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

2022

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

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

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What is IEA PVPS Task 1?

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental, and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers, and to enhance technology co-operation. An important deliverable of Task 1 is the annual "Trends in photovoltaic applications" report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the country National Survey Report for the year 2022. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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COVER PICTURE

Endangered San Joaquin kit foxes at California Valley Solar Ranch – image provided courtesy of Clearway Energy and H.T. Harvey & Associates, Ecological Consultants.

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1 INSTALLATION DATA

The photovoltaic (PV) power systems market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W_{dc} 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 2022 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2022, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

The United States' (U.S.) PV market experienced a rollercoaster year, with new grid-connected PV installations added in 2022 at approximately 21 100 MW_{dc} representing a decline since the record level of deployment achieved in 2021.[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 2022, there were more than 4 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 12,5 GW_{dc} in 2022[3], a 27% decline over 2021 levels.

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 2022, the United States installed 1,1 GW_{dc} of community solar projects – its second largest year ever after 2021, bringing cumulative capacity to 5,4 GW_{dc}.[4] The ownership structures of community solar projects can vary widely, and have been implemented by utilities, developers, and other organizations.

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

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[1] Wood Mackenzie/SEIA US Solar Market Insight®, Full report, Q2 2023, June 2023

[2] Id.

[3] Id.

[4] Id.

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 Solar Energy Industries Association (SEIA) and Wood Mackenzie.[5] These organizations survey nearly 200 installers, manufacturers, utilities, and state agencies to obtain granular installation data on installations in every state. Rather than using a capacity cutoff to differentiate between residential, commercial, and utility systems, Wood Mackenzie defines a system according to its contracted power off-taker.

Table 1: Annual PV power installed during calendar year 2022[6]

		Installed PV capacity in 2022 [MW]	AC or DC
	Decentralized	8 625	DC
	Centralized	12 502	DC
	Off-grid	Not Available	DC
	Total	21 127	DC

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

[6] Wood Mackenzie/SEIA US Solar Market Insight®, Full report, Q2 2023, June 2023

Table 2: PV power installed during calendar year 2022[7]

<table>
<tr><th colspan="3"></th><th>Installed PV capacity [MW]</th><th>Installed PV capacity [MW]</th><th>AC or DC</th></tr>
<tr><td rowspan="10">Grid-connected</td><td rowspan="3">BAPV</td><td>Residential</td><td rowspan="3">8 625</td><td>5 959</td><td>DC</td></tr>
<tr><td rowspan="2">Commercial and Industrial</td><td rowspan="2">2 667</td><td>DC</td></tr>
<tr><td>DC</td></tr>
<tr><td rowspan="3">BIPV</td><td>Residential</td><td rowspan="3">Not Available</td><td></td><td></td></tr>
<tr><td>Commercial</td><td></td><td></td></tr>
<tr><td>Industrial</td><td></td><td></td></tr>
<tr><td rowspan="3">Utility-scale</td><td>Ground-mounted</td><td rowspan="3">12 502</td><td>Not Available</td><td></td></tr>
<tr><td>Floating[8]</td><td>10</td><td>DC</td></tr>
<tr><td>Agricultural</td><td>Not Available</td><td></td></tr>
<tr style="display:none"></tr>
<tr><td colspan="2" rowspan="3">Off-grid</td><td>Residential</td><td rowspan="3">Not Available</td><td></td><td></td></tr>
<tr><td>Other</td><td></td><td></td></tr>
<tr><td>Hybrid systems</td><td></td><td></td></tr>
<tr><td colspan="2">Total</td><td></td><td colspan="2">21 127</td><td>DC</td></tr>
</table>

Table 3: Data collection process

If data are reported in AC, please mention a conversion coefficient to estimate DC installations.	Not Applicable
Is the collection process done by an official body or a private company/Association?	Collaboration between official body (DOE and NREL) and Association (SEIA)
Link to official statistics (if this exists)	http://www.seia.org/research-resources/us-solar-market-insight http://www.eia.gov/electricity/

[7] Id.

[8] Chopra, Sagar and Garasa Sagardoy, Daniel. Floating solar landscape 2022. Wood Mackenzie/SEIA. August 2022.

