Technology Collaboration Programme
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International Energy Agency
Photovoltaic Power Systems Programme

Task 1 Strategic PV Analysis and Outreach

PVPS

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

2023

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

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 Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6.000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's 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.

The IEA PVPS participating countries are Australia, Austria, Belgium, Canada, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkiye, and the United States of America. The European Commission, Solar Power Europe, the Solar Energy Research Institute of Singapore and Enercity SA 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 2023. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

Authors

- **Main Content:** Krysta A. Dummit, U.S. Department of Energy; David Feldman, National Renewable Energy Laboratory; Shayna Grossman, ORISE Science and Technology Policy Fellow at the U.S. Department of Energy
- **Data:** U.S. Energy Information Administration, Wood Mackenzie, Solar Energy Industries Association
- **Analysis:** Krysta A. Dummit, U.S. Department of Energy; David Feldman, National Renewable Energy Laboratory; Shayna Grossman, ORISE Science and Technology Policy Fellow at the U.S. Department of Energy

COVER PICTURE

Stacie Peterson, AgriSolar Clearinghouse, sheep grazing under solar panels with pollinators, as submitted to the American-Made Solar Photo Competition: Hit Me with Your Sun Shot

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

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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 2023 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2023, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

The United States' (U.S.) PV market experienced a record year in 2023, with new grid-connected PV installations added at approximately 26,3 GW_{ac} representing a sharp increase in deployment in comparison with 2022.[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, decentralized grid-connected PV systems are defined as residential, commercial, and industrial applications, while centralized grid-connected PV systems are defined as utility applications. Floating PV, agricultural PV, and various forms of building-integrated PV (BIPV) are included in the U.S. PV market, however they do not yet represent significant enough market share to be tabulated separately.

Decentralized PV systems can be mounted on the ground near the facility, on the building roof, or integrated into the building roof, walls, or windows. Most decentralized grid-connected PV systems are building-applied PV (BAPV). Decentralized 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 system. By the end of 2023, there were more than 4,7 million decentralized 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 18,4 GW_{ac} in 2023, a 63% increase over 2022 levels and 34% increase relative to 2021 levels.[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 have grown rapidly in parts the United States, due in part to local and state incentives or mandates. In 2023, the United States installed 1,04 GW_{ac} of community solar projects, bringing cumulative capacity to 7,2 GW_{ac}.[4] The ownership structures of community solar projects can vary widely, and have been implemented by utilities, developers, and other organizations.

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[1] U.S. Energy Information Administration, Electric Power Monthly, Table 6.1, March 2024.

[2] National Renewable Energy Laboratory. Spring 2024 Quarterly Solar Industry Update. May 2024.

[3] Id.

[4] National Renewable Energy Laboratory, Sharing the Sun Community Solar Project Data (December 2023), April 2024.

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. Most systems are rated at less than 1 kW_{dc}, 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. Off-grid non-domestic PV systems are used in commercial, industrial, agricultural, and government activities. Telecommunications are often powered by PV, as well as data communication for weather and storm warnings, security phones on highways, and traffic signals. Off-grid PV capacity is not regularly tracked by official sources in the United States.

1.2 Total photovoltaic power installed

Deployment statistics are collected by the United States Energy Information Administration.[5] This agency surveys 500 of the largest electric utilities, 3300 electric power industry participants, and every electricity generating unit in the U.S. over 1 MW_{ac} to obtain granular installation data on installations in every state. Capacity of solar PV resources is collected directly from respondents through several survey forms. To disaggregate the different types of PV capacity (utility-scale, residential, and commercial and industrial), EIA collects net metering capacity data broken out by customer class from reporting utilities and uses this data in conjunction with several other types of data (including a list of all generating units over 1 MW) and mathematical modeling techniques.

Table 1: Annual PV power installed during calendar year 2023[6]

		Installed PV capacity in 2023 [MW]	AC or DC
	Decentralized	7 876	AC
	Centralized	18 443	AC
	Off-grid	Not Available	AC
	Total	26 319	AC

Table 2: PV power installed during calendar year 2023[7]

			Installed PV capacity [MW]	Installed PV capacity [MW]	AC or DC
Grid-connected	BAPV	Residential	7 876	6 556	AC
		Commercial		1 073	AC

[5] U.S. Energy Information Administration, Electric Power Monthly, Appendix C, March 2024.

[6] U.S. Energy Information Administration, Electric Power Monthly, Table 6.1A, March 2024.

[7] U.S. Energy Information Administration, Electric Power Monthly, Tables 6.1A and 6.1B, March 2024

		Industrial		247	AC
	BIPV	Residential	Not Available		
		Commercial			
		Industrial			
	Utility-scale	Ground-mounted	18 443		
		Floating			
		Agricultural			
Off-grid		Residential	Not Available		
		Other			
		Hybrid systems			
Total			26 319		AC

Table 3: Data collection process

If data are reported in AC, please mention a conversion coefficient to estimate DC installations.	0.8256 is the statement conversion factor from DC to AC from reporting source for decentralized systems[8] and centralized system conversion factor is computed from reported AC and DC capacities of operating units > 1 MW in size. In 2023 that ratio was 1.32.[9]
Is the collection process done by an official body or a private company/Association?	The bulk of the data collection is done by an official government body, the U.S. Energy Information Administration (EIA), which is an independent body under the U.S Department of Energy (DOE).
Link to official statistics (if this exists)	https://www.eia.gov/electricity/
	EIA monthly data for 2023 are not final.

[8] U.S. Energy Information Administration. Annual Electric Power Industry Report, Form-861, June 2024.

[9] U.S. Energy Information Administration, Form 860, Early release 2023 data. June 2024.

Table 4: The cumulative installed PV power in 4 sub-markets[10]

Year	Off-grid [MW]	Grid-connected distributed [MW]	Grid-connected centralized [MW]	Total [MW]
2010	Not Available	Not Available	393	Not Available
2011	Not Available	Not Available	1 052	Not Available
2012	Not Available	Not Available	2 694	Not Available
2013	Not Available	Not Available	5 336	Not Available
2014	Not Available	7 327	8 657	15 983
2015	Not Available	9 779	11 905	21 684
2016	Not Available	12 765	20 193	32 958
2017	Not Available	16 148	25 209	41 357
2018	Not Available	19 547	30 121	49 668
2019	Not Available	23 214	35 710	58 924
2020	Not Available	27 585	46 306	73 891
2021	Not Available	33 081	60 070	93 151
2022	Not Available	39 828	71 386	111 214
2023	Not Available	47 704	89 829	137 533

[10] U.S. Energy Information Administration, Electric Power Monthly, Table 6.1A, March 2024.

Table 5: Other PV market information[11]

	2023
Number of PV systems in operation in your country	4 789 554: (Residential: 4 642 957, Industrial: 140 400, Utility-scale: 6 197)
Decommissioned PV systems during the year [MW]	Not Available
Repowered PV systems during the year [MW]	Not Available

Table 6: PV power and the broader national energy market

	Data	Year
Total power generation capacities [GW]	1 237 GW_{ac}[12]	2023
Total renewable power generation capacities (including hydropower) [GW]	381 GW_{ac}[13]	2023
Total electricity demand [TWh]	4 252 TWh[14]	2023
New power generation capacities installed [GW]	46,2 GW_{ac} (including 6,4 GW_{ac} of grid-scale battery storage)[15]	2023
New renewable power generation capacities (including hydropower) [GW]	381,4 GW_{ac}[16]	2023
Estimated total PV electricity production (including self-consumed PV electricity) in [TWh]	235,3 TWh[17]	2023

[11] U.S. Energy Information Administration, Preliminary Monthly Electric Generator Inventory (860M), March 2024. and U.S. Energy Information Administration. Annual Electric Power Industry Report, Form-861, June 2024.

[12] U.S. Energy Information Administration, Electric Power Monthly, Table 6.1, February 2024.

[13] Id.

[14] U.S. Energy Information Administration, Electricity Data Browser, net generation for all sectors, annual, accessed April 2024.

[15] U.S. Energy Information Administration, Electric Power Monthly, Table 6.1, March 2024.

[16] Id.

[17] U.S. Energy Information Administration, Electricity Data Browser, net generation for all sectors, annual, accessed April 2024.

Total PV electricity production as a % of total electricity consumption	5,5%[18]	2023
Average yield of PV installations [kWh/kWac]	1920 kWh/kWac [19]	2023

1.3 Key enablers of PV development

Key demand drivers for PV development within the United States include energy storage, which surpassed 7,2 GW_{ac} of annual installations in 2023,[20] as well as electric vehicle demand, which increased by nearly 1.5 million vehicles in 2023.[21] Demand for energy efficient appliances has also increased within the United States, bolstered by President Biden's invocation of the Defense Production Act for clean energy technologies including heat pumps.[22] The Infrastructure Investment and Jobs Act (IIJA), which was signed into law in November of 2021, also provided billions in incentives for the construction of a national electric vehicle charging infrastructure, as well as funds for the purchasing of clean school buses and ferries.[23] Other demand drivers include high and increasing costs of retail electricity, customer desire for increased resilience (including backup power), and PV on new home construction.

Table 7: Information on key enablers.

	Description	Annual Volume	Total Volume	Source
Decentralized storage systems In MW	Behind-the-meter battery storage systems, connected to the electric grid.	550,5 MW_{ac}	2 030 MW_{ac}	U.S. Energy Information Administration. Annual Electric Power Industry Report, Form-861

[18] Id.

[19] U.S. Energy Information Administration, Electricity Data Browser, net generation for all sectors, annual, accessed June 2024 and U.S. Energy Information Administration, Electric Power Monthly, Table 6.1, June 2024. Reported units are MWac, however, in kWh/kWdc, this computation works out to ~1560 kWh/kWdc.

[20] U.S. Energy Information Administration, Preliminary Monthly Electric Generator Inventory (860M), March 2024. and U.S. Energy Information Administration. Annual Electric Power Industry Report, Form-861, June 2024. Note: EIA reports no storage from Puerto Rico.

[21] Argonne National Lab. Light Duty Electric Drive Vehicles Monthly Sales Updates – Historical Data. Accessed June 2024.

[22] The White House. FACT SHEET: President Biden Takes Bold Executive Action to Spur Domestic Clean Energy Manufacturing. June 6, 2022.

[23] Public Law 117-58 – Infrastructure Investment and Jobs Act. Nov 2021.

Centralized storage systems In MW	In-front-of-the-meter battery storage systems	6 682,5 MW_{ac}	15 829 MW_{ac}	U.S. Energy Information Administration, Preliminary Monthly Electric Generator Inventory (860M), March 2024
Residential Heat Pumps [#]	Unitary Heat Pumps	3 616 632 (includes non-residential heat pumps as well)	Not Available	Air-Conditioning, Heating, and Refrigeration Institute Monthly Shipment Report, December 2023[24]
Electric cars [#]	Plug-in Electric Vehicles (car and light truck)	1 440 000	4 722 000 (est.)	Argonne National Lab, Energy Systems and Infrastructure Analysis, Light Duty Electric Drive Vehicles, Monthly Sales Update, May 2024[25]

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

PV module prices are estimated bottom-up overnight capital costs (i.e., cash costs) of representative PV components under market conditions experienced during the analysis period. Bottom-up costs are based on national averages and do not necessarily represent typical costs in all local markets and do not reflect all experiences. The mean reported market costs and prices for subcomponents for representative systems are based on aggregated interview data.[26]

According to several installers and developers surveyed by the National Renewable Energy Laboratory, features that characterized 2022—including high and volatile component prices, limited component supplies, and outsized profits made by some companies because of constrained competition—moderated in 2023. However, others reported few or no component cost reductions in 2023 as well as ongoing cost uncertainties related to trade policies and Inflation Reduction Act implementation (see Section 3.2.2). Some companies reported using new strategies to secure component supplies, such as developing relationships with additional module manufacturers and working through equipment distributors.[27]

Table 8: Typical module prices[28]

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 [US$/W]
2023	Not Available	Not Available	0,39

2.2 System prices

PV system prices are estimated bottom-up overnight capital costs (i.e., cash costs) of representative PV components under market conditions experienced during the analysis period. Bottom-up costs are based on national averages and do not necessarily represent typical costs in all local markets and do not reflect all experiences. The mean reported market costs and prices for subcomponents for representative systems are based on aggregated interview data.[29]

[26] National Renewable Energy Lab. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, with Minimum Sustainable Price Analysis: Q1 2023, September 2023. Modeled market price (MMP) benchmarks are used in this report.

[27] Id.

[28] Id.

[29] National Renewable Energy Lab. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, with Minimum Sustainable Price Analysis: Q1 2023, September 2023. Modeled market price (MMP) benchmarks are used in this report.

According to several installers and developers surveyed by the National Renewable Energy Laboratory, features that characterized 2022—including high and volatile component prices, limited component supplies, and outsized profits made by some companies because of constrained competition—moderated in 2023. However, others reported few or no component cost reductions in 2023 as well as ongoing cost uncertainties related to trade policies and Inflation Reduction Act implementation (see Section 3.2.2), high wages and strong competition for labour, and higher costs for interconnection studies for certain projects.[30]

Table 9: Turnkey PV system prices of different typical PV systems[31]

Category/Size	Typical applications and brief details	Current prices [US$/W]
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.	2,49
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.	Not Available
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.[32]	1,78
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected industrial buildings, warehouses, etc.	Not available
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. [33]	1,22
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.[34]	1,16

[30] Id.

[31] National Renewable Energy Lab. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, with Minimum Sustainable Price Analysis: Q1 2023, September 2023.

[32]

[33] Most pricing is based on competitive power purchase agreement awards. Tax breaks are standardly received.

[34] Id.

