MW				4,39	3,65	3,29	2,86	2,43	2,12	1,71	NA

Source: Data from Lawrence Berkeley National Laboratory.[20] Pricing for "residential" and "non-residential" represent the median reported price for behind-the-meter systems for their given size and market segments. Pricing for "ground-mounted" represents the median price of systems 5 MW or greater. Prices in 2017 only include a subset of systems installed in the first half of 2017.

2.3 Cost breakdown of PV installations

Data provided by GTM Research, the Solar Energy Industries Association (SEIA), and Green Tech Media Research (GTM Research). These companies use 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.

[18] Id.

[19] GTM Research SEIA, Q4 2017: U.S. Solar Market Insight. December 2017.

[20] 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. Bolinger, Mark, Joachim Seel, and Kristina Hamachi LaCommare. 2017. "Utility-Scale Solar 2016: An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States." Berkeley, CA: Lawrence Berkeley National Laboratory.

2.3.1 Residential PV System < 5-10 kW

Table 10: Cost breakdown for a residential PV system – local currency

Cost category	Average (local currency/W)[21]	Low (local currency/W)	High (local currency/W)
Hardware			
Module	0,39	NA	NA
Inverter	0,22	NA	NA
Other (racking, wiring…)	0,31	NA	NA
Soft costs			
Installation	0,21	NA	NA
Customer Acquisition	NA	NA	NA
Profit	NA	NA	NA
Other (permitting, contracting, financing…)	NA	NA	NA
Subtotal Hardware	0,92	NA	NA
Subtotal Soft costs	1,96[22]	NA	NA
Total	2,88	NA	NA

2.3.2 Utility-scale PV systems > 10 MW

Table 11: Cost breakdown for a utility-scale PV system – local currency

Cost Category	Average (local currency/W)	Low (local currency/W)	High (local currency/W)
Hardware			
Module	0,39	NA	NA
Inverter	0,09	NA	NA
Other (racking, wiring, etc.)	0,13	NA	NA
Soft cost	NA	NA	NA
Installation Labor	0,11	NA	NA
Customer acquisition	NA	NA	NA
Profit	NA	NA	NA
Other (contracting, permitting, financing etc.)	NA	NA	NA
Subtotal Hardware	0,61	NA	NA
Subtotal - Soft cost	0,37	NA	NA
Total Installed Cost	0,98	NA	NA

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

[21] Id.

[22] Includes direct labor, engineering, permitting, interconnection, inspection, supply chain, overhead, and margin.

think they may not stay in the property long enough for the resulting savings to cover the upfront costs.[23]

Table 12: PV financing scheme

Average rate of loans – residential installations	Weighted average cost of capital for a portfolio of rooftop installations: 6.2-12.7%[24]
Average rate of loans – commercial installations	Weighted average cost of capital for a portfolio of rooftop installations: 6.2-12.7%[25]
Average cost of capital – industrial and ground-mounted installations	Weighted average cost of capital for a portfolio of rooftop installations: 5.6-9.6%[26]

2.5 Specific investments programs

Table 13: Specific investment programs

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 2017, third party owned systems accounted for 41% of residential installations. However, TPO is declining in many markets due to a combination of declining system costs, and new loan products entering the market.[27]
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.[28]

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

[24] Feldman, D; Schwabe, P. (2017). "PV Project Finance in the United States, 2016." National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy16osti/66991.pdf

[25] Ibid

[26] Ibid

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

[28] 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.

Investment in PV plants against free electricity	
Crowdfunding (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.[29]
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.[30] In 2017, 67% of community solar programs were administered by third-party organizations, while the remainder were administered directly by utilities.[31]
Other (please specify) 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 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.[32]

2.6 Additional Country information

Table 14: Country information

[29] 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.

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

[31] Smart Electric Power Alliance (SEPA). "Community Solar Program Design Models."

[32] Schwabe, P.; D. Feldman; J. Fields; E. Settle. 2016. "Wind Energy Finance in the United States: Current Practice and Opportunities." NREL/TP-6A20-68227.

Retail Electricity Prices for an household (range)	Average: 0,13 USD. Range 0,10 USD (Louisiana) – 0,39 USD (Hawaii) / KWh[33]
Retail Electricity Prices for a commercial company (range)	Average: 0,11 USD. Range 0,08 USD (Oklahoma) –0,27 USD (Hawaii) / KWh[34]
Retail Electricity Prices for an industrial company (range)	Average: 0,07 USD. Range 0,05 USD (Washington) – 0,23 USD (Hawaii) / KWh[35]
Population at the end of 2017 (or latest known)	326 965 105 [36]
Country size (km^2)	9 833 517[37]
Average PV yield (according to the current PV development in the country) in kWh/kWp	Typical solar radiation in the United States ranges from 3 kWh/m^2/day to 7 kWh/m^2/day[38]
Name and market share (by customer) of major electric utilities.	Southern California Edison (3,6%), Pacific Gas and Electric (3,6%), Florida Power and Light (3,5%), Consolidated Edison (1,8%), Georgia Power (1,8%)[39]

3 POLICY FRAMEWORK

This chapter describes the support policies aiming directly or indirectly to drive the development of PV. Direct support policies have a 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.