Table 4: The cumulative installed PV power in 4 sub-markets[9]

Year	Off-grid [MW]	Grid-connected distributed [MW]	Grid-connected centralized [MW]	Total [MW]
2010	Not Available	1 649	366	2 015
2011	Not Available	2 804	1 153	3 957
2012	Not Available	4 375	2 955	7 330
2013	Not Available	6 283	5 845	12 129
2014	Not Available	8 606	9 762	18 368
2015	Not Available	11 847	13 995	25 842
2016	Not Available	16 201	24 866	41 067
2017	Not Available	20 806	31 342	52 147
2018	Not Available	25 418	37 460	62 879
2019	Not Available	30 467	45 950	76 418
2020	Not Available	36 065	60 262	96 327
2021	Not Available	43 002	77 427	120 429
2022	Not Available	51 627	89 929	141 556

Table 5: Other PV market information

	2022
Number of PV systems in operation in your country	4 043 034: (Residential: 3 908 565, Industrial: 130 474, Utility-scale: 3 995)[10]
Decommissioned PV systems during the year [MW]	Not Available
Repowered PV systems during the year [MW]	Not Available

[9] Id.

[10] Id.

Table 6: PV power and the broader national energy market

	Data	Year
Total power generation capacities [GW]	1 200 GW_{ac}[11]	2022
Total renewable power generation capacities (including hydropower) [GW]	348 GW_{ac}[12]	2022
Total electricity demand [TWh]	4 302 TWh[13]	2022
New power generation capacities installed [GW]	37,4 GW_{ac} (including 4,1 GW_{ac} of storage)[14]	2022
New renewable power generation capacities (including hydropower) [GW]	26,3 GW_{ac}[15]	2022
Estimated total PV electricity production (including self-consumed PV electricity) in [TWh]	204,1 TWh[16]	2022
Total PV electricity production as a % of total electricity consumption	5,1%[17]	2022
Average yield of PV installations (in kWh/kW_{dc})	1 985[18]	2022

[11] U.S. Energy Information Administration, Electric Power Monthly, Table 6.1, February 2023.

[12] Id.

[13] U.S. Energy Information Administration, Electricity Data Browser, net generation for all sectors, annual, accessed April 2023.

[14] U.S. Energy Information Administration, Preliminary Monthly Electric Generator Inventory (860M), March 2023 and Energy Information Administration, Short Term Energy Outlook, April 2023.

[15] Id.

[16] U.S. Energy Information Administration, Electricity Data Browser, net generation for all sectors, annual, accessed April 2023.

[17] Id.

[18] U.S. Energy Information Administration, Electricity Data Browser, net generation for all sectors, annual, accessed April 2023 and U.S. Energy Information Administration, Electric Power Monthly, Table 6.1, February 2023.

1.3 Key Enablers of PV Development

Key demand drivers for PV development within the United States include energy storage, which surpassed 4,8 GW (13,8 MWh) of annual installations in 2022,[19] as well as electric vehicle demand, which increased by nearly 1 million vehicles in 2022.[20] 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.[21] 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.[22] 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.

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[19] Wood Mackenzie Power & Renewables, U.S. Energy Storage Monitor, Q2 2023 Full Report. Values differ from EIA data as it includes more distributed storage, including a sizeable amount from Puerto Rico.

[20] Argonne National Lab. Light Duty Electric Drive Vehicles Monthly Sales Updates – Historical Data. Accessed June 2023.

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

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

Table 7: Information on key enablers.

	Description	Annual Volume	Total Volume	Source
Decentralized storage systems In MWh (MW)	Behind-the-meter battery storage systems, connected to the electric grid.	1 835 MWh (751 MW_{ac})	5 517 MWh (2 332 MW_{ac})	Wood Mackenzie Power & Renewables, U.S. Energy Storage Monitor, Q2 2023 Full Report.
Centralized storage systems In MWh (MW)	In-front-of-the-meter battery storage systems	11 991 MWh (4 006 MW_{ac})	25 984 MWh (9 301 MW_{ac})	Wood Mackenzie Power & Renewables, U.S. Energy Storage Monitor, Q2 2023 Full Report.
Residential Heat Pumps [#]	Unitary Heat Pumps	4 323 728	Not Available	Air-Conditioning, Heating, and Refrigeration Institute Monthly Shipment Report, December 2022
Electric cars [#]	Plug-in Electric Vehicles (car and light truck)	914 068	3 250 000 (est.)	Argonne National Lab, Energy Systems and Infrastructure Analysis, Light Duty Electric Drive Vehicles, Monthly Sales Update, May 2023[23]

[23] Argonne National Lab. Light Duty Electric Drive Vehicles Monthly Sales Updates – Historical Data. Accessed June 2023.

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module Prices

PV module prices are national weighted average delivered prices for silicon modules.[24] Due to the data sources used, prices are more in-line with turnkey pricing on standard systems for medium and large-scale installers.

Lowest module prices were found in utility-scale, fixed tilt applications (US$0,35/W) in the first quarter of 2022, while the highest module prices were found in the residential sector (US$0,56/W) in the fourth quarter of 2022. Module costs rose during 2022 because of inflation, trade uncertainty (including an investigation into circumvention of antidumping/countervailing duties and scrutiny of the supply chain to ensure compliance with forced-labour laws), high polysilicon costs, and state-level and national policy uncertainties.