Table 10: National trends in system prices for different applications

Year	Residential BAPV Grid-connected, roof-mounted, distributed PV system 5-10 kW **[US$/W]**	Small commercial BAPV Grid-connected, roof-mounted, distributed PV systems 10-100 kW **[US$/W]**	Large commercial BAPV Grid-connected, roof-mounted, distributed PV systems 100-250 kW **[US$/W]**	Centralized PV Grid-connected, ground-mounted, centralized PV systems 10-50 MW **[US$W]**
2023	2,49	Not Available	1,78	1,16 – 1,22

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 2023 is presented in Table 11 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 Table 11 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.

PV system prices are estimated bottom-up overnight capital costs (i.e., cash costs) of representative PV components under market conditions experienced during the analysis period. Bottom-up costs are based on national averages and do not necessarily represent typical costs in all local markets and do not reflect all experiences. Costs are based on those incurred by a typical, experienced installed in a competitive market on a representative system (without premium features or complementary services). Profit margins can also vary widely across the industry. The mean reported market costs and prices for subcomponents for representative systems are based on aggregated interview data. [35]

[35] National Renewable Energy Lab. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, with Minimum Sustainable Price Analysis: Q1 2023, September 2023. Modeled market price (MMP) benchmarks are used in this report.

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

Cost category	Average [US$/W]	Low [US$/W]	High [US$/W]
Hardware			
Module	0,38	Not Available	Not Available
Inverter	0,33	Not Available	Not Available
Mounting material	0,24	Not Available	Not Available
Other electronics (cables, etc.)	0,33	Not Available	Not Available
Subtotal Hardware	**1,28**		
Soft costs			
Planning	0,50	Not Available	Not Available
Installation work	0,17	Not Available	Not Available
Shipping and travel expenses to customer	0,025	Not Available	Not Available
Permits and commissioning (i.e. cost for electrician, etc.)	0,08	Not Available	Not Available
Project margin	0,43	Not Available	Not Available
Subtotal Soft costs	**1,21**		
Total (excluding VAT)	**2,49**		
Average VAT	0,04		
Total (including VAT)	**2,57**		

Table 12: Cost breakdown for a grid-connected, ground-mounted, centralized PV systems of >10 MW

Cost category	Average [US$/W]	Low [US$/W]	High [US$/W]
Hardware			
Module	0,38	Not Available	Not Available
Inverter	0,05	Not Available	Not Available
Mounting material	0,12	Not Available	Not Available

Other electronics (cables, etc.)	0,18	Not Available	Not Available
Subtotal Hardware	**0,73**		
Soft costs			
Planning		Not Available	Not Available
Installation work	0,25	Not Available	Not Available
Shipping and travel expenses to customer	0,03	Not Available	Not Available
Permits and commissioning (i.e. cost for electrician, etc.)	0,04	Not Available	Not Available
Project margin	0,11	Not Available	Not Available
Subtotal Soft costs	**0,43**		
Total (excluding VAT)	**1,16**		
Average VAT	0,04		
Total (including VAT)	**1,21**		

2.4 Financial Parameters and specific financing programs

Most U.S. utility-scale PV systems—82% of installations in 2023, 85% cumulative—are owned by independent power producers, which sell their electricity under long-term contracts (see Figure 1).[36] Direct utility ownership of PV systems is more common in states where there are established rules that encourage direct utility ownership of solar assets, such as Florida and Virginia.[37]

[36] U.S. Energy Information Administration, Form 860, Early release 2023 data. June 2024.

[37] Id.

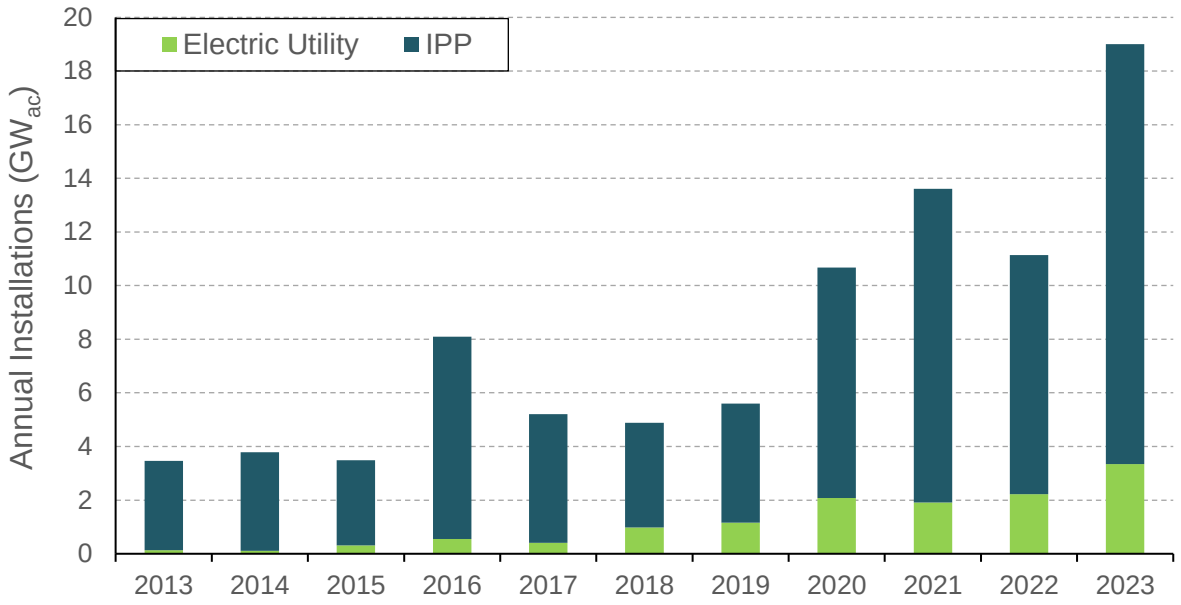

Figure 1 PV system asset ownership for systems ≥1 MW_{ac}. IPP = independent power producer[38]

For residential systems, third-party ownership (TPO) represented about 23% of installations in 2023, while loans represented another 58% (down from 69% in 2022), and the remainder of systems being purchased with cash.[39] Many installers reported that their financing mix flipped from predominantly loan in 2022 to TPO in 2023, potentially as a result of the availability of bonus credits under the Investment Tax Credit (ITC) that are not available to individual tax payers and high interest rates. Loan rates available to individuals wishing to purchase residential systems depend heavily on the credit rating of the individual, the term of the loan, and whether the installer paid loan providers to provide more favourable rates. Risk-based pricing, with lenders providing homeowners with a rate based on their credit score, is also becoming more popular.[40]

[38] Id.

[39] Wood Mackenzie/SEIA. US residential solar finance update: H1 2024®, April 2024. NB: in October 2023, Wood Mackenzie changed its methodology for calculating the share of TPO. Therefore, there are slight changes to the TPO market share going back to 2019.

[40] Id.

Table 13: PV financing information in 2023

Different market segments	Loan rate [%]
Average rate of loans – residential installations	1,99-11,59% (25-5 year)[41]
Average rate of loans – commercial installations	5,4% (20-year) [42]
Average cost of capital – industrial and ground-mounted installations	5,4% (20-year) [43]

2.5 Specific investments programs

Most renewable capacity within the United States is sold to utilities and power marketers, but retail off-takes – including community solar and corporate power purchase agreements (PPAs) (see Section **Error! Reference source not found.** and Section **Error! Reference source not fo und.**, respectively)– and onsite projects are a growing share (see Figure 2).[44]

[41] Id.

[42] 20-Year High Quality Market (HQM) Corporate Bond Spot Rate, Jan 2023-Dec 2023.

[43] Id.

[44] Galen, Barbose. U.S. State Renewable Portfolio & Clean Electricity Standards: 2023 Status Update. Lawrence Berkeley National Laboratory. 2023.

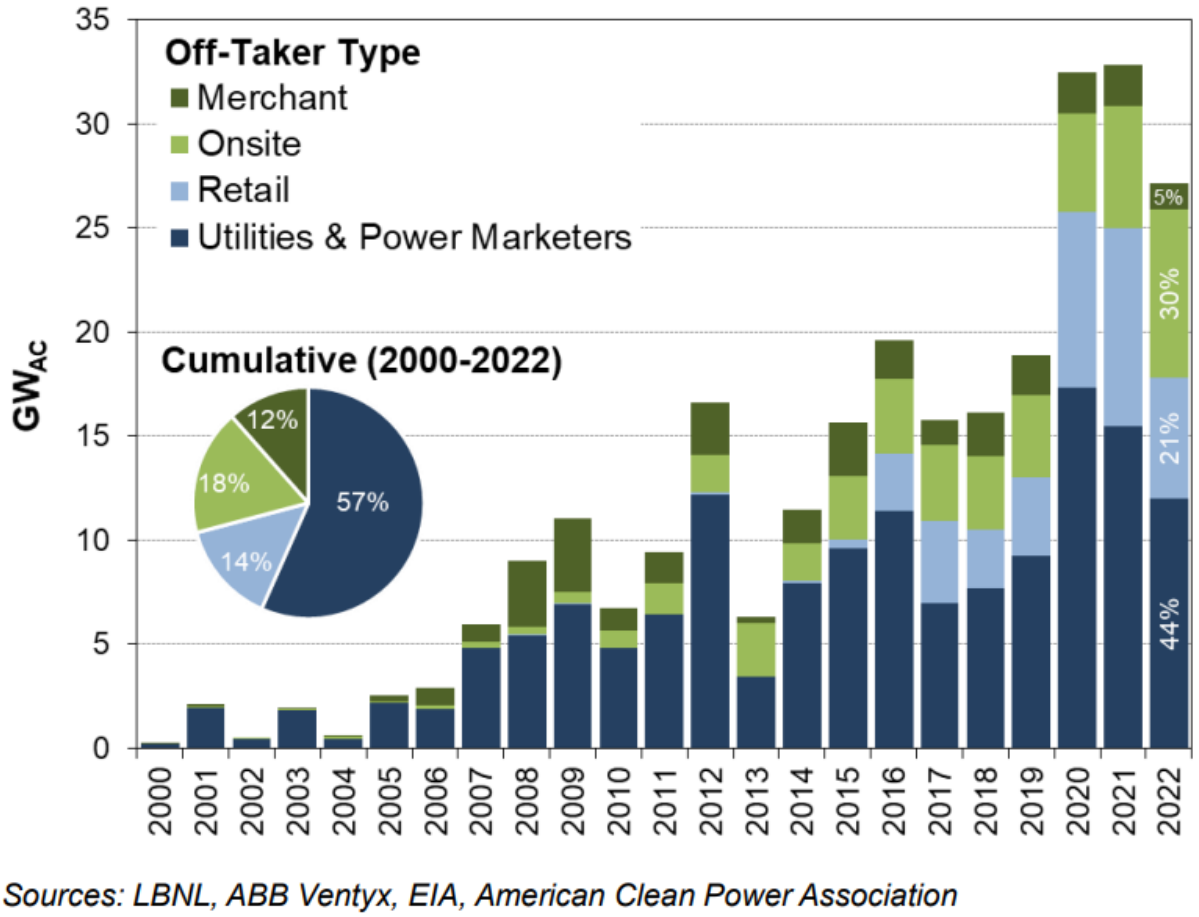

Figure 2 Annual renewable capacity additions by off-taker type.[45]

2.6 Merchant PV / PPA / CPPA

Within the United States, corporate solar adoption continues to grow mainly as a result of off-site corporate solar procurement. Through 2023, the leading five U.S. off-site corporate solar offtakers were Amazon, Meta, Microsoft, Google, and Verizon, with a collective 40 GW of power purchase agreements (PPAs). In 2023 alone, Amazon signed 4 GW of Meta signed 2.8 GW worth of off-site PPAs.[46] These installations are driven in large part by corporate clean energy goals, with 18 of the top 25 corporate solar users setting some sort of carbon neutrality or 100% renewable energy goal. The locations of these installations are also driven by the energy demands of the large data centres owned by many of these companies; for example, in 2022, the state of Virginia saw 2 GW_{dc} of corporate solar deployment and was

[45] Id.

[46] Harrison, Kyle. Corporate PPA Deal Tracker: April 2024. BloombergNEF. June 2024.

estimated to handle nearly 70% of global internet traffic.[47] The rapid growth in the use of artificial intelligence and cloud computing has only intensified this energy demand.[48]

While green tariffs and physical PPAs are still common ways for corporations to procure solar energy, synthetic/virtual PPAs are becoming increasingly popular and have given corporate off-takers and utilities more flexibility.[49] Unlike with a physical PPA, a virtual PPA is a financial contract – rather than a contract for power – in which the developer sells the electricity to the grid at market prices and the off-taker purchases electricity from the grid, but both have agreed ahead of time on a minimum price for the developer will get for that power. If market prices are below that minimum, the off-taker makes up the difference. If market price is above that value, the developer gives that profit to the off-taker. This is known as a contract for difference.[50] According to BNEF, around 67% of corporate PPAs in the United States were virtual in 2023 (see Figure 3).[51] Some corporations are also taking ownership stakes in solar projects and then purchasing RECs directly from the project to help achieve their renewable energy goals.[52] One or more commercial customers also often act as the anchor tenant for community solar projects, a sector which continues to grow.[53]

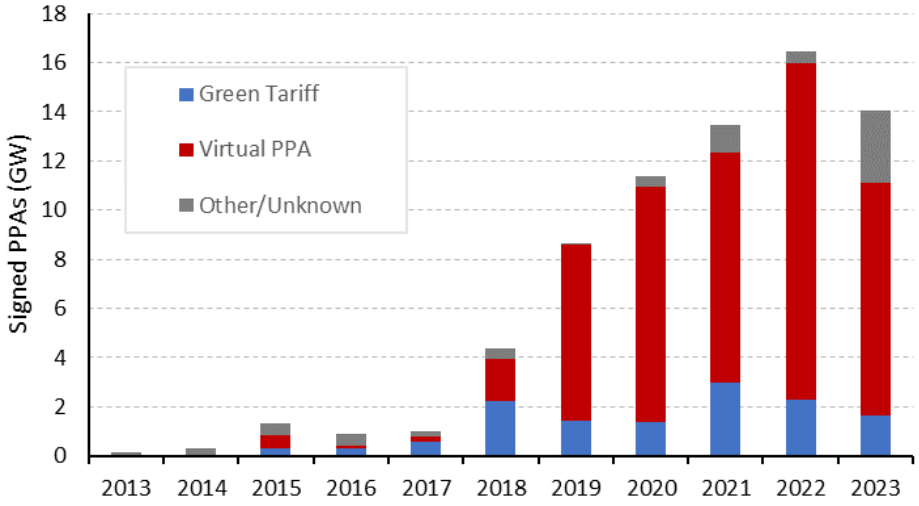

Figure 3 Annual signed power purchase agreements (PPAs).[54]

[47] SEIA. Solar Means Business Tracking Solar Adoption by America's Top Brands 2022. Accessed June 2023.