3.1 Direct support policies for PV installations

3.1.1 New, existing or phased out measures in 2017

3.1.1.1 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,

[33] Data, as of 2016, from EIA, forms EIA-861- schedules 4A-D, EIA-861S and EIA-861U. http://www.eia.gov/electricity/data/browser, accessed July 13, 2018.
[34] Ibid.
[35] Ibid.

[36] Annual Estimates of the Resident Population for the United States, States, Counties, and Puerto Rico Commonwealth and Municipals: as of December 31, 2017. Source: U.S. Census Bureau, Population Division. Release Date: June 2017. Census.gov, accessed July 13, 2018.

[37] 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.

[38] Data from the National Renewable Energy Laboratory, PVWatts – version 1. http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/, accessed July 10, 2014.

[39] Data, as of 2016, from EIA, forms EIA-861. http://www.eia.gov/electricity/data/browser, accessed July 13, 2018.

North Carolina, Oregon, Puerto Rico, Rhode Island, Vermont, Virginia, and Washington. These states collectively account for 45,4% of U.S. GDP.[40]

3.1.1.2 Description of support measures (excluding BIPV, VIPV and rural electrification)

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.[41] 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.

3.1.1.3 BIPV development measures

The voluntary Leadership for Energy and Environmental Design (LEED) certification program produces criteria and guidelines for incorporating energy efficient practices and renewable energy systems into buildings. To date over 44,000 buildings have been LEED certified in the U.S. Numerous state and local governments provide incentives for builders that achieve LEED status.[42]

3.1.1.4 Utility-scale measures including floating and agricultural PV

NA

3.1.1.5 Rural electrification measures

Nearly 99 % of Americans have access to electricity.[43] 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.

3.1.1.6 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 target (1.3 GW by 2025) and New York (1.5 GW by 2025). Separately, in 2015 demand response consisted of nearly 4% of U.S. total demand. Nearly 60% of the total demand response came from 25 utilities in 17 states.[44]

3.1.1.7 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

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

[41] 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 July 13, 2018.

[42] LEED http://programs.dsireusa.org/system/program?type=10&

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

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

Revenue Service (IRS) tax credit is for $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.

Table 15: PV support measures (summary table)

	On-going measures residential	Measures that commenced during 2017 - residential	On-going measures Commercial + industrial	Measures that commenced during 2017 – commercial + industrial	On-going measures Ground-mounted, including floating	Measures that commenced during 2017 – ground mounted, including floating
Feed-in tariffs	6 states currently have FiT programs.	NA	7 states currently have FiT programs.		NA	NA
Feed-in premium (above market price)	Performance based incentive programs for PV systems in the residential sector exist in 20 states.	NA	Performance based incentive programs for PV systems in the non-residential sector exist in 23 states.	NA	Oregon projects with a capacity between 2 and 10 MW are eligible for a $0.005 per kWh incentive	NA
Capital subsidies	Grant programs for PV systems in the residential sector exist in 7 states.	NA	Grant programs for PV systems in the non-residential sector exist in 18 states.	NA	NA	NA
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.	Massachusetts released its final program design for the solar incentive that will succeed the SREC program; a 1.6 GW declining block program.	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.	Massachusetts released its final program design for the solar incentive that will succeed the SREC program; a 1.6 GW declining block program.	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.	Massachusetts released its final program design for the solar incentive that will succeed the SREC program; a 1.6 GW declining block program. Max system size 5 MW.
Renewable portfolio	29 states plus the	NA	29 states plus the	NA	29 states plus the	NA

standards (RPS) with/without PV requirements	District of Columbia, Guam, Puerto Rico, and Virgin Islands, have an RPS.		District of Columbia, Guam, Puerto Rico, and Virgin Islands, have an RPS.		District of Columbia, Guam, Puerto Rico, and Virgin Islands, have an RPS.	
201 Income tax credits	Federal: federal investment tax credit of 30 % for residential, commercial, and utility systems. State: 13 states offer personal tax credits for solar projects.	NA	Federal: federal investment tax credit of 30 % for residential, commercial, and utility systems. State: 13 states offer corporate tax credits for solar projects.	NA	Federal: federal investment tax credit of 30 % for residential, commercial, and utility systems. State: 13 states offer corporate tax credits for solar projects.	NA
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 more sizeable portion of their load.		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.		N/A	N/A
Net-metering	38 states plus the District of Columbia and Puerto Rico have net metering policies.	5 states adopted net metering successors to traditional net metering, and another two states approved	38 states plus the District of Columbia and Puerto Rico have net metering policies.	5 states adopted net metering successors to traditional net metering, and another two states approved	NA	NA