Table 8: Typical module prices[25]

Year	Lowest price of a standard module crystalline silicon [US$/W]	Highest price of a standard module crystalline silicon [US$/W]	Typical price of a standard module crystalline silicon [US$/W]
2022	0,35	0,56	0,42

[24] Wood Mackenzie/SEIA US Solar Market Insight®, Full report, 2022 Year in review, March 2023

[25] Wood Mackenzie/SEIA US Solar Market Insight®, Full report, 2022 Year in review, March 2023

2.2 System Prices

Wood Mackenzie and SEIA use a bottom-up methodology based on tracked wholesale pricing of major solar components and data collected from interviewing industry stakeholders to model national average prices.[26] System prices are defined from the perspective of the seller, and national average PV system prices reflect the installed prices for a given quarter. Due to the data sources used, prices are more in-line with turnkey pricing on standard systems for medium and large-scale installers.

Nationally, system pricing increased year-over-year for all market segments (residential – up 7%, commercial – up 2%, small centralized (fixed tilt) – up 8%, small centralized (one-axis) – up 3%).[27] The main contributors to increased costs were inflation, pandemic-related supply chain disruptions, and higher logistics and labour costs. Partially offsetting these trends was commercial and centralized systems shifting to larger wafer sizes, which helped amortize the per-module installation costs over a higher number of watts.[28]

[26] Id.

[27] Id.

[28] Id.

Table 9: Turnkey PV system prices of different typical PV systems[29]

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.	3,06
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.	1,56
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 (fixed tilt)	Grid-connected, ground-mounted, fixed-tilt, 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.	0,87
Small centralized PV 1-20 MW (one-axis tracking)	Grid-connected, ground-mounted, horizontal single-axis tracking, 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.	0,97
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.	Not Available

[29] Values appear relatively unchanged to those reported in 2021 as sales tax was included in previous editions. In reality, solar PV system pricing increased year-over-year by 7% in the residential segment, 2% for commercial, 8% for small centralized (fixed-tilt), and 3% for small centralized (single-axis tracking) solar systems.

Table 10: National trends in system prices for different applications[30]

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]**
2022	3,06	Not Available	1,56	0,87 – 0,97

[30] Values appear relatively unchanged to those reported in 2021 as sales tax was included in previous editions. In reality, solar PV system pricing increased year-over-year by 7% in the residential segment, 2% for commercial, 8% for small centralized (fixed-tilt), and 3% for small centralized (single-axis tracking) solar systems.

2.3 Cost Breakdown of PV Installations

The cost breakdown of a typical 5-10 kW_{dc} roof-mounted, grid-connect, distributed PV system on a residential single-family house and a typical >10 MW_{dc} Grid-connected, ground-mounted, centralized PV systems at the end of 2022 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 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 summing the average end price to customer. The “low” and “high” categories are the lowest and highest quarterly average cost reported within each segment. These costs are individual posts, i.e. summing these costs do not give an accurate system price.

Wood Mackenzie and SEIA use a bottom-up methodology based on tracked wholesale pricing of major solar components to and data collected from interviewing industry stakeholders to model national average prices for a given quarter.[31] Due to the data sources used, prices are more in-line with turnkey pricing on standard systems for medium and large-scale installers.

[31] Id.

Table 11: Cost breakdown for a grid-connected roof-mounted, distributed residential PV system of 5-10 kW[32]

Cost category	Average [US$/W]	Low [US$/W]	High [US$/W]
Hardware			
Module	0,56	Not Available	Not Available
Inverter	0,37	Not Available	Not Available
Mounting material	0,09	Not Available	Not Available
Other electronics (cables, etc.)	0,24	Not Available	Not Available
Subtotal Hardware	**1,26**		
Soft costs			
Planning	0,72	Not Available	Not Available
Installation work	0,18	Not Available	Not Available
Shipping and travel expenses to customer	0,11	Not Available	Not Available
Permits and commissioning (i.e. cost for electrician, etc.)	0,08	Not Available	Not Available
Project margin	0,73	Not Available	Not Available
Subtotal Soft costs	**1,80**		
Total (excluding sales tax)	**3,06**		
Average sales tax	0,24		
Total (including sales tax)	**3,30**		

[32] Id.