[48] Stiffler, Lisa. As AI use surges, tech companies race to secure clean energy and preserve climate goals (msn.com). MSN. Accessed July 2024.

[49] SEIA. Solar Means Business Tracking Solar Adoption by America's Top Brands 2022. Accessed June 2023.

[50] 3Degrees Staff. Renewable energy power purchase agreements. February 5, 2018. Accessed July 2023.

[51] Harrison, Kyle. Corporate PPA Deal Tracker: April 2024. BloombergNEF. June 2024.

[52] SEIA. Solar Means Business Tracking Solar Adoption by America's Top Brands 2022. Accessed June 2023.

[53] Connelly, Caitlin. US community solar market outlook H1 2024. Wood Mackenzie. February 2024.

[54]

2.7 Additional Country information

Table 14: Country information

Retail electricity prices for a household [US$/W]	0,1598 (average)[55]
Retail electricity prices for a commercial company [US$/W]	0,1274 (average)[56]
Retail electricity prices for an industrial company [US$/W]	0,0806 (average)[57]
Liberalization of the electricity sector	35 of the 50 U.S. States have partly or entirely broken apart the generation, transmission, and retail distribution of energy into separate businesses.[58]

[55] U.S. Energy Information Administration, Electric Power Monthly, Table ES1.B, February 2024.
[56] Id.

[57] Id.

[58] Penn, I. Why Are Energy Prices So High? Some Experts Blame Deregulation. - The New York Times (nytimes.com), accessed July 2023.

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.

U.S. PV market development is supported by both national, state-level, and local financial incentives, though state and local policies vary in form and magnitude. Existing policy at the national and state level and historical rapid declines in technology costs have enabled PV to continue to grow rapidly in the United States.

Table 15: Summary of PV support measures[59]

Category	Residential			Commercial + Industrial			Centralized		
Measures in 2023	**Legacy**	**On-going**	**New**	**Legacy**	**On-going**	**New**	**Legacy**	**On-going**	**New**
Feed-in tariffs	Yes	Yes	-	Yes	Yes	-	-	Yes	-
Feed-in premium (above market price)	Yes	Yes	-	-	-	-	-	-	-
Capital subsidies	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-
Green certificates	Yes	Yes	-	Yes	Yes	-	-	Yes	-
Renewable portfolio standards with/without PV requirements	-	Yes	-	-	Yes	-	-	Yes	-
Income tax credits	-	Yes	-	-	Yes	-	-	Yes	-
Self-consumption	-	Yes	-	-	Yes	-	-	-	-
Net-metering	Yes	Yes	-	Yes	Yes	-	-	-	-
Net-billing	Yes	Yes	Yes	Yes	Yes	Yes	-	-	-

[59] North Carolina Clean Energy Technology Center. DSIRE (dsireusa.org) Summary Tables. Accessed June 2024.

Collective self-consumption and delocalized net-metering	-	Yes	-	-	Yes	-	-	Yes	-
Sustainable building requirements	-	Yes	-	-	Yes	-	-	-	-
BIPV incentives	-	-	-	-	-	-	-	-	-
Merchant PV facilitating measures	-	Yes	Yes	-	Yes	Yes	-	Yes	Yes

3.1 National targets for PV

In December of 2021, President Biden signed Executive Order 14057, committing the United States to achieving a carbon pollution-free power sector by 2035, and achieving net zero emissions economy-wide by no later than 2050.[60] To meet the urgency of the climate crisis and President Biden's Executive Order 14057 at minimum cost, it is estimated annual PV deployment would need to double in the early 2020s and to quintuple by the end of the decade in the most aggressive grid decarbonization scenario.[61] Recognizing this need, the U.S. Department of Energy's Solar Energy Technologies Office has set goals centred around reducing the cost to produce solar electricity, maintaining reliable electricity, helping solar energy contribute beyond electricity, and deploying solar technologies rapidly.[62]

3.2 Direct support policies for PV installations

In 2022, the Inflation Reduction Act (IRA) was passed, the most significant change in direct support policies for solar energy in the United States in history. IRA is a federal law that includes – among many other grants, loans, and tax credit expansions – incentives designed to spur both small-scale and large-scale PV installations and manufacturing in a socially equitable manner. In 2023, several of the provisions under IRA were clarified and implemented (see Section 3.2.2).

In addition to the implementation of IRA policy provisions, the U.S Bureau of Land Management (BLM) proposed rules to bolster solar development on public (BLM) lands and

[60] Exec. Order No. 14057, 86 FR 70935, 2021.

[61] Margolis, Robert, Kristen Ardani, Paul Denholm, Trieu Mai, Eric O'Shaughnessy, Timothy Silverman, and Jarett Zuboy. 2021. "Solar Futures Study." U.S. Department of Energy.

[62] U.S. Department of Energy. 2021. "Solar Energy Technologies Office 2021 Multi-Year Program Plan."

create a more efficient permitting process. BLM further clarified these proposed rules releasing a roadmap for effectively siting renewable energy on public lands (see Section **Error! R eference source not found.**).

At the state level, various changes to direct generation compensation measures, rate design, and solar ownership were proposed and implemented throughout 2023. The provision likely to impact the largest number of PV installations was the California Public Utility Commission's changes to their net energy metering policies, which were approved at the end of 2022 and went into effect in 2023 (see Section 3.3.2).[63]

3.2.1 Mandatory solar

Currently, California is the only state in the United States to have a solar energy mandate for new buildings.[64] In May 2018, California became the first state in the nation to require that all new low-rise homes install PV equipment with an annual output greater than or equal to the homes' annual electrical consumption. A few types of new residential construction are exempt from the code, including properties with small enough roofs or properties that receive an abundance of shade. The standard went into effect on January 1, 2020. [65] The standard for single-family homes was updated in 2023 and now includes a provision that new single-family homes must be also wired so that energy storage systems can easily be added later.[66] In January 2023, California began to require PV and battery storage on newly constructed non-residential and high-rise multifamily buildings that meet certain criteria.[67] Multi-unit tenant buildings in utility service territories without virtual net metering are exempt, and buildings less than 5000 square feet are exempt from the storage requirement.[68]

Several cities within California also have solar installation mandates including Lancaster,[69] Sebastopol,[70] San Francisco,[71] and Santa Monica.[72] Outside of California, solar mandates

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[63] North Carolina Clean Energy Technology Center, The 50 States of Solar: 2023 Policy Review and Q4 2023 Quarterly Report, January 2024.

[64] Lozanova, Sara. California Solar Mandate for Installing Solar Panels in California. GreenLancer. December 2023. Accessed July 2024.

[65] North Carolina Clean Energy Technology Center, DSIRE (dsireusa.org), accessed June 2024.

[66] California Energy Commission. 2021 Building Energy Efficiency Standards Summary. August 2021.

[67] National Renewable Energy Laboratory. Winter 2023 Solar Industry Update. January 2023.

[68] California Energy Commission. 2022 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. August 2022.

[69] North Carolina Clean Energy Technology Center, DSIRE (dsireusa.org), accessed June 2024.

[70] North Carolina Clean Energy Technology Center, DSIRE (dsireusa.org), accessed June 2024.

[71] Slowey, Kim. San Francisco passes mandatory solar ordinance for new buildings.Construction Dive, April 2016. Accessed July 2023.

[72] Pickerel, Kelly. Santa Monica City Council votes to require solar on all new construction Solar Power World. May 2016. Accessed July 2023.

have also been passed in cities ranging from Seattle[73] to South Miami[74] to New York City.[75] Several states and cities also have what are referred to as "solar-ready" mandates, which, while not requiring that solar be installed when a new building is built, do require that it be designed so that solar panels can easily be added later.[76] Mandates can apply to new homes, new commercial buildings, or municipal buildings.

3.2.2 Inflation Reduction Act (IRA) policy implementation

The Inflation Reduction Act (IRA) is the most significant action the U.S. Congress has taken on clean energy and climate change in the nation's history. The law contains nearly US$370 billion in investments aimed at reducing energy burdens for families and businesses, accelerating private investment in clean energy, strengthening supply chains from critical mineral production to energy efficient appliances, and creating new economic opportunities for workers.[77] There are also several grant and loan programs that could be used to fund transmission and energy infrastructure. Additionally, the law advances President Biden's Justice40 Initiative, which commits to delivering 40 percent of the overall benefits of climate, clean energy, and related federal investments to communities that are marginalized, overburdened by pollution, and underserved by infrastructure and other basic services.[78]

The bulk of the funding directed towards PV within IRA comes in the form of tax credits, which can be divided into solar deployment-related and solar manufacturing-related categories, which last for approximately the next ten years (see Figure 4). There are also several grant and loan programs that could be used to fund transmission and energy infrastructure, as well as funding directed towards solar deployment in Tribal communities, rural communities, and energy justice communities.[79] One of the larger such programs is the Solar For All program administered by the U.S. Environmental Protection Agency's Greenhouse Gas Reduction Fund which will allocate US$7 billion in grants to up to 60 states, Tribal organizations, municipal governments, and eligible non-profit entities to expand solar power access to low-income and disadvantage communities.[80] In early 2024, the 60 selectees were announced. The combined

[73] Seattle Department of Construction and Inspections. Tip 422. October 2021.

[74] NBC 6 South Florida writers. South Miami Set to Become First City in Florida to Require Solar Panels on New Homes July 2017. Accessed July 2024.

[75] Brooklyn SolarWorks Team. NYC Local Law 92 & 94: What to Know. Feb 2022. Accessed July 2024.

[76] O'Guin, Travis. Powering Tomorrow: Understanding Solar Mandates in New Construction Solar Kal, January 2024. Accessed July 2023.

[77] The White House. Building a Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action. January 2023.

[78] The White House. Justice40. Accessed July 2023.

[79] The White House. Building a Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action. January 2023.

[80] U.S. Environmental Protection Agency Press Office. Biden-Harris Administration Launches $7 Billion Solar for All Grant Competition to Fund Residential Solar Programs that Lower Energy Costs for Familiaes and Advance Environmental Justice Through Investing in America Agenda. June 28, 2023.

efforts of the selected projects are expected to bring solar energy to 900,000 low-income and disadvantaged households nationwide.[81]

	Applicable Facilities	Value	Direct Pay	Transfer
MPTC	All	Varies by component	Yes (5 years)	Yes
48C	Facility construction meets labor rules	30%	Tax-exempt‡ only	Yes
	Facility construction *doesn't* meet labor rules	6%		
PTC*	Facilities < 1 MW_{ac} and/or meet labor rules	2.75 ¢/kWh†	Tax-exempt‡ only	Yes
	Facilities ≥ 1 MW_{ac} that *don't* meet labor rules	0.55¢/kWh†		
ITC*	Facilities < 1 MW_{ac} and/or meet labor rules	30%	Tax-exempt‡ only	Yes
	Facilities ≥ 1 MW_{ac} that *don't* meet labor rules	6%		
25D	All	30%	No	No

+10% domestic content bonus for ITC or PTC
+10% energy community bonus for ITC or PTC
+10-20% low-income bonus for ITC *only*

†Adjusted for inflation
*Could be extended based on GHG emissions
‡domestic content requirements apply

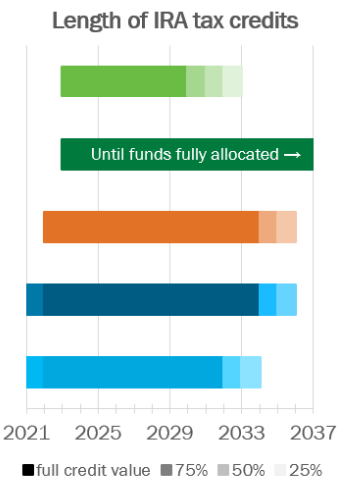

Figure 4 Summary of the tax credits applicable to PV within IRA. MPTC = Manufacturing Production Tax Credit, PTC = Production Tax Credit, ITC = Investment Tax Credit, GHG = greenhouse gas

There are three solar deployment-related tax credits within IRA.[82]

1. **Residential Clean Energy Credit (25D)**[83] – The 30% Residential Clean Energy Credit (25D), which covered the costs of a residential solar PV system installed during a tax year, was extended and expanded to include the costs of energy storage of 3 kWh or greater. This would include the installation of standalone energy storage in a home.
2. **Investment Tax Credit (ITC)** – The 30% Investment Tax Credit (ITC), which could be taken on the costs of a commercial or utility-scale solar system installed during the tax year, was also extended and expanded to include microgrid controllers, standalone energy storage of 5 kWh or greater, and interconnection property costs for projects less than 5 MW_{ac} in size.
3. **Production Tax Credit (PTC)** – As a result of IRA, commercial and utility-scale solar systems now also have the choice of, instead of taking the ITC, electing to take the production tax credit (PTC), which provides a tax credit per kWh on the electricity

[81] U.S. Environmental Protection Agency, Biden-Harris Administration Announces $7 Billion Solar for All Grants to Deliver Residential Solar, Saving Low-Income Americans $350 Million Annually and Advancing Environmental Justice Across America, April 2024.