		major changes to their successor programs.[45]		major changes to their successor programs.[46]		
Net-billing	5 states have moved from net metering to net-billing.	In 2017, Jacksonville Electric Authority, Indiana, New York, and Utah approved transitions from net metering to net billing.	5 states have moved from net metering to net-billing.	In 2017, Jacksonville Electric Authority, Indiana, New York, and Utah approved transitions from net metering to net billing.		
Collective self-consumption and virtual net-metering	17 States have virtual net metering or community solar policies.	NA	17 States have virtual net metering or community solar policies.	NA	NA	NA
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.	NA	Green banks have been created in California, Connecticut, Hawaii, Maryland, Massachusetts, Nevada, New York, Pennsylvania, and Vermont.	NA	Green banks have been created in California, Connecticut, Hawaii, Maryland, Massachusetts, Nevada, New York, Pennsylvania, and Vermont.	NA
Activities of electricity utility businesses	Several electricity utilities have begun engaging with PV development, either through direct ownership of centralized and distributed	In 2017, North Carolina passed a bill allowing investor-owned utilities to lease PV systems to their customers.	Several electricity utilities have begun engaging with PV development, either through direct ownership of centralized and distributed	In 2017, North Carolina passed a bill allowing investor-owned utilities to lease PV systems to their customers.	Several electricity utilities have begun engaging with PV development, either through direct ownership of centralized and distributed	*NA*

[45] North Carolina Clean Energy Technology Center & Meister Consultants Group, *The 50 States of Solar: 2017 Annual Review and Q4 Quarterly Report*, January 2018.

[46] Ibid.

	PV assets, community solar programs, partial ownership in PV development companies, or joint marketing agreements.		PV assets, community solar programs, partial ownership in PV development companies, or joint marketing agreements.		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.	NA	Federal: No federal codes exist, but DOE produces best-practices guides for sustainable building for both residential and commercial buildings.	NA	NA	NA
BIPV incentives	NA	NA	NA	NA	NA	NA

3.2 Self-consumption measures

Table 16: Self-Consumption Schemes -

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	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 TOU rates in others
	5	Maximum timeframe for compensation of fluxes	Varies by state
	6	Geographical compensation	On-site; at least 15 states have community solar or

			virtual net metering policies[47]
Other characteristics	7	Regulatory scheme duration	Unlimited
	8	Third party ownership accepted	Yes, at least 26 states + Washington DC and Puerto Rico
	9	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	Some states have implemented minimum bills for NEM customers
	10	Regulations on enablers of self-consumption (storage, DSM…)	ToU Tariffs in some states
	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 Collective self-consumption, community solar and similar measures

At the end of Q1 2018, eighteen states and the District of Columbia had community solar enabling policies.[48] Community solar is also available in states without distinct policies, but often require utility participation.

3.4 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.

3.5 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

[47] North Carolina Clean Energy Technology Center & Meister Consultants Group, *The 50 States of Solar: 2016 Annual Review and Q4 Quarterly Report*, January 2017.

[48] North Carolina Clean Energy Technology Center & Meister Consultants Group, *The 50 States of Solar: Q1 2018 Quarterly Report*, April 2018.

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.[49]

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. Distributed PV systems are either self-financed, financed through a loan, or are third-party financed. Approximately 41% of U.S. residential systems installed in 2017 used third-party financing arrangements.[50] At least 26 states, the District of Columbia, and Puerto Rico allow for third party financing of solar systems such as PPAs or solar leases (9 states apparently disallow the process or have legal barriers). Additionally, 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.

3.6 Indirect policy issues

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- and low-carbon power sources," which can include solar.[51] 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.

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[49] 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.

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

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

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.

4 INDUSTRY

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

Table 17: Production information for the year for silicon feedstock, ingot and wafer producers

Manufacturers (or total national production)	Process & technology	Total Production	Product destination (if known)	Price (if known)
SunEdison, REC Silicon, Hemlock	Polysilicon feedstock	29 777 tonnes	N/A	N/A
SunEdison / 1366 Technologies	Wafers	0 MW	N/A	N/A

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 18, below.