Table 12: Cost breakdown for a grid-connected, ground-mounted, centralized PV systems of >10 MW[33]

Cost category	Average [US$/W]	Low [US$/W]	High [US$/W]
Hardware			
Module	0,41	0,42	0,40
Inverter	0,04	0,04	0,04
Mounting material	0,10	0,07	0,12
Other electronics (cables, etc.)	0,06	0,05	0,06
Subtotal Hardware	**0,61**		
Soft costs			
Planning	0,03	0,02	0,03
Installation work	0,09	0,08	0,10
Shipping and travel expenses to customer	0,06	0,05	0,06
Permits and commissioning (i.e. cost for electrician, etc.)	0,08	0,08	0,09
Project margin	0,08	0,08	0,08
Subtotal Soft costs	**0,34**		
Total (excluding sales tax)	**0,95**		
Average sales tax	0,04		
Total (including sales tax)	**0,99**		

[33] Id.

2.4 Financial Parameters and Specific Financing Programs

Most U.S. utility-scale PV systems—80% of installations in 2022, 86% cumulative—are owned by independent power producers, which sell their electricity under long-term contracts (see Figure 1).[34] 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.[35]

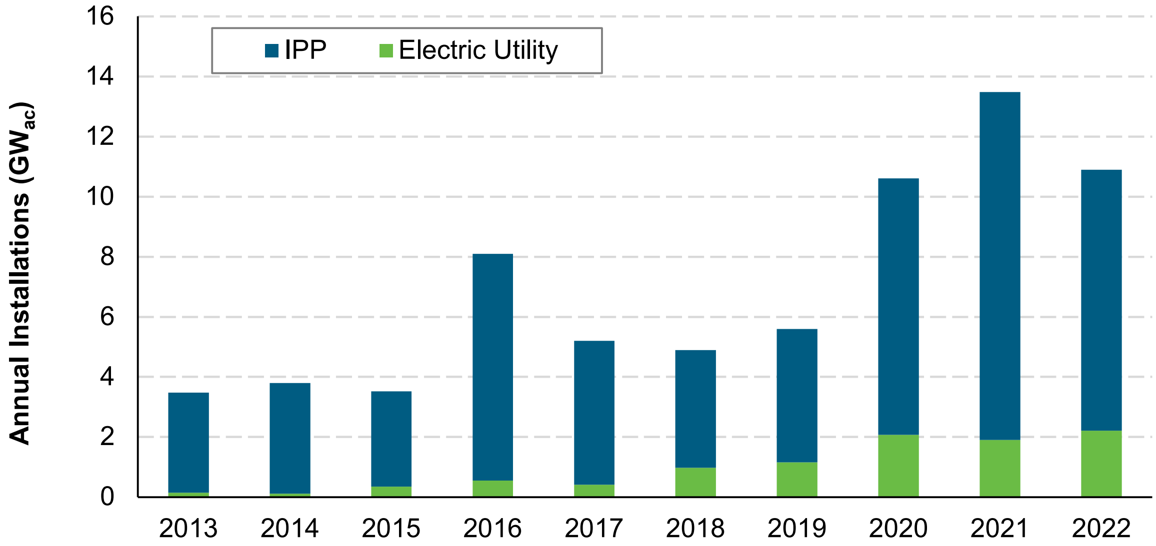

Figure 1 PV system asset ownership for systems ≥1 MW_{ac}. IPP = independent power producer[36]

For residential systems, third-party ownership represented about 20% of installations in 2022, while loans represented another 70%, and the remainder of systems being purchased with cash.[37] 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.

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[34] U.S. Energy Information Administration, Form 860, Early release 2022 data. June 2023.

[35] Id.

[36] Id.

[37] Wood Mackenzie/SEIA. US residential solar finance update: H1 2023®, April 2023

Table 13: PV financing information in 2022

Different market segments	Loan rate [%]
Average rate of loans – residential installations	4,5-12% (25-7 year)[38]
Average rate of loans – commercial installations	5% (20-year)[39]
Average cost of capital – industrial and ground-mounted installations	5% (20-year)[40]