[82] The White House. Building a Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action. January 2023.

[83] U.S. Internal Revenue Service. New and Improved 25C and 25D. July 2023.

generated for the first 10 years of operation. These rates are adjusted annually for inflation and the rate in 2022 was 2.75 ¢/kWh.[84]

All three solar deployment-related tax credits phase out over the course of several years (see Figure 4), although the ITC and PTC could both be extended if the United States has not successfully reduced greenhouse gas emissions from the production of electricity below 25% of what they were in 2022.

Starting in 2023, there are also several bonus credits available for the ITC and/or PTC with the goal of incentivizing domestic manufacturing (+10% bonus), deployment within low-income communities (+10-20% bonus, depending on type and success of application, only available for the ITC up to 1.8 GW of projects per year plus any carryover from previous years), and ensuring an equitable energy transition by encouraging deployment in so-called energy communities which have been adversely impacted by the energy transition (+10% bonus). These bonuses are cumulative; the hypothetical maximum value of the ITC is 70% and for the PTC is 3.3 ¢/kWh. The ITC and PTC also have apprenticeship and prevailing wage requirements that must be met for projects 1 MW_{ac} or larger that began construction after January 30, 2023, otherwise the value of the tax credit is reduced by a factor of five.

There are two manufacturing-related tax credits within IRA.

1. **Qualifying Advanced Energy Project Credit (48C)** – The 30% Qualifying Advanced Energy Project Credit (48C), which was first introduced within the American Reinvestment and Recovery Act in 2009, was reauthorized with a further US$10 billion in funding and expanded to include facility expansions, recycling, greenhouse gas reduction modifications, and critical mineral processing facilities.[85] In keeping with the Justice40 Initiative, US$4 billion of the US$10 billion allocation must go towards projects located in energy communities and applicants will be judged on several other criteria including local job creation and commercial viability. In the initial funding round (for a total of US$4B across all technologies), polysilicon, wafers, solar glass, and ingot/wafer production tools were highlighted as priority areas within the PV supply chain.[86] Selections for the first round of funding were announced in March of 2024, and several selectees chose to self-disclose their allocations.[87]
2. **Advanced Manufacturing Production Tax Credit (MPTC)** – The Advanced Manufacturing Production Tax Credit (MPTC) is the second manufacturing-related credit. The MPTC can be taken per unit of clean energy components produced in the United States and sold within a given year (see **Error! Reference source not found.**). T his is the shortest of the tax credits, beginning to phase out in 2030, and the value of the MPTC is not adjusted for inflation.

In order to expand access to these tax credits, two new mechanisms were also introduced starting in 2023: elective (a.k.a., direct) payment and transferability. These options allow

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[84] Hyde, Charles. Renewable Electricity Production Credit Amounts for Calendar Year 2022. Announcement 2022-23. U.S. Internal Revenue Service.

[85] The White House. Building a Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action. January 2023.

[86] U.S. Internal Revenue Service. IRS provides additional guidance for advanced energy projects | Internal Revenue Service, May 2023.

[87] U.S. Department of Energy, Applicant Self-Disclosed 48C Projects. Accessed June 2024.

taxpayers whose tax burden would normally be too low to take advantage of these tax credits to either transfer for cash (i.e., sell) their credits to another taxpayer or, in the case of tax-exempt organizations taking advantage of any of the tax credits and businesses taking advantage of the MPTC, receive the full value of their tax credit from the government in the form of a direct payment. In order to receive this benefit, entities much pre-register with the IRS. Projects starting construction in 2024 must meet domestic content requirements or may only receive 90% of the direct pay refund. The residential clean energy credit is the only credit that is ineligible for both direct payment and transferability.

In 2023, the U.S. Department of Treasury and the Internal Revenue Service (IRS) made significant progress on implementing the Low-Income Communities Bonus,[88] the Energy Community Bonus (including a map[89] of eligible locations),[90] the Domestic Content Bonus,[91] the direct pay and transferability processes,[92] the 48C allocation process,[93] and the implementation of the MPTC.[94]

After the passage of IRA, domestic deployment projections rose significantly and there were announcements of manufacturing facilities up and down the supply chain.[95] While lack of clarity around the IRA regulations was cited as one of the reasons this projected growth has been slow to materialize,[96] both domestic manufacturing and deployment have experience record growth levels. And many project owners and analysts have credited the expanded and new IRA tax credits as the driving force behind this growth.[97]

3.2.3 Renewable Portfolio Standards

State incentives in the United States have been driven in large part by the passage of Renewable Portfolio Standards (RPS). An RPS, also called a renewable electricity standard (RES), requires electricity suppliers to purchase or generate a targeted amount of renewable energy by a certain date. Although design details vary considerably, RPS policies typically enforce compliance through penalties, and many include the trading of renewable energy certificates (RECs). Alternatively, a clean energy standard (CES) is similar to an RPS but

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[88] Internal Revenue Service, Additional Guidance on Low-Income Communities Bonus Credit Program, August 2023.

[89] U.S. Department of Energy. IRA Energy Community Tax Credit Bonus, Accessed June 2024.

[90] Internal Revenue Service, IRS issues guidance on eligibility requirement for energy communities for the bonus credit program under the Inflation Reduction Act, April 4, 2023.

[91] Internal Revenue Service, IRS provides initial guidance for the domestic content bonus credit | Internal Revenue Service, May 12, 2023.

[92] U.S. Internal Revenue Service. Elective pay and transferability. Accessed July 2024.

[93] U.S. Internal Revenue Service. IRS provides additional guidance for advanced energy projects | Internal Revenue Service, May 2023.

[94]U.S. Department of Treasury and Internal Revenue Service. Section 45X Advanced Manufacturing Production Credit. December 15, 2023.

[95] National Renewable Energy Laboratory. Spring 2024 Quarterly Solar Industry Update. May 2024.

[96] Wood Mackenzie/SEIA. US Solar Market Insight Full Report Q3 2023. September 2023.

[97] Wood Mackenzie/SEIA. US Solar Market Insight Full Report 2023 Year in Review. March 2024.

allows a broader range of electricity generation (e.g., nuclear) resources to qualify for the target.

At the end of 2023, twenty-eight states, three territories, and the District of Columbia, had RPS, while eleven states had also passed CES.[98] One state – Minnesota – revised or enacted RPS or CES in 2023.[99] Roughly half of all growth in U.S. renewable electricity generation and capacity since 2000 is associated with state RPS requirements, though that percentage has declined in recent years, representing 30% of all U.S. renewable energy capacity additions in 2022.[100] Sixteen states in 2022 also had specific carve-outs for solar or distributed generation, typically in the range of 1-5% of retail sales.[101]

A common feature of RPS policies is a renewable electricity credit (REC) trading system. A utility that generates more renewable electricity than the RPS requirement may either trade or sell RECs to other electricity suppliers who may not have enough RPS-eligible electricity to meet their RPS requirements. Some states make a certain number of credits available for sale.[102] Solar renewable energy credits (SRECs) are awarded to meet solar or distributed generation carve-outs.[103] SRECs are rarely sold directly to utilities by residential system owners, instead working through a broker to monetize the credits. Prices can vary state-by-state and depend on a variety of factors including supply, demand, and the alternative compliance payment level set by the state, which can set a de facto price cap on the SREC.

3.2.4 BIPV development measures

While many local and state governments have based green building codes, energy standards, and even mandatory solar energy requirements (see Section 3.2.1), there are no current policies in place to specifically incentivize or mandate building-integrated PV in the United States.

3.2.5 Merchant PV development measures

While virtual PPAs are prevalent among private companies (see Section 0 for further discussion), there are currently no frameworks in place to facilitate further development.

According to American Green Bank Consortium, in the decade between 2011 and 2021, American Green Banks have caused US$7B in clean energy investment.[104] In addition, along with the various tax credits previously mentioned, the Inflation Reduction Act also included

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[98] North Carolina Clean Energy Technology Center. Renewable & Clean Energy Standards. December 2023.

[99] Galen, Barbose. U.S. State Renewable Portfolio & Clean Electricity Standards: 2024 Status Update. Lawrence Berkeley National Laboratory. 2024.

[100] Id.

[101] Id.

[102] U.S. Energy Information Administration, Renewable energy explained: Portfolio standards. Accessed July 2023.

[103] Thoubboron, Kerry. SRECs: understanding solar renewable energy credits. EnergySage. August 2022.

[104] American Green Bank Consortium. GREEN BANKS IN THE UNITED STATES: 2021 U.S. Green Bank Annual Industry Report With Data from Calendar Year 2020. May 2021

US$14B for the National Clean Investment Fund as part of the U.S. Environmental Protection Agency's Greenhouse Gas Reduction Fund.[105] Applications were due in October 2023 and the three selected national nonprofits partnering with private capital providers to deliver financing at scale to businesses, communities, community lenders, and others were announced in April 2024.[106]

3.3 Self-consumption measures

Nearly every state within the United States considered or implemented a rate design or policy change in 2023, including 31 states, the District of Columbia (DC), and Puerto Rico that considered changes to distributed generation compensation policies, 35 states and DC considering a residential fixed charge or minimum bill increase, and 23 states and DC considering changes to community solar policies and programs.[107] Every state (including DC) but Tennessee, Texas, and Idaho possess some level of state-wide distributed generation compensation policy, although some utilities in both Idaho and Texas offer net metering. In 2023, 33 states and DC have state-developed mandatory net metering rules for certain utilities, and 13 states have rules other than net-metering in place. Two states are in transition from net metering to other statewide distributed generation rules.[108]

Table 16: Summary of self-consumption regulations for small private PV systems in 2023[109]

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	Varies by state – interconnection charges common, grid access charges and minimum bills growing in popularity
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	Varies by state – net billing, net metering, and feed-in tariffs are all in use; net billing is growing in popularity. Typically,

[105] U.S. Environmental Protection Agency Press Office. EPA Releases Framework for the Implementation of the Greenhouse Gas Reduction Fund as Part of President Biden's Investing in America Agenda. April 2023.

[106] U.S. Environmental Protection Agency Press Office. Biden-Harris Administration Announces $20 Billion in Grants to Mobilize Private Capital and Deliver Clean Energy and Climate Solutions to Communities Across America. April 2024.

[107] North Carolina Clean Energy Technology Center. 50 States of Solar: Q4 2023 Quarterly Report & 2023 Annual Review Executive Summary, January 2024.

[108] Id.

[109] North Carolina Clean Energy Technology Center. DSIRE (dsireusa.org) Summary Tables. Accessed June 2024.

			customers are limited to the amount they consume annually or monthly and beyond that receive significantly less for the exported energy (e.g., wholesale rates).
	5	Maximum timeframe for compensation of fluxes	Varies by state, typically annually
	6	Geographical compensation (virtual self-consumption or metering)	Virtual metering available in some locations
Other characteristics	7	Regulatory scheme duration	Varies by state, generally unlimited
	8	Third party ownership accepted	Yes
	9	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	Varies by state, but time-of-use rates increasingly popular
	10	Regulations on enablers of self-consumption (storage, DSM…)	Varies by state, but DSM mechanisms are increasingly popular
	11	PV system size limitations	Varies by state
	12	Electricity system limitations	Varies by state
	13	Additional features	Many other incentives at the state or federal level, depending on location

While data on distributed capacity is known, production and therefore rates of self-consumption remain relatively poorly understood. For example, the U.S. Energy Information Administration collects data on net metering capacity, but small-scale production is generally modelled.

3.3.1 Trends in state distributed solar compensation policies

In 2023, states continued to move away from retail rate net metering and toward net billing successor tariffs for distributed solar compensation. This is exemplified by California implementing their net billing tariff, NEM 3.0 (see Section 3.3.2), and by several other states, including Arkansas, Idaho, and Hawaii, approving transitions from net metering to net billing.[110]

3.3.2 Impacts of the California NEM 3.0 transition

The California Public Utilities Commission (CPUC) approved Net Metering 3.0 (NEM 3.0) rules in December 2022, transitioning the state's major utilities to a net billing structure with hourly avoided cost rate credits for energy exported to the grid. This policy was implemented starting

[110] North Carolina Clean Energy Technology Center. 50 States of Solar: Q4 2023 Quarterly Report & 2023 Annual Review Executive Summary, January 2024.

in April 2023.[111] The aim of this transition was to mitigate cost-shifting from PV to non-PV customers, compensate PV based on its value to the grid, and—in conjunction with highly differentiated time-of-use import rates—encourage electrification and use of energy storage.[112] In November 2023, CPUC reduced PV compensation for multimeter– i.e., school, farms, shopping centers, multifamily housing, etc. – properties. A separate decision also reduced compensation rates for single-family homes that host solar-plus-storage systems under NEM 3.0 by limited which bill charges can be offset by exports.[113]

As a result of the changing NEM rules, there was a large surge in residential PV installations in California in the first half of 2023 as residents sought to take advantage of the expiring NEM 2.0 rules.[114] Residential installations were lower in the second half of 2023, with Q4 installations down 17% y/y in California. Commercial PV in California similarly saw a surge of NEM 2.0 installations, however the peak came later in the year due to longer project timelines.[115] California accounted for 31% of residential installs and 32% of commercial and industrial installations in 2023,[116] and thus these regulations are expected to continue to have a large impact on those markets.

Along with strongly impacting solar deployment, NEM 3.0 also strongly impacted storage attachment rates, setting a record high of 31% for residential systems in Q4 2023.[117]

3.4 Collective self-consumption, community solar and similar measures

3.4.1 Community Solar

Community solar refers to local solar facilities shared by multiple community subscribers who receive credits on their electricity bills for their share of the electricity produced from the facility. Within the United States, there are two major community solar structures: third-party-led community solar and utility-led community solar. Third-party-led community solar represents the majority of the U.S. market. Homeowners, renters, residents in multi-family affordable housing (MFAH), and apartment tenants unable to install rooftop solar are typical subscribers to community solar systems. Additionally, non-residential entities like commercial and industrial companies, non-profits, or municipal and government entities often serve as “anchor

[111] North Carolina Clean Energy Technology Center. 50 States of Solar: Q4 2022 Quarterly Report & 2022 Annual Review Executive Summary, January 2023.