Table 18: Production and production capacity information for 2017

Cell/Module manufacturer (or total national production)	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MW)		Maximum production capacity (MW/yr)	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
Total		*263*	*679*	*906*	*1 444*
Thin film manufacturers					
Total		NA	*291*	NA	*508*
Cells for concentration					
		NA	*NA*	NA	*NA*
TOTALS		**263**	**970**	**906**	**1 952**

Tables 17 and 18 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 2017 First Solar produced 2,3 GW of PV modules and SunPower produced approximately 1,2 GW of PV modules.[52]

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

4.3 Manufacturers and suppliers of other components

U.S. companies shipped approximately 3,1 GW_{AC} of PV inverters in 2017; approximately one-third of all U.S. systems installed during that time period.[53] The supporting structures of 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.

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

5 PV IN THE ECONOMY

Table 19: Estimated PV-related labour places in 2017[54]

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.
Manufacturers of products throughout the PV value chain from feedstock to systems, including company R&D	36 885
Distributors of PV products	30 912
System and installation companies	165 174
Electricity utility businesses and government	NA
Other	17 300
Total	250 271

5.1 Business value –

Table 20: Value of PV business

Sub-market	**Capacity installed *in 2017* (MW)**	**Price per W** *(from table 7)*	**Value**	**Totals**
Off-grid domestic	*not available*	*not available*		
Off-grid non-domestic	*not available*	*not available*	*not available*	
Grid-connected distributed	**2 248 (residential)** **2 202 (non-residential)**	**2,88 (residential)** **1,55 (non-residential)**	*BUSD 6,5* *BUSD 3,4*	*BUSD 9,9*
Grid-connected centralized	**6 231**	**0,98**	*BUSD 6,1*	*BUSD 6,1*
				BUSD 16,0
Export of PV products				*NA*
Change in stocks held				*NA*
Import of PV products				*NA*
Value of PV business				***BUSD 16,0***

[54] Jobs numbers in table are from Solar Foundation. (2018). National Solar Jobs Census 2017. Washington, DC: The Solar Foundation.

U.S. PV wafer, cell, and module manufacturing has experienced periods of growth and contraction over the past 15 years. In 2017, there was virtually no wafer production in the U.S. and the two largest c-Si cell manufacturers filed for bankruptcy.

On May 17, 2017, based on a petition from Suniva and later joined by SolarWorld, the United States International Trade Commission (ITC) instituted an investigation under Section 201 of the Trade Act of 1974 to determine whether increased imports of silicon solar cells and modules were a substantial cause of serious injury to the United States domestic industry. The ITC determined that increased silicon solar cell and module imports are a substantial cause of serious injury to the domestic industry. Although the Commissioners did not agree on a single remedy to recommend, most of them favored an increase in duties with a carve-out for a specified quantity of imported cells. Following the investigation and recommendations of the ITC, an interagency team led by USTR sought via Federal Register Notices on October 25, 2017 and November 14, 2017 the views of all participants in the solar industry and conducted a public hearing on December 6, 2017.[55]

U.S. manufacturing also has a significant presence in other part of the PV value chain, including polysilicon, encapsulants, wiring, and fasteners. Thus, between 2010 and 2017 the number of U.S. solar manufacturing jobs has increased by 48%, from 24 916 to 36 885.[56] Furthermore, manufactured hardware is only a portion of the total solar value chain. Industry-wide, approximately 156 800 jobs relating to solar were added from 2010 to 2017, growing from 93 500 to 250 000 employees.[57]

6 INTEREST FROM ELECTRICITY STAKEHOLDERS

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.

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.[58]

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

[55] https://ustr.gov/sites/default/files/files/Press/fs/201 Cases Fact Sheet.pdf

[56] Solar Foundation. (2018). National Solar Jobs Census 2017. Washington, DC: The Solar Foundation.

[57] Ibid.

[58] 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.

- 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.

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.

7 HIGHLIGHTS AND PROSPECTS

In 2017, the U.S. market installed approximately 10,7 GW of PV, compared to 15,1 GW in 2016 – the second largest year ever.[59] 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 a small number of states, such as California, North Carolina, Arizona, Nevada, and New Jersey, which comprise roughly two-thirds of the market. However, this trend is changing slowly as 32 states currently have 100 MW or more of PV capacity and 43 states each have more than 15 MW of capacity.[60] While annual installations are expected to remain flat in 2018, installations are expected to remain robust for the next 5 years due in part to the 30% federal investment tax credit.[61] 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 2017 was installed outside of state RPS requirements.

[59] EIA, Electric Power Monthly (February 2017).

[60] "U.S. Solar Market Insight Report: Q2 2018." GTM Research/SEIA. March 2018.

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