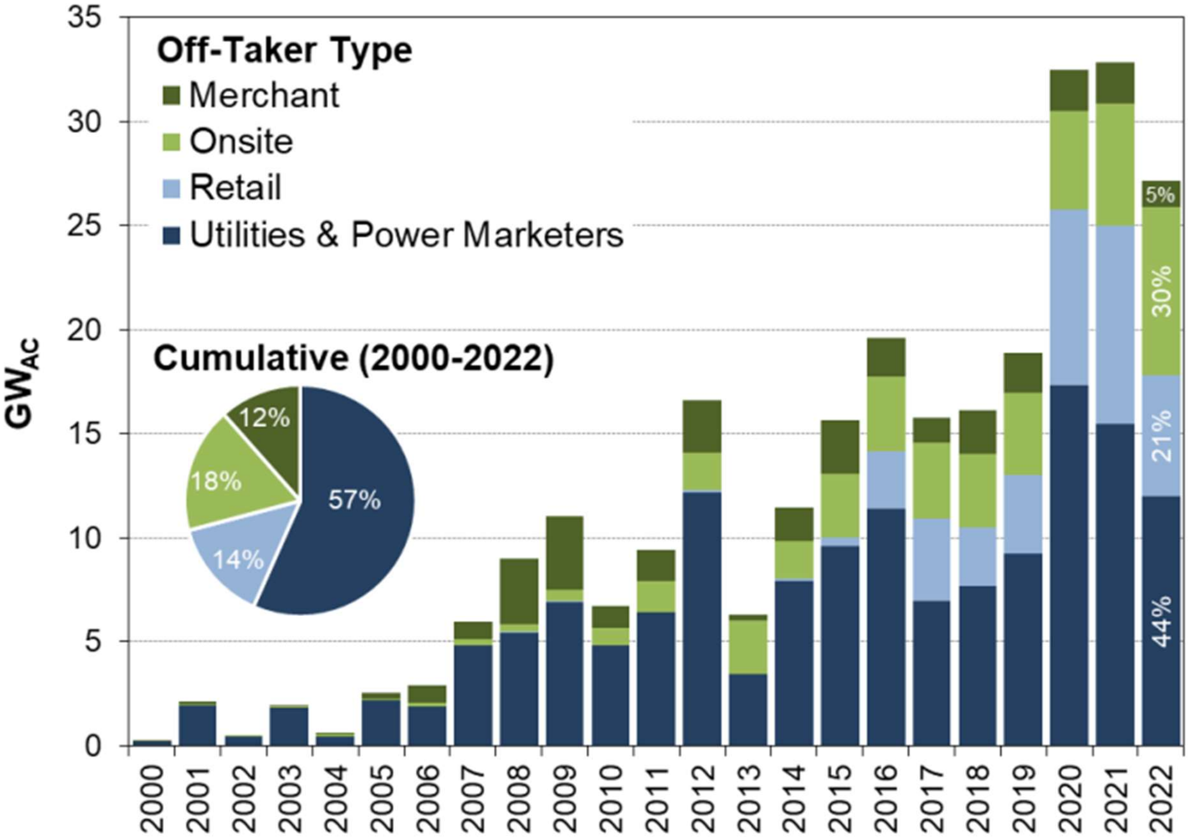
[38] Id.

[39] 20-Year High Quality Market (HQM) Corporate Bond Spot Rate, Jan 2022-Dec 2022.

[40] Id.

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 3.4.1 and Section 2.6, respectively)– and onsite projects are a growing share (see Figure 2).[41]



Sources: LBNL, ABB Ventyx, EIA, American Clean Power Association

Figure 2 Annual renewable capacity additions by off-taker type.[42]

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

[42] Id.

2.6 Merchant PV / PPAs / Corporate PPAs

Within the United States, corporate solar adoption continues to grow mainly as a result of off-site corporate solar procurement. One quarter of installed large-scale projects installed in 2021 featured one or more commercial buyers. Meta, Amazon, and Apple lead in off-site deployment, while Target, Prologis, and Walmart lead in on-site PV capacity. 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, the state of Virginia has seen 2 GW_{dc} of corporate solar deployment and is estimated to handle nearly 70% of global internet traffic.[43]

Similarly to the residential systems discussed in Section 2.4, approximately 70% of on-site corporate PV systems installed in 2022 were customer-owned and financed up-front using a combination of capital and loans. This is up from approximately 50% in 2019 because of financiers growing more comfortable with the risk profile of solar projects and loan offerings improving. The remaining 30% of corporate PV systems are third-party owned and financed through lease agreements or power purchase agreements.[44]

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.[45] 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.[46] According to BNEF, around 90% of corporate PPAs in the United States were virtual in 2022.[47] 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.[48] One or more commercial customers also often act as the anchor tenant for community solar projects, which continues to grow within the United States.[49]

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

[44] Id.

[45] Id.

[46] 3Degrees Staff. Renewable energy power purchase agreements. February 5, 2018. Accessed July 2023.

[47] Fernandez, Jaime. Corporate PPA Deal Tracker: November 2022. BloombergNEF. December 2022.

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

[49] Connelly, Caitlin. US community solar market outlook H1 2023. Wood Mackenzie. February 2023.

2.7 **Additional Country Information**

Table 14: Country information[50]

Retail electricity prices for a household [US$/kWh]	0,1512 (average)
Retail electricity prices for a commercial company [US$/kWh]	0,1255 (average)
Retail electricity prices for an industrial company [US$/kWh]	0,0845 (average)
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.[51]

[50] U.S. Energy Information Administration, Electricity Data Browser, average retail price of electricity in 2022, annual, accessed July 2023.