[112] National Renewable Energy Laboratory. Winter 2023 Quarterly Solar Industry Update. January 2023.

[113] National Renewable Energy Laboratory. Winter 2024 Quarterly Solar Industry Update. January 2024.

[114] National Renewable Energy Laboratory. Winter 2024 Quarterly Solar Industry Update. January 2024.

[115] Wood Mackenzie/SEIA. US Solar Market Insight Full Report 2023 Year in Review. March 2024.

[116] U.S. Energy Information Administration. Annual Electric Power Industry Report, Form-861M, June 2024.

[117] Wood Mackenzie/SEIA. US Solar Market Insight Full Report 2023 Year in Review. March 2024.

tenants." An anchor tenant signs a longer-term contract for offtake from the project and tends to use a significant amount of the electricity supplied by the project.[118]

In 2021, the U.S. Department of Energy announced ambitious targets under the National Community Solar Partnership (NCSP): powering the equivalent of five million households via community solar by 2025 and creating US$1 billion in electricity bill savings.[119] As discussed in Section **Error! Reference source not found.**, the Inflation Reduction Act contained a 10-20% bonus on the value of the Investment or Production Tax Credits (ITC or PTC) for projects in low-income communities. One of the categories highlighted within the legislation that would be eligible for a 20% bonus was low-income economic benefits projects where 50% of the benefits, which could include discounted rates on electricity bills, went to low-income subscribers, i.e., a low-income community solar program. There is an annual cap for projects which are eligible, and projects are allocated tax credits based on a number of different criteria. In 2023, 600 MW of the 1.8 GW cap were allocated to qualified low-income economic benefits projects.[120]

As of the end of 2023, 24 states and the District of Columbia and Puerto Rico had passed legislation enabling community solar.[121] This legislation has two primary forms: (1) establishing a state mandate for community solar or (2) developing state-level programs that support or incentivize community solar. Several states, including Florida, Texas, and Georgia also have sizable community solar programs without enabling legislation, but instead utilities have voluntarily adopted community solar programs.[122] Recent policy trends in the community solar space have reflected the desire that states have to use community solar as a vehicle to include low- and middle- income (LMI) participants in the clean energy economy. Many new program modifications include carve-outs or subprograms in community solar programs for LMI subscribers, increased credit rates, reduced fees, and automatic enrollment.[123] As of June 2023, at least 17 states and the District of Columbia have passed legislation with provisions that expand community solar access for LMI communities.[124]

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[118] Connelly, Caitlin. US community solar market outlook: H1 2024 Report. Wood Mackenzie. February 2024.

[119] U.S. Department of Energy. DOE Sets 2025 Community Solar Target to Power 5 Million Homes. October 8, 2021.

[120] U.S. Department of Energy Office of Energy Justice and Equity. Low-Income Communities Bonus Credit Program | Department of Energy. Accessed July 12, 2024. and U.S. Internal Revenue Service. Low-Income Communities Bonus Credit Program Unallocated Environmental Justice Solar and Wind Capacity Limitation Carryover from the 2023 Program Year to the 2024 Program Year. Accessed July 12, 2024.

[121] North Carolina Clean Energy Technology Center. 50 States of Solar: Q4 2023 Quarterly Report & 2023 Annual Review Executive Summary, January 2024.

[122] National Renewable Energy Laboratory. Sharing the Sun: Community Solar Deployment and Subscriptions (as of June 2023), November 2023.

[123] North Carolina Clean Energy Technology Center. 50 States of Solar: Q4 2023 Quarterly Report & 2023 Annual Review Executive Summary, January 2024.

[124] National Renewable Energy Laboratory. Sharing the Sun: Community Solar Deployment and Subscriptions (as of June 2023), November 2023.

Community solar installations increased 3% in 2023 compared to 2022. Despite this slight uptick from last year, there are still obstacles in this market segment due to continued interconnection queue delays in key state markets. New York, which has historically made up a majority of the national community solar market due to strong incentives, saw a decline in community solar installations in 2023.[125] Cumulatively, there were 6,6 GW_{dc} of community solar installed in the United States by the end of 2023.[126]

3.4.2 Virtual net metering

Virtual or aggregated net metering is net metering for electricity generated in a different location than where it is consumed. The energy generated is fed into the grid, but the consumer is credited with the generation as though it had happened on-site. Virtual net metering is a common mechanism available to community solar projects within the United States, where subscribers receive weighted credits for the energy generated by the system based on what fraction of the array they subscribed to.[127] Some community solar programs have location/proximity requirements on community solar subscribers.[128] At the end of 2023, 43 states and the District of Columbia allowed some form of virtual net metering.[129]

In 2023, California regulators established new virtual net metering rate structures. The new rate structures generally follow the NEM 3.0 structure (see Section 3.3.2) with a 15-minute netting interval for residential customers and excess credit compensated using an avoided cost calculator.[130] Additionally, regulators in Colorado adopted revised virtual net metering rules for multi-tenant properties that allow separately metered properties to participate in the program. Connecticut also expanded eligibility for their virtual net metering program.[131]

3.5 Tenders, auctions & similar schemes

The United States government does not use tenders, auctions, reverse auctions, or similar processes to grant PPAs for PV systems, though utilities and other businesses contracting for solar energy use a variety of procurement methods.

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[125] Wood Mackenzie/SEIA. US Solar Market Insight Full Report 2023 Year in Review. March 2024.

[126] Wood Mackenzie US Community Solar Outlook: H1 2024, February 2024.

[127] Mooney, Mary Elizabeth. What is virtual net metering? EnergySage. October, 2022.

[128] Xu, Kaifeng, Jenny Sumner, Emily Dalecki, and Robin Burton. Expanding Solar Access: State Community Solar Landscape (2022). National Renewable Energy Laboratory. March 2023.

[129] Wood Mackenzie/SEIA. US Solar Market Insight Full Report 2023 Year in Review. March 2024.

[130] North Carolina Clean Energy Technology Center. 50 States of Solar: Q4 2023 Quarterly Report & 2023 Annual Review Executive Summary, January 2024.

[131] Id.

3.6 Other utility-scale measures including, floating and agricultural PV

Dual-use PV, especially agricultural PV (or agrivoltaics), is gaining popularity within the United States, with an estimated 0.6 GW installed in 2023 and cumulative capacity reaching 10 GW as of June 2024.[132] While it has yet to represent a significant fraction of yearly installations, actors at nearly every level of government have shown interest in spurring growth in this sector. For instance, in 2022 the U.S. Department of Energy ran the FARMS (Foundational Agrivoltaic Research for Megawatt Scale) funding opportunity.[133] On the state level, the Massachusetts solar incentive program – the Solar Massachusetts Renewable Target (SMART) Program – includes an adder for solar projects co-located with agriculture in the state. This incentive went into effect in 2018 and the guidelines for the program have frequently been updated -- most recently in June 2023 -- to remain up to date with trends in the agricultural PV space.[134] New Jersey also has funding available for agricultural PV, through the Dual-Use Solar Energy Pilot Program, which was passed into law in 2021.[135]

Floating solar PV demand within the United States remains a small fraction of planned installations, especially in comparison to global deployments in Asia and the Pacific. However, it is gaining traction in areas with higher land costs, with 7 MW_{dc} of capacity additions estimated in 2023.[136]

Along with a growing diversity in project types, project size within the United States is also growing (see Figure 5).[137] This is because in many parts of the United States land is relatively cheap, benefits from high irradiation, and has an extremely flat geography which facilitates the installation of large-scale projects. There is also a diversity of permitting, interconnection, transmission, labour, and weatherization requirements between states, driving large-scale development to states with faster timelines and fewer requirements.[138]

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[132] InSPIRE, National Renewable Energy Laboratory, Agrivoltaics Map. Accessed June 17, 2024.

[133] U.S. Department of Energy Solar Energy Technologies Office. Foundational Agrivoltaic Research for Megawatt Scale (FARMS) Funding Program. Accessed July 2023.

[134] Commonwealth of Massachusetts. Solar Massachusetts Renewable Target (SMART) Program. Accessed June 2024.

[135] Rutgers University. Rutgers/NJAES Agrivoltaics Research and Extension Program. Accessed June 2024.

[136] Garasa Sagardoy, Daniel. Floating solar landscape 2023. Wood Mackenzie. November 2023.

[137] U.S. Energy Information Administration, Form 860, Early release 2023 data. June 2024.

[138] Kenning, Tom. Texas PV market ripens as major global investors drive financing flurry. PV-Tech. July 13, 2023.

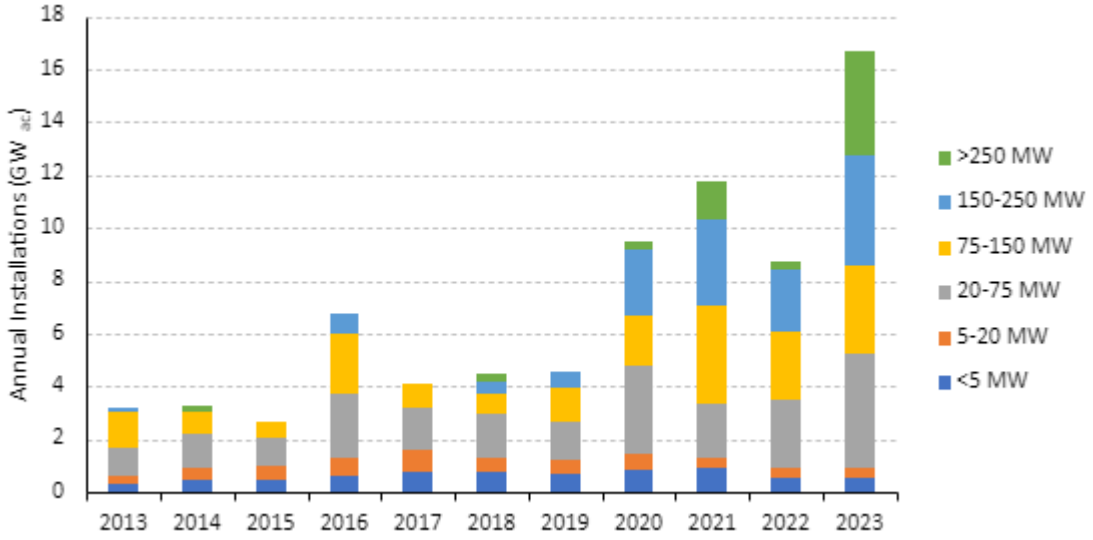

Figure 5 Annual utility-scale PV installations broken down by system size.[139]

3.7 Social Policies

At the national level, President Biden's Justice40 Initiative commits to delivering 40 percent of the overall benefits of climate, clean energy, and related federal investments to communities that are marginalized, overburdened by pollution, and underserved by infrastructure and other basic services.[140] This includes carve-outs targeting those populations within both the Inflation Reduction Act (IRA) and the Infrastructure Investment and Jobs Act (IIJA), as well as changes throughout existing federal funding programs. In 2023, the White House issued further guidance to federal agencies on using the Climate and Economic Justice Screening Tool to identify Disadvantaged communities for funding purposes[141], and President Biden reaffirmed his commitment to his Justice40 initiative by issuing an executive order on environmental justice.[142] As noted in Section **Error! Reference source not found.**, IRA featured several i ncentives targeted towards increasing participation of low-income households in PV deployment, including the Solar for All Program, the 10-20% low-income bonus available for the Investment Tax Credit, and the inclusion of direct pay mechanisms for tax-exempt organizations to take full advantage of the available tax credits. There is also significant funding, including grants, loans, and tax credit bonuses, made available within IRA for PV deployment in Tribal lands, which have been historically underserved by U.S. electricity networks.

At the state level, many states implemented or expanded programs targeting low-income households for participation in both community solar programs and rooftop solar programs in

[139] U.S. Energy Information Administration, Form 860, Early release 2023 data. June 2024.

[140] The White House. Justice40. Accessed June 2024.

[141] U.S. Council on Environmental Quality. Climate & Economic Justice Screening Tool. Accessed June 2024.

[142] U.S. Executive Office of the President. Revitalizing Our Nation's Commitment to Environmental Justice for All, April 21, 2023.

2023. [143] Maryland enacted legislation that establishes a permanent state-level community solar program and requires community solar facilities to deliver 40% of their output to low- and moderate- income (LMI) subscribers. Minnesota and New Jersey enacted similar community solar legislation. California regulators also approved an adder for LMI customers participating in virtual net metering. Additionally, several states, including Colorado and Maine, have passed legislation allowing or requiring unused net excess generation credits to be applied to low-income customer accounts. Many states and localities also provide incentives for PV deployment on schools and other public buildings.[144]

3.8 Retroactive measures applied to PV

No retroactive measures were applied in 2023.

3.9 Indirect policy issues

3.9.1 Rural electrification measures

There are several national programs targeted towards increasing rural electrification within the United States, including several which received plus-ups in the Inflation Reduction Act. The Rural Energy for America Program (REAP) through the U.S. Department of Agriculture received US$1,7 billion in grants and US$9,7 billion was also made available for loans to rural electric co-operatives to fund the purchase of renewable energy or renewable energy equipment through the Empowering Rural America program.[145] While the United States consistently ranks with greater than 99% of the population having access to electricity,[146] the U.S. Department of Energy Office of Indian Energy estimates that 17,000 homes or 54,400 people without access to electricity across Indian Country.[147] The Inflation Reduction Act contained US$145 million in grants, US$18 billion in loans, and carve-outs within the low-income bonus to the Investment Tax Credit for Tribal solar deployment to address this disparity.

In June 2023, the U.S. Bureau of Land Management (BLM) proposed an update of its renewable energy regulations to promote more deployment on public lands. The new rules would streamline the application process for wind and solar projects, reduce acreage rental

[143] North Carolina Clean Energy Technology Center, The 50 States of Solar: 2023 Policy Review and Q4 2023 Quarterly Report, January 2024.

[144] North Carolina Clean Energy Technology Center. DSIRE (dsireusa.org) Summary Tables. Accessed June 2024.

[145] The Associated Press. Biden administration announces nearly $11B for renewable energy in rural communities. National Public Radio. March 16, 2023.

[146] The World Bank. Access to electricity (% of population) – United States. Accessed June 2024.

[147] U.S. Department of Energy Office of Indian Energy. Tribal Electricity Access and Reliability (Report to Congress) . August 2023.

rates, and reduce project capacity fees by around 80%.[148] The rules were finalized in May 2024.[149]

3.9.2 Support for electricity storage and demand response measures

Along with incentives for PV deployment, the Inflation Reduction Act also expanded all three deployment-related tax credits (see Section **Error! Reference source not found.**) to include v arious types of energy storage, as well as including battery technologies in the list of those incentivized by the manufacturing-related tax credits.

Nine states have statewide targets for energy storage deployment with New York leading the way with a 2030 target of 6 GW.[150] States and utilities have also been increasingly incentivizing energy storage deployment using time-varying credit rates in distributed generation compensation programs. For example, in 2023, North Carolina approved a new time-of-use net metering tariff for Duke Energy along with a “Power Pair” incentive for solar plus storage systems, and in Hawaii, the Public Utilities Commission approved time-varying export credit rates for Hawaiian Electric Company’s distributed energy resource tariff. Additionally, as noted in Section 3.3.2, California’s NEM 3.0 policy has significantly boosted the electricity storage market by including time-varying credit rates.[151] Several states also have energy storage procurement mandates, goals, or targets.[152]

3.9.3 Support for encouraging social acceptance of PV systems

Social acceptance of large-scale solar (LSS) facilities is high in the United States, as exemplified by a national survey, which found that people living within 3 miles of an LSS project generally feel positively toward the neighbouring LSS facility.[153] A similar study conducted by the Washington Post and the University of Maryland found that 75% of those polled, regardless of political affiliation, said they were comfortable living near a field of solar panels.[154]

However, despite high levels of social acceptance, local community opposition to PV projects, especially large-scale projects, has been growing in recent years, causing delays and cancellations. This trend is seen in the rising number of counties passing restrictive policies

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[148] U.S. Bureau of Land Management. Interior Department Proposes Rule to Bolster Solar and Wind Development on Public Lands, Continue Progress on Efficient and Responsible Permitting | Bureau of Land Management. June 15, 2023.

[149] U.S. Bureau of Land Management. Rights-of-Way, Leasing, and Operations for Renewable Energy. May 1, 2024.

[150] McNamara, Will, Howard Passell and Todd Olinksy-Paul. States Energy Storage Policy Best Practices for Decarbonization. Sandia National Laboratories | Clean Energy States Alliance. February 2023.

[151] North Carolina Clean Energy Technology Center, The 50 States of Solar: 2023 Policy Review and Q4 2023 Quarterly Report, January 2024.

[152] McNamara, Will, Howard Passell and Todd Olinksy-Paul. States Energy Storage Policy Best Practices for Decarbonization. Sandia National Laboratories | Clean Energy States Alliance. February 2023.

[153] Lawrence Berkeley National Laboratory. Perceptions of Large-Scale Solar Project Neighbors: Results From a National Survey. April 2024.

[154] The Washington Post. Washington Post-University of Maryland Climate poll. July 13, 2023.

toward utility-scale PV development.[155] Utility-scale wind and solar project developers when surveyed have reported that opposition to solar and wind has become more prevalent and more expensive to deal with than it was 5 years ago, and, they say that community opposition is currently one of the leading causes of project cancellations. However, 75% of utility-scale wind and solar developers also agreed that increased community engagement results in fewer project cancellations.[156]

To bolster community engagement and establish best practices around siting large-scale solar projects at the national level, the U.S. Department of Energy created the Renewable Energy Siting through Technical Engagement and Planning (R-STEP) program. This program helps communities better plan for and meaningfully engage in the development of large-scale renewable energy and energy storage projects by supporting state-level programs that serve as resources for their local areas. R-STEP also acts as a resource for state-based entities to share information and best practices with one another. Through knowledge sharing, these entities are able to help actors in their states deploy renewable energy projects in ways that are informed by meaningful community engagement.[157]

Additionally, the U.S. Department of Energy's Solar Energy Evolution and Diffusion Studies (SEEDS) funding opportunity, aims to spur social science research that leads to actionable solutions for improving the large-scale solar siting process. In the most recent round of funding under this program, announced in December 2023, SEEDS specifically solicited proposals for research on community acceptance and opposition to large-scale solar.[158]

Longstanding programs like the U.S. Department of Energy's SolSmart program, which encourages local governments to increase solar energy deployment by providing national recognition at multiple levels of designation and technical assistance with flexible implementation of solar-friendly actions,[159] and the Solar Energy Innovation Network program, which supports teams across the United States pursuing novel applications of solar and other distributed energy resources with goal of finding robust and replicable solutions,[160] also aim to increase social acceptance of PV systems.

3.9.4 International trade issues

The U.S. PV market faced significant headwinds in 2022 because of actions intended to address accusations of forced labour within the supply chain – namely the Hoshine Withhold Release Order (WRO) and the Uyghur Forced Labor Prevention Act. These actions delayed and/or halted module shipments until adequate documentation could be produced attesting to

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[155] USA Today. Inside how wind and solar energy are being restricted across the US. February 4, 2024.

[156] Lawrence Berkeley National Laboratory. Survey of Utility-Scale Wind and Solar Developers Report. January 2024.

[157] U.S. Department of Energy. Renewable Energy Siting through Technical Engagement and Planning. Accessed June 2024.

[158] U.S Department of Energy. Funding Notice: Solar Energy Evolution and Diffusion Studies 4 (SEEDS 4). December 14, 2023.

[159] Gao, Xue, Casey Canfield, Tian Tang, and John Cornwell. Encouraging voluntary government action via a solar-friendly designation program to promote solar energy in the United States. PNAS. March 2022.

[160] National Renewable Energy Laboratory. Solar Energy Innovation Network. Accessed July 2023.

the lack of forced labour in the supply chain. Accusations of circumvention of anti-dumping and countervailing duties (AD/CVD) were also levelled at manufacturers in Cambodia, Malaysia, Thailand, and Vietnam, initiating an investigation. In August 2023, the final determination of the investigation found that some, though not all, of the Chinese companies accused of circumventing AD/CVD were circumventing.[161] However, the immediate impact of this determination was mitigated by President Biden having declared an emergency with respect to the electric grid reliability and waiving the imposition of duties resulting from the AD/CVD circumvention investigation until June 2024.

Import levels decreased in Q3 2021 as a result of these headwinds. However, after the 2-year waiver of new AD/CVD duties was announced in June 2022, imports had grown steadily over the course of about a year and a half before hitting a plateau in Q3 2023. In 2023, module imports were nearly double the levels that they were in 2022 (see Figure 6).[162] Installers and developers reported an easing of supply chain constraints in 2023, with record growth in 2023 in part driven by the deployment of delayed projects.[163] Despite record increases in domestic manufacturing capacity, the vast majority of PV modules deployed within the United States remain imported.[164]

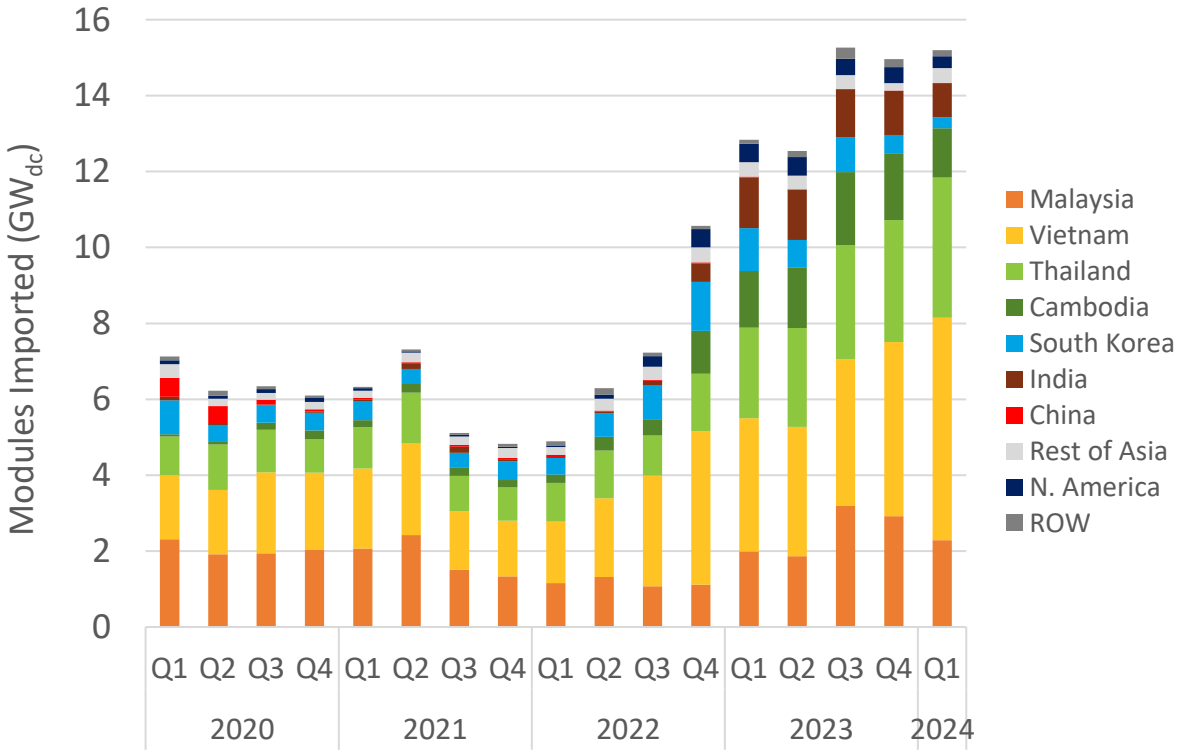

Figure 6 Total U.S. module imports by region. [165]

[161] U.S. Department of Commerce. Department of Commerce Issues Final Determination of Circumvention Inquiries of Solar Cells and Modules from China. August 18, 2023.

[162] National Renewable Energy Laboratory. Spring 2024 Quarterly Solar Industry Update. May 2024.

[163] Wood Mackenzie/SEIA. US Solar Market Insight Full Report 2023 Year in Review. March 2024.

[164] National Renewable Energy Laboratory. Spring 2024 Quarterly Solar Industry Update. May 2024.

[165] Id.

3.10 Financing and cost of support measures

The diversity of PV support measures within the United States is matched by the diversity of funding sources for support schemes. Funding is available from the government in the form of tax credits, grants, and loans at the federal, state, and local levels. Costs are also born indirectly through increased electricity prices to support renewable portfolio standards and renewable energy credits. There are also various green banks established across the United States. Green Banks are public, quasi-public, or non-profit financing entities that leverage public and private capital to pursue goals for clean energy projects that reduce emissions.

3.11 Grid integration policies

3.11.1 Grid connection policies

Thirty-seven states plus the District of Columbia and Puerto Rico have statewide interconnection procedures for , while thirteen states have not adopted state-wide procedures.[166]

Within the United States, electric transmission system operators (independent system operators, regional transmission organizations, or utilities) require projects seeking to connect to the grid, which usually identify themselves via an interconnection request, to undergo a series of impact studies before they can be built. This process establishes what new transmission equipment or upgrades may be needed before a project can connect to the system and assigns the costs of that equipment. The lists of projects in this process are known as “interconnection queues”. Once the studies are successfully completed, the transmission system operators create an interconnection agreement with the project owner that stipulates operational terms and cost responsibilities. At any point during this process, a project can be withdrawn from the queue.[167]

According to a Lawrence Berkeley National Lab study, at approximately 1,1 TW_{ac} in the interconnection queue in 2023, solar projects account for largest share of the 2,6 TW_{ac} of generation capacity in the queue (see Figure 7**Error! Reference source not found.**).[168] A further 1,0 TW_{ac} of storage is also in the queue, with over half of solar and storage capacity in the queue being from hybrid projects. Only 13% of proposed solar projects (and 10% of solar plus battery projects) entering queues from 2000 to 2018 have reached commercial operations. As the number of projects in the queues have grown, the average time spent in queues has increased over time. The typical projects completed in 2022-2023 took 5 years from interconnection request to commercial operation. This compares to 3 years in 2015 and less than 2 years in 2008.

[166] Freeing the Grid. Interconnection Key Takeaways. Accessed June 2024.

[167] Bothwell, Brian and Young, Chuck. Utility-Scale Energy Storage: Technologies and Challenges for an Evolving Grid. U.S. Government Accountability Office. March 2023.

[168] Rand, Joseph et al. Queued Up: 2024 Edition - Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2023. Lawrence Berkeley National Laboratory. April 2024.