[51] 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[52]

Category	Residential		Commercial + Industrial		Centralized	
Measures in 2022	**On-going**	**New**	**On-going**	**New**	**On-going**	**New**
Feed-in tariffs	Yes	-	Yes	-	Yes	-
Feed-in premium (above market price)	Yes	-	-	-	-	-
Capital subsidies	Yes	-	Yes	-	Yes	-
Green certificates	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	-	-	-
Net-billing	Yes	-	Yes	-	-	-
Collective self-consumption and delocalized net-metering	Yes	-	Yes	-	Yes	-
Sustainable building requirements	Yes	-	Yes	-	-	-
BIPV incentives	-	-	-	-	-	-
Merchant PV facilitating measures	Yes		Yes		Yes	

[52] North Carolina Clean Energy Technology Center. DSIRE (dsireusa.org) Summary Tables. Accessed July 2023.

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.[53] 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.[54] 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.[55]

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

[54] 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.

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

3.2 Direct Support Policies for PV Installations

The most significant change in direct support policies within the United States in 2022 was undoubtedly the passage of the Inflation Reduction Act (IRA), a federal law which included – 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 (see Section 3.2.1).

At the state level, various changes to direct generation compensation measures, rate design, and solar ownership were also proposed throughout 2022. 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 (see Section 3.3.1).[56]

3.2.1 Inflation Reduction Act (IRA)

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.[57] The law also 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.[58]

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 3). 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.[59] 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.[60]

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[56] North Carolina Clean Energy Technology Center, The 50 States of Solar: 2022 Policy Review and Q4 2022 Quarterly Report, January 2023.

[57] 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.

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

[59] 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.

[60] 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.

	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 3 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.[61] 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. 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. 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 generated for the first 10 years of operation. These rates are adjusted annually for inflation and the rate in 2022 is 2.75 ¢/kWh.[62] All three solar deployment-related tax credits phase out over the course of several years (see Figure 3), 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.

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), 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

[61] 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.

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

wage requirements that must be met for projects 1 MW_{ac} or larger, otherwise the value of the tax credit is reduced by a factor of five.

There are two manufacturing-related tax credits within IRA. 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.[63] 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, polysilicon, wafers, solar glass, and ingot/wafer production tools were highlighted as priority areas within the PV supply chain.[64] 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 Figure 4). This is the shortest of the tax credits, beginning to phase out in 2030, and the value of the MPTC is not adjusted for inflation.