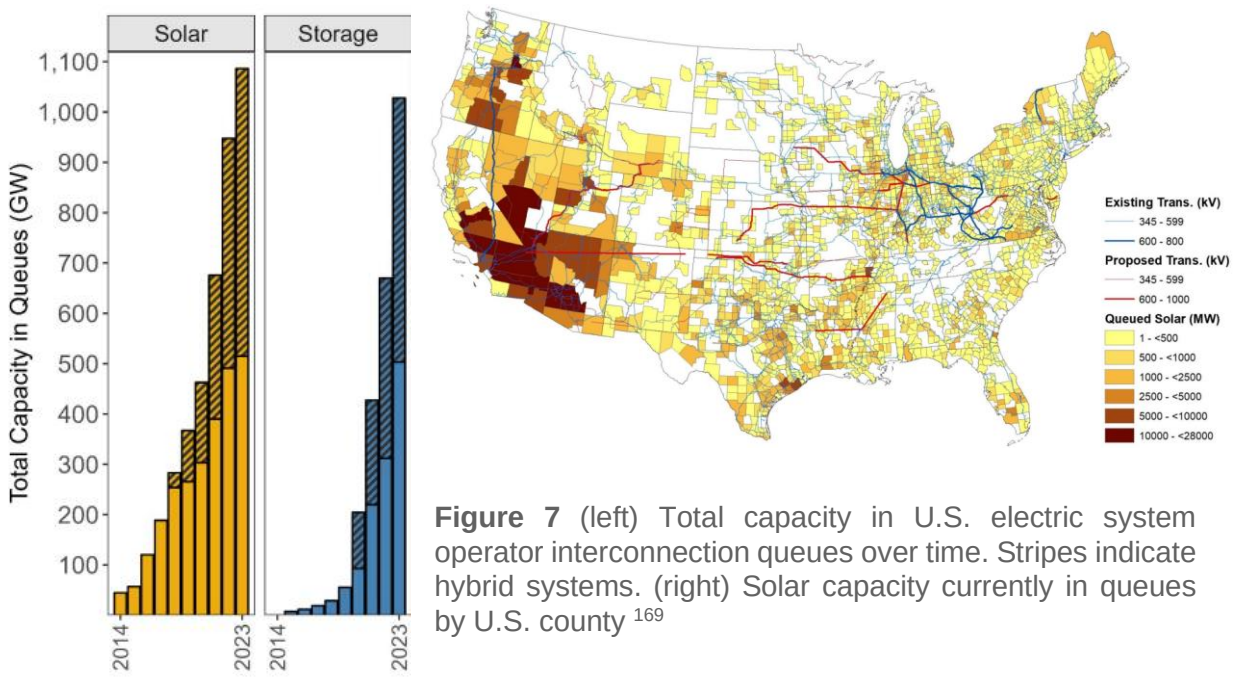

Figure 7 (left) Total capacity in U.S. electric system operator interconnection queues over time. Stripes indicate hybrid systems. (right) Solar capacity currently in queues by U.S. county [169]

In July 2023, the Federal Energy Regulatory Commission issued order 2023, which aims to expedite and improve the grid interconnection process through multiple methods. The rule implements a cluster study process that allows for a group interconnection study rather than sequential inteconnection studies, it enhances financial withdrawal penalties to discourage withdrawals from the queue, and places firm study deadlines and penalties for missig the study deadlines.[170] This rule took effect on November 6, 2023 and transmission providers had until April 3, 2024 to file compliance paperwork.[171]

In general, interconnection cost data remain difficult to collect and vary by location, however costs have grown substantially over time, with broader transmission system upgrades being the primary driver.[172]

Different rules govern the grid connection processes for residential systems, which generally have to go through permitting and inspection processes dictated by their local governmentsin addition to utility approval to build.[173] Many states of mandated interconnection application timelines for the pre-installation approval phase, and while some applications are not reviewed

[169] Rand, Joseph et al. Queued Up: 2024 Edition - Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2023. Lawrence Berkeley National Laboratory. April 2024.

[170] National Renewable Energy Laboratory. Fall 2023 Solar Industry Update. October 26, 2023.

[171] U.S. Federal Energy Regulatory Commission. Explainer on the Interconnection Final Rule. Accessed June 2024.

[172] Lawrence Berkeley National Laboratory. Generator Interconnection Costs to the Transmission System | Energy Markets & Policy. Accessed July 12, 2024.

[173] Cook, Jeff; Akar, Sertac; Chang, Danny; Fensch; Anneliese; Nissen, Katie; O'Shaughnessy, Eric; Kaifeng, Xu. SolarAPP+ Performance Review (2023 Data). National Renewable Energy Lab. June 2024.

and approved within those timelines, the timeline has dropped from 10-32 business days in 2015 to 0-12 business days in 2020.[174]

3.11.2 Grid access policies

For large-scale photovoltaic generators, grid access and offtake is usually dictated through long-term contracts, however the details of these contracts can vary significantly.[175] In general, the balance between supply and demand in the United States energy grid is maintained by price signals, including negative pricing when necessary or offers from generators to curtail at some level of compensation, known as decremental bids.[176] However, orders to reduce output, known as curtailments, may also be used when price signals are insufficient.[177] There are two types of curtailments: system-wide curtailments that occur when there is an oversupply and localized curtailments that occur when the amount of power from one transmission point to another is controlled for congestion management.[178] Both types of curtailment have been growing within the United States, as renewable energy penetration grows.[179] For example, in California in 2023, 2,7 TWh were curtailed including wind and solar, with the majority the result of localized curtailment/congestion.[180] Solar accounts for over 90% of that curtailment.[181] Curtailment risk can have an impact on the long-term contracts governing PV installations,[182] and have led to the creation of wider markets to better balance supply and demand – like California's Western Energy Imbalance Market which avoided 310 GWh of curtailements in 2023[183] – as well as being one of the driving factors behind the boom in energy storage projects.

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[174] Fekete, Emily S.; Cruce, Jesse R.; Dong, Shiyuan; O'Shaughnessy, Eric; Jeff; Cook. A Retrospective Analysis of Distributed Solar Interconnection Timelines and Related State Mandates. National Renewable Energy Lab. January 2022.

[175] O'Shaughnessy, Eric; Cruce, Jesse R.; Xu, Kaifeng. Rethinking solar PV contracts in a world of increasing curtailment risk. Energy Economics, Volume 98, 2021, pp. 105264.

[176] O'Shaughnessy, Eric; Cruce, Jesse R.; Xu, Kaifeng. Too much of a good thing? Global trends in the curtailment of solar PV. Solar Energy, Volume 208, 2020, pp. 1068-1077.

[177] U.S. Energy Information Administration. Solar and wind power curtailments are rising in California October 30, 2023.

[178] Micek, Kassia. US CURTAILMENT TRACKER: CAISO curtailments reach record in March, systemwide curtailments hit nine-month high | S&P Global Commodity Insights. S&P Global Market Intelligence, Benjamin Morse (ed.). April 25, 2023.

[179] Wilson, Adam. Curtailment, congestion costs rise as transmission upgrades lag renewable growth. S&P Global Market Intelligence. November 2, 2023.

[180] California Independent System Operator. Wind and Solar Curtailment December 31, 2023. December 31, 2023.

[181] U.S. Energy Information Administration. Solar and wind power curtailments are rising in California October 30, 2023.

[182] O'Shaughnessy, Eric; Cruce, Jesse R.; Xu, Kaifeng. Rethinking solar PV contracts in a world of increasing curtailment risk. Energy Economics, Volume 98, 2021, pp. 105264.

[183] Market Performance and Advanced Analytics. Western Energy Imbalance Market Benefits Report Fourth Quarter 2023. California ISO. January 2024.

Grid access fees for residential and/or commercial customers have also been on the rise for several years,[184] with Hawaii and North Carolina joining the ranks of New York, South Carolina, and others in 2023.[185] Notably, California's final NEM 3.0 rules did not include a grid-participation charge that had been in the draft proposal.[186] However, in general, residential installations in the United States are not subject to curtailment.

[184] North Carolina Clean Energy Technology Center, The 50 States of Solar: States Eye Grid Access Fees, Time-Varying Rates, and Storage in Net Metering Successor Tariff Design During 2021, January 2022.

[185] North Carolina Clean Energy Technology Center, The 50 States of Solar: 2023 Policy Review and Q4 2023 Quarterly Report, January 2024.

[186] National Renewable Energy Laboratory. Winter 2023 Solar Industry Update. January 2023.

4 INDUSTRY

As discussed in Section 3.2.2, the Inflation Reduction Act contained significant incentives for domestic manufacturing across the PV supply chain. As of May 2024, there had been over 300 GW_{dc} of manufacturing capacity announced across the solar supply chain, including polysilicon, wafer, cells, ingot, tracking, production tools, inverters, and other module components across 97 new facilities or expansions. While announcements are not guarantees, the list of companies includes several current large domestic manufacturers such as First Solar, Qcells, and Nextracker as well as global leaders such as Canadian Solar, Enphase, JA Solar, LONGi, Maxeon, Meyer Burger, and Trina.[187]

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

Table 17: Silicon feedstock, ingot and wafer producer's production information for 2023[188]

Manufacturers	Process & technology	Total Production	Product destination	Price
DC Alabama	Silicon feedstock	42 000	Not Available	Not Available
Globe Metallurgical	Silicon feedstock	16 000	Not Available	Not Available
Mississippi Silicon	Silicon feedstock	36 000	Not Available	Not Available
WVA Manufacturing	Silicon feedstock	73 000	Not Available	Not Available
Globe Metallurgical	Silicon feedstock	24 000	Not Available	Not Available
Hemlock Semiconductor Corporation	Polysilicon (Siemens)	32 000	Not Available	Not Available
REC Silicon	Polysilicon (FBR)	18 000	Not Available	Not Available
REC Silicon	Silanes	2 000	Not Available	Not Available
Wacker Polysilicon North America	Polysilicon (Siemens)	19 000	Not Available	Not Available

[187] National Renewable Energy Laboratory. Spring 2024 Solar Industry Update. May 14, 2024.

[188] U.S. Department of Energy. Solar Manufacturing Map. Accessed January and June 2024.

CubicPV	c-Si Wafers	Not Available (20 MW_{dc}/yr capacity)	Not Available	Not Available

Wacker Polysilicon and Hemlock Semiconductor Corporation both produce polysilicon for both the solar and semiconductor industries. Total production values within Table 17 refers to both solar and semiconductor polysilicon production. Production values are estimates based on previously published capacities and publicly available data.[189] Wacker also has significant polysilicon production capacity in Germany. REC Silicon confirmed in February 2023 that they were no longer producing polysilicon at their facility in Montana, and their facility began operating at the end of 2023, although first shipments were delayed to Q2 2024.[190]

CubicPV is currently the only domestic wafer manufacturer in the United States. See Figure 8 for the locations of the facilities listed in Table 17.

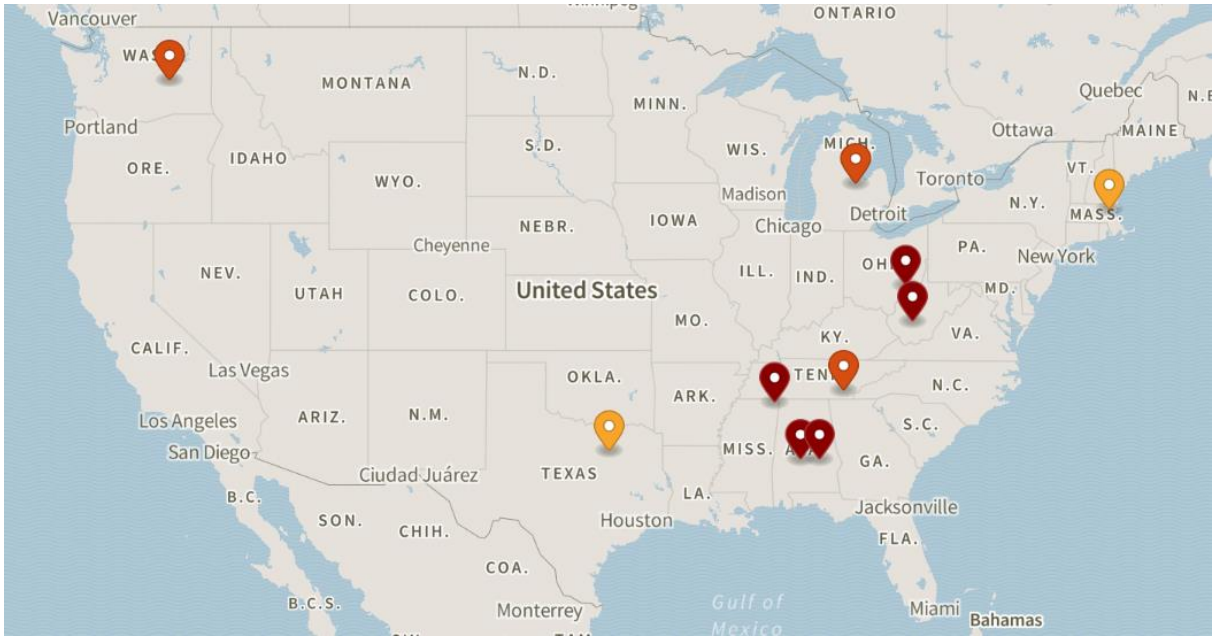

Figure 8 Domestic silicon feedstock (dark red), polysilicon (bright red), and wafer (orange) manufacturing facilities and company headquarters as of June 2024.[191]

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,

[189] Id.

[190] Norman, Will. REC Silicon to ship polysilicon from Moses Lake plant in Q2. PV Tech. May 2, 2024.

[191] U.S. Department of Energy. Solar Manufacturing Map. Accessed June 2024.

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 manufacturing together with production capacity information is summarised in Table 18 below and depicted in Figure 9.

Table 18: PV cell and module production and production capacity information for 2023

Cell/Module manufacturer	Technology	Total Production [MW]		Maximum production capacity [MW/yr]	
		Cell	Module	Cell	Module
Wafer-based PV manufactures[192]					
Auxin Solar	c-Si	-	Not Available	-	150
CHERP Inc.	c-Si	-	Not Available	-	15
Crossroads Solar	c-Si	-	Not Available	-	50
GAF Energy	c-Si	-	Not Available	-	300
Heliene	c-Si	-	Not Available	-	800
Hightec Solar	c-Si	-	Not Available	-	100
JinkoSolar	c-Si	-	Not Available	-	400
Merlin Solar	c-Si	-	Not Available	-	5
Mission Solar	c-Si	-	Not Available	-	300
Qcells	c-Si	-	Not Available	-	5100
Silfab Solar	c-Si	-	Not Available	-	800
SPI Energy / Solar4America	c-Si	-	Not Available	-	700
Sunspark USA/SolarMax Technology	c-Si	-	Not Available	-	250
SunTegra	c-Si	-	Not Available	-	10
Sub-totals	**c-Si**	**-**	**3690 (est.)[193]**	**-**	**8 980**
Thin film manufacturers					

[192] U.S. Department of Energy. Solar Manufacturing Map. Accessed January 2024 and June 2024.

[193] Value deduced from c-Si cell imports in 2023. U.S. Census Bureau. USA Trade Online. HTS code 8541420010. Accessed April 2024.

First Solar	CdTe	4 440[194]	4 440[195]	6 300[196]	6 300[197]
Toledo Solar	CdTe	Not Available	Not Available	100	100
Sub-totals	**CdTe**	**Not Available**	**Not Available**	**6 400**	**6 400**
Totals		**4 500 (est.)**	**8 200 (est.)**	**6 400**	**15 280**

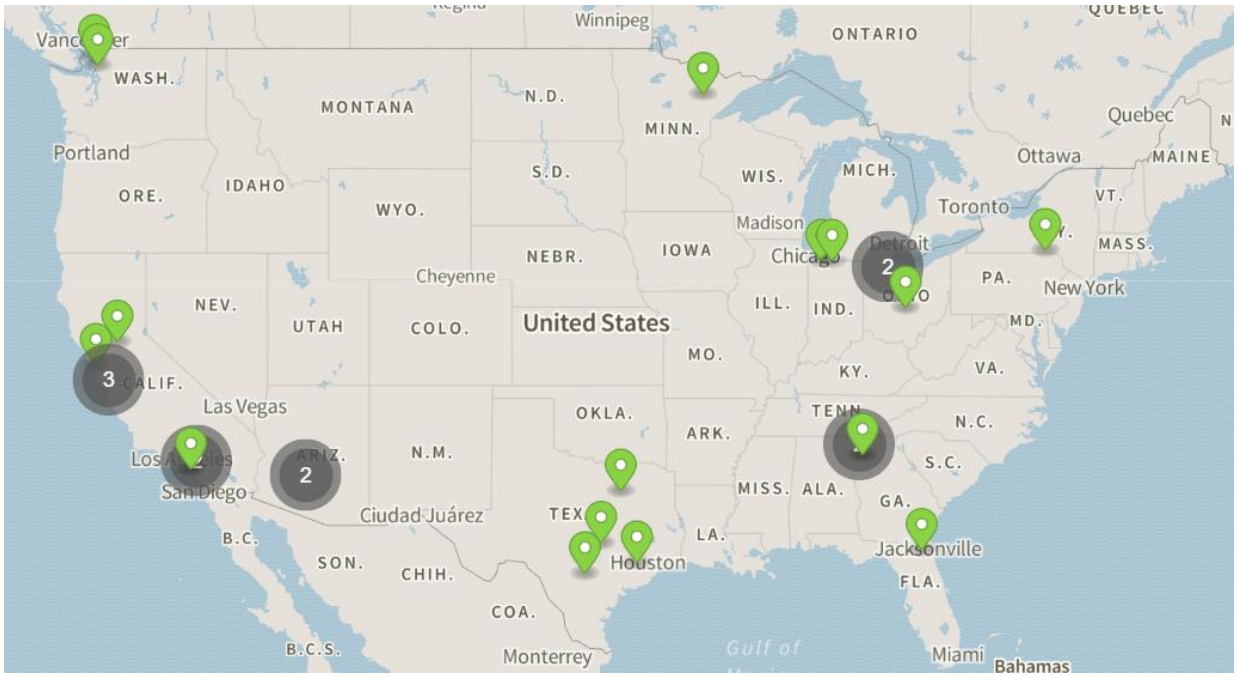

Figure 9 Domestic PV module manufacturing facilities and company headquarters as of June 2024.[198]

4.3 Manufacturers and suppliers of other components

Structural balance-of-system (S-BOS), electrical balance-of-system (E-BOS), inverters, and various module components such as sealants, encapsulant, and float glass continue to be produced in the United States (see Figure 10).[199] Recycling facilities are also a growing part of

[194] PV Tech Research. PV Manufacturing & Technology Quarterly Report - Release 32 - February 2024.

[195] Id.

[196] U.S. Department of Energy. Solar Manufacturing Map. Accessed January 2024 and June 2024.

[197] Id.

[198] U.S. Department of Energy. Solar Manufacturing Map. Accessed June 2024.

[199] Id.

the domestic solar supply chain, as more of an emphasis is being place on the life cycle of the solar panel.

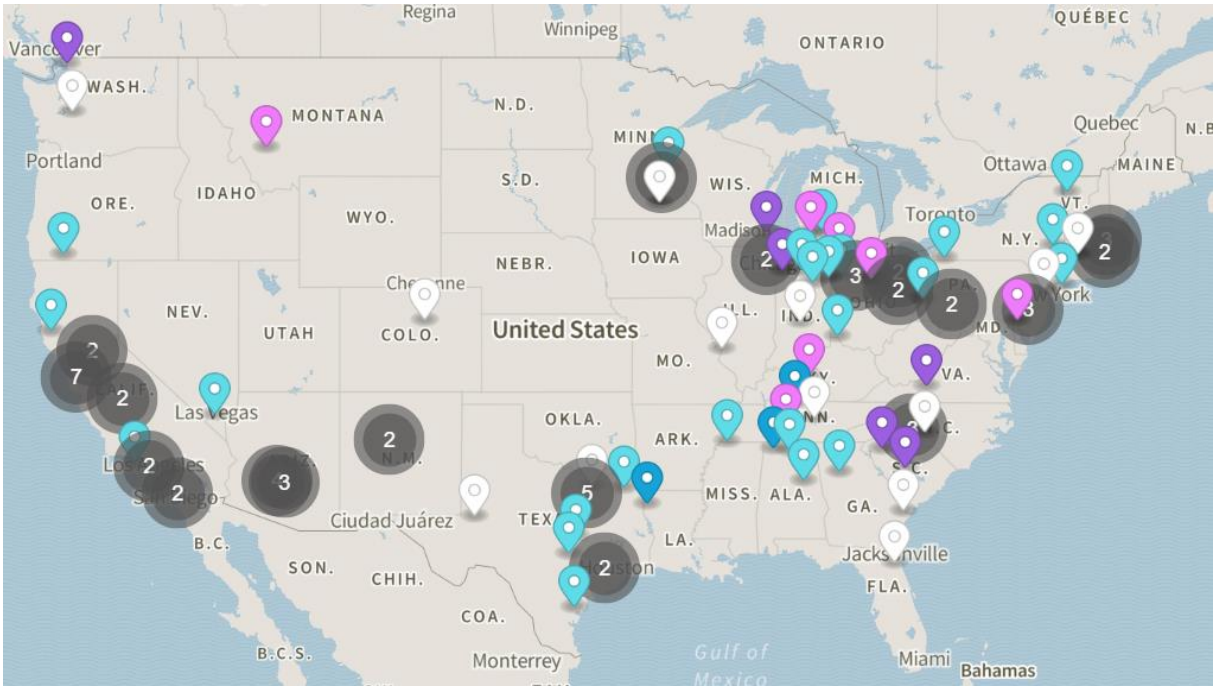

Figure 10 Domestic S-BOS (dark blue), E-BOS (light blue), inverter (purple), component (pink), and recycling (white) facilities and company headquarters.[200]

Battery implementation represents a 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. As discussed in Section **Error! Reference source not found.**, s everal forces are working to drive greater battery attachment rates in the United States including time-of-use rates and tax credits available to individuals and businesses for installing storage systems, as well as tax credits available to manufacturers producing storage systems.

[200] Id.

5 PV IN THE ECONOMY

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

5.1 Labour places

Table 19: Estimated PV-related full-time labour places in 2023

Market category	Number of full-time labour places[201]
Research and development (not including companies)	Not Segmented
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	33 273
Distributors of PV products and installations	212 117
Other	34 057
Total	279 477

5.2 Business value

Table 20: Rough estimation of the value of the PV business in 2023 (VAT is excluded)

Sub-market	Capacity installed [MW_{ac}]	Average price [US$/$W_{ac}$]	Value [US$]	Sub-market [US$]
Off-grid	Not Available	Not Available	Not Available	Not Available
Grid-connected residential	6 556	2,49	16 324 440 000	16 324 440 000
Grid-connected commercial and industrial	1 320	1,78	2 349 600 000	2 349 600 000
Grid-connected centralized	18 443	1,16	21 393 880 000	21 393 880 000
Value of PV business in 2023				40 067 920 000

[201] Interstate Renewable Energy Council. National Solar Jobs Census 2023. September 2024.

6 INTEREST FROM ELECTRICITY STAKEHOLDERS

6.1 Structure of the electricity system

In certain states and regions, regulated utilities own all generation, transmission lines, distribution lines, and directly sell to retail customers. Since the 1990's other regions have become "deregulated", where these different pieces are broken up and generation companies are separate from distribution companies. In deregulated areas, customers can choose where to purchase their electricity. In 2021, 54% of the electricity produced in the United States was from projects owned by electric utilities, 45% by Independent Power Producers (IPPs), and the remaining 1% was imported from Mexico and Canada. Segmenting electric utilities further, 34% of the electricity was produced from projects owned by Investor-Owned Utilities (IOUs), 15% from government owned utilities, and 5% from cooperative utilities.[202]

Regulated utilities plan for investment to service load, which must be approved by regulators, with the cost passed onto customers through rate tariffs. In deregulated markets, centralized wholesale markets run by regional transmission organizations (RTOs) or Independent System Operators (ISOs) act as grid operators, creating a platform for generators to sell power to load serving entities; under this model, the investment risk is born by the electric supplier, not the end customer. Interstate electricity sales, including wholesale markets, are regulated by the Federal Energy Regulation Commission.

Electric retailers are also regulated by the North American Electric Reliability Corporation (NERC) to ensure grid reliability. In certain markets, RTOs operate capacity auctions and in some instances ancillary service markets to create this reliability.[203]

States and regions do not always fit into regulated or deregulated market structures, but may deregulate a portion of the electricity market, or rely on electricity or transmission markets where needed. For example, vertically integrated utilities still trade in wholesale markets with other utilities during certain times of the year to satisfy their demand needs.

6.2 Interest from electricity utility businesses

PV activity is heavily impacted by state regulations and the how energy markets are set up in different regions. In regulated markets, regulated utilities are the only entities allowed to sell power, and therefore PV build-out must be done through the regulators and the regulated-utilities. Some states have had to pass laws allowing for businesses to own and operate distributed PV systems on customer's property (otherwise known as third-party ownership, or TPO). The Public Utility Regulatory Policies Act (PURPA) provided opportunities for renewable energy deployment by, even in regulated markets, requiring utilities to purchase renewables at their avoided cost. However, as "avoided cost" is managed by the state, it has had a mixed effect in creating markets for PV.

[202] Edison Electric Institute. Industry Data. 2021. Accessed July 2024.

[203] Cleary, Kathryne; Palmer, Karen. US Electricity Markets 101. Resources for the Future. 2022.

Currently one of the largest barriers to greater PV deployment is transmission interconnection approval by ISOs and RTOs of PV systems. Lawrence Berkely National Laboratory estimates that there is more than 1 TW of solar projects waiting for interconnection approval.[204]

6.3 Interest from municipalities and local governments

Municipal and local government have acted as catalysts or barriers to further PV deployment. Lawrence Berkely National Laboratory found zoning, grid interconnection, and community opposition are three leading causes of project cancellation for solar projects.[205] In fact, 2023 was the first time that the number of countries restricting utility-scale solar projects (61) almost equalled the number of counties adding their first solar farm (62). Impediments to clean energy deployment include outright bans, moratoriums, height and setback regulations, noise limits, limits on the amount of agricultural land that can be used for solar, and local governments refusing to sign agreements with solar developers.[206]

However, municipal and local government have also supported further solar industry deployment. These include pro-solar laws, partnerships with solar companies, and solar electricity procurement. In 2021, six U.S. cities were already running on 100% renewable electricity and 130 North American cities and seven U.S. states committed to becoming 100% renewable energy powered by 2050.[207]

[204] Rand, Joseph et al. Queued Up: 2024 Edition - Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2023. Lawrence Berkeley National Laboratory. April 2024.

[205] Nilson, Robi; Hoen, Ben; Rand, Joe. Survey of Utility-Scale Wind and Solar Developers Report. Lawrence Berkely National Laboratory. 2024.

[206] National Renewable Energy Laboratory. Spring 2024 Quarterly Solar Industry Update. May 2024.

[207] Sierra Club. Check Out Where We Are Ready For 100%. April 2022. Accessed July 2024.

7 HIGHLIGHTS AND PROSPECTS

7.1 Highlights

Records were broken across the United States in 2023, from deployment to domestic manufacturing to imports as market disruptions from international trade issues decreased and policy and financial certainty increased as the Inflation Reduction Act was implemented. Solar PV – and increasingly solar+storage – continued to grow in popularity, while facing headwinds from growing interconnection queue timelines, increasing curtailment, increasing local opposition, and an uptick in prices.

7.2 Prospects

The Inflation Reduction Act (IRA) will shape PV manufacturing, financing, and deployment for the next decade at least within the United States. As programs targeting an equitable energy transition commence, access to PV power has the potential to be transformative. International trade issues continue to loom as the nascent manufacturing market seeks to protect itself, and it remains to be seen what sectors of the supply chain and business models will find success on U.S. shores.