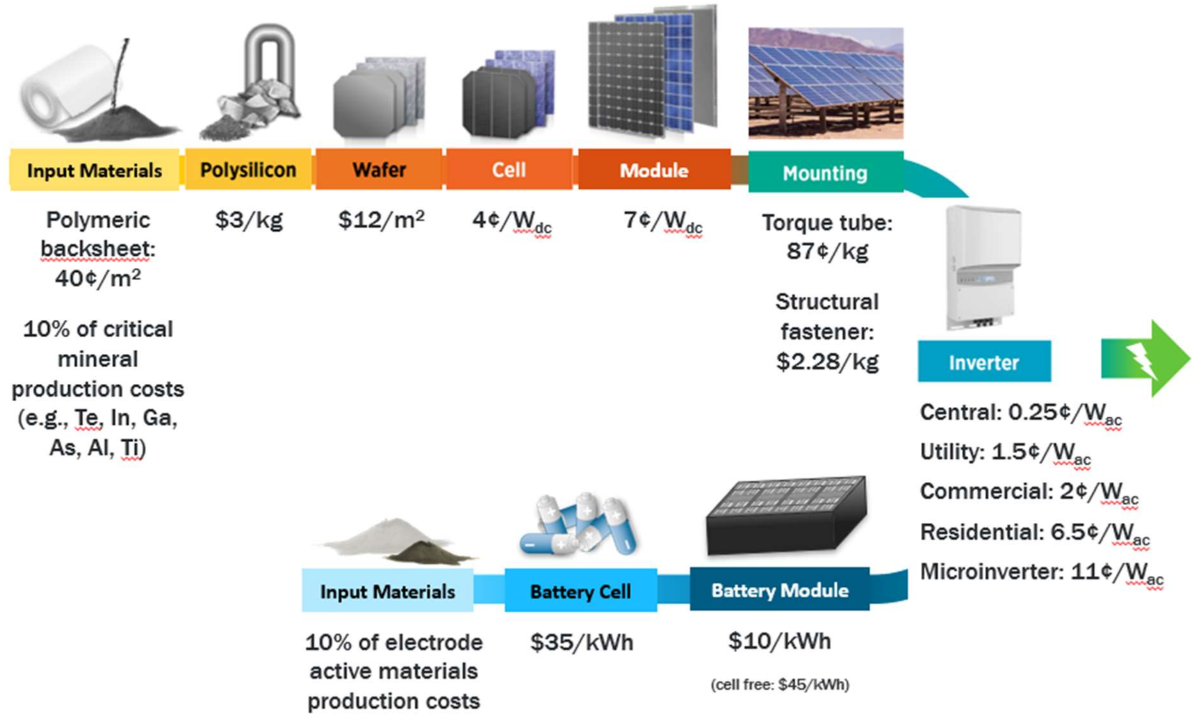

Figure 4 Components along the PV supply chain that are eligible for the MPTC. Wafer, cell, and module incentives apply to both thin film and crystalline silicon technology.

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

[63] 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.

[64] U.S. Internal Revenue Service. Additional Guidance for the Qualifying Advanced Energy Project Credit Allocation Program under Section 48C(e).

businesses taking advantage of the MPTC, receive the full value of their tax credit from the government in the form of a direct payment. The residential clean energy credit is the only credit that is ineligible for both direct payment and transferability.

Since the passage of IRA, domestic deployment projections have risen significantly and there have been announcements of manufacturing facilities up and down the supply chain.[65] It remains to be seen as more guidance is released by the U.S. Department of Treasury and the Internal Revenue Service and manufacturing facilities begin operations what the ultimate impact of these tax credits will be.

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

At the end of 2022, twenty-nine states, three territories, and Washington D.C., had RPS, while seven states and one territory had renewable power goals.[66] Four states – Rhode Island, California, Hawaii, and Connecticut – revised or enacted RPS or CES in 2022.[67] 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.[68] Sixteen states also had specific carve-outs for solar or distributed generation, typically in the range of 1-5% of retail sales.[69]

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.[70] Solar renewable energy credits (SRECs) are awarded to meet solar or distributed generation carve-outs.[71] 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-

[65] National Renewable Energy Laboratory. Fall 2022 Quarterly Solar Industry Update. October 2022.

[66] North Carolina Clean Energy Technology Center. Renewable & Clean Energy Standards. November 2022.

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

[68] Id.

[69] Id.

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

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

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.

3.3 Self-Consumption Measures

Nearly every state within the United States considered or implemented a rate design or policy change in 2022, including 32 states that considered changes to distributed generation compensation policies, 28 states considering a residential fixed charge or minimum bill increase, and 24 states and the District of Columbia considering changes to community solar policies and programs.[72] Every state (including the District of Columbia) 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 2022, 35 states and the District of Columbia have state-developed mandatory net metering rules for certain utilities, and 13 states have rules other than net-metering in place.[73]

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

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

Table 16: Summary of self-consumption regulations for small private PV systems in 2022[74]

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, 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, demand-side management (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

[74] North Carolina Clean Energy Technology Center. DSIRE (dsireusa.org) Summary Tables. Accessed July 2023.

3.3.1 California Net Metering (NEM) 3.0

The California Public Utilities Commission approved Net Metering 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 starting in April 2023. The Commission declined to adopt a grid participation charge or minimum bill in this proceeding, but will consider these in a broader ratemaking investigation.[75] The aim is 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.[76] California accounted for about 36% of U.S. residential PV and 19% of nonresidential (excluding utility-scale) PV installed in 2022, thus these new regulations will impact a large fraction of the U.S. distributed PV market.[77]

3.3.2 Other State Policy Changes

Overall, states moved away from traditional retail rate net metering in 2022, with the notable exception of Florida which saw its governor veto a proposed net metering successor tariff. Net billing is becoming the dominant successor tariff within the United States, although there remains a diversity of approaches to grid access fees, minimum bills, and the use of time-of-use rates.[78]

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

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

[77] Id.

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

3.4 Collective Self-consumption, Community Solar, and Similar Measures

3.4.1 Community Solar

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 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.[79]

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.[80] As discussed in Section 3.2.1, 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 will be allocated tax credits based on a number of different criteria.

As of June 2022, 22 states and the District of Columbia had passed legislation enabling community solar. 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. Twenty of these programs have some type of cap on capacity, funding, or community solar deployment that is eligible. Several states, including Florida, Texas, Arizona, and Georgia also have sizable community solar programs without enabling legislation, but instead utilities have voluntarily adopted community solar programs.[81]

Community solar installations declined 16% in 2022 compared to 2021, primarily driven by continued interconnection queue delays in key state markets. New York, which installed a record-breaking 532 MW_{dc} in 2022, made up 52% of the national market due to strong incentives.[82] Cumulatively, there was 5,3 GW_{dc} of community solar installed in the United States by the end of 2022.

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

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[79] Connelly, Caitlin. US community solar market outlook H1 2023. Wood Mackenzie. February 2023.

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

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

[82] Wood Mackenzie/SEIA US Solar Market Insight®, Full report, 2022 Year in review, March 2023.

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.[83] Some community solar programs have location/proximity requirements on community solar subscribers.[84] Currently 41 states and the District of Columbia allow some form of virtual net metering.[85]

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

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

[85] SEIA. Community Solar. Accessed July 2023.

3.5 Tenders, Auctions, and Similar Schemes

The United States does not use tenders, auctions, reverse auctions, or similar processes to grant PPAs for PV systems.

3.6 Other Utility-Scale Measures Including Floating and Agricultural PV

While dual-use PV, especially agricultural PV (or agrivoltaics), is gaining attention within the United States, it has yet to represent a significant fraction of installations – as typified by the FARMS (Foundational Agrivoltaic Research for Megawatt Scale) funding opportunity recently run by the U.S. Department of Energy.[86] 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 10 MW_{dc} of capacity additions estimated in 2022.[87]

Project size within the United States is growing (see Figure 5).[88] 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.[89]

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

[87] Chopra, Sagar and Garasa Sagardoy, Daniel. Floating solar landscape 2022. Wood Mackenzie/SEIA. August 2022.

[88] U.S. Energy Information Administration, Form 860, Early release 2022 data. June 2023.

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

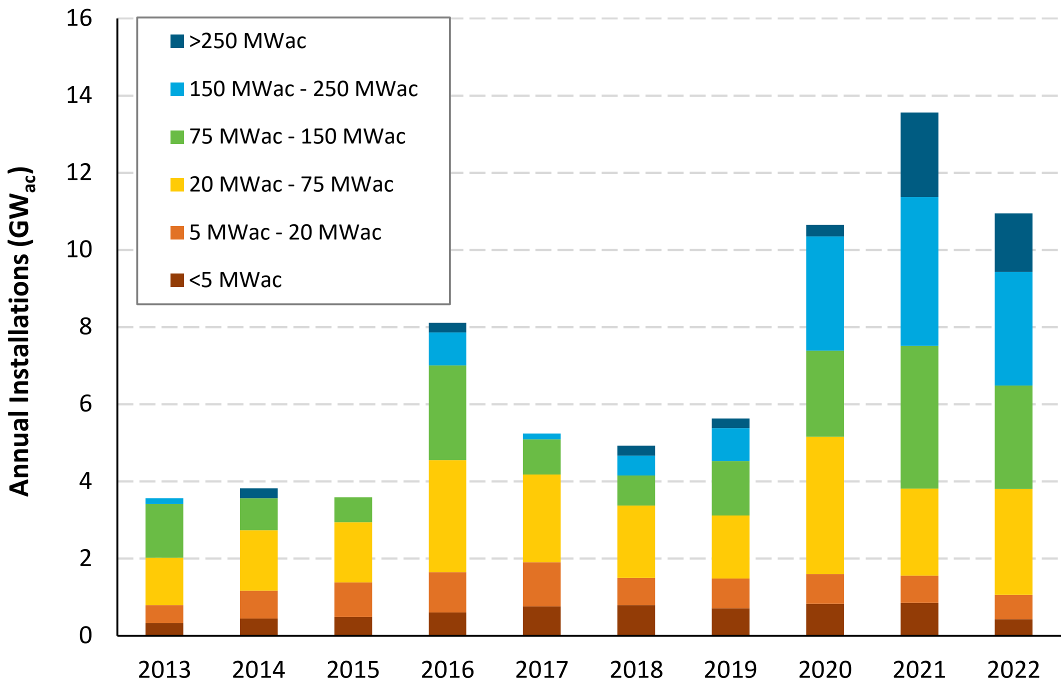

Figure 5 Annual utility-scale PV installations broken down by system size.[90]

[90] U.S. Energy Information Administration, [Form 860](), Early release 2022 data. June 2023.

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.[91] 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. As noted in Section 3.2.1, IRA featured several incentives targeted towards increasing participation of low-income households in PV deployment, including the Greenhouse Gas Reduction Fund, 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 2022. [92] These programs come in many forms including quotas for participation, exemptions to minimum bill requirements, and rebates based on income level (see Figure 6).[93] In 2022, many states also added labour requirements to their PV incentives. Many states and localities also provide incentives for PV deployment on schools and other public buildings.[94]

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

[92] North Carolina Clean Energy Technology Center, The 50 States of Solar: 2022 Policy Review and Q4 2022 Quarterly Report, January 2023.

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

[94] North Carolina Clean Energy Technology Center, The 50 States of Solar: 2022 Policy Review and Q4 2022 Quarterly Report, January 2023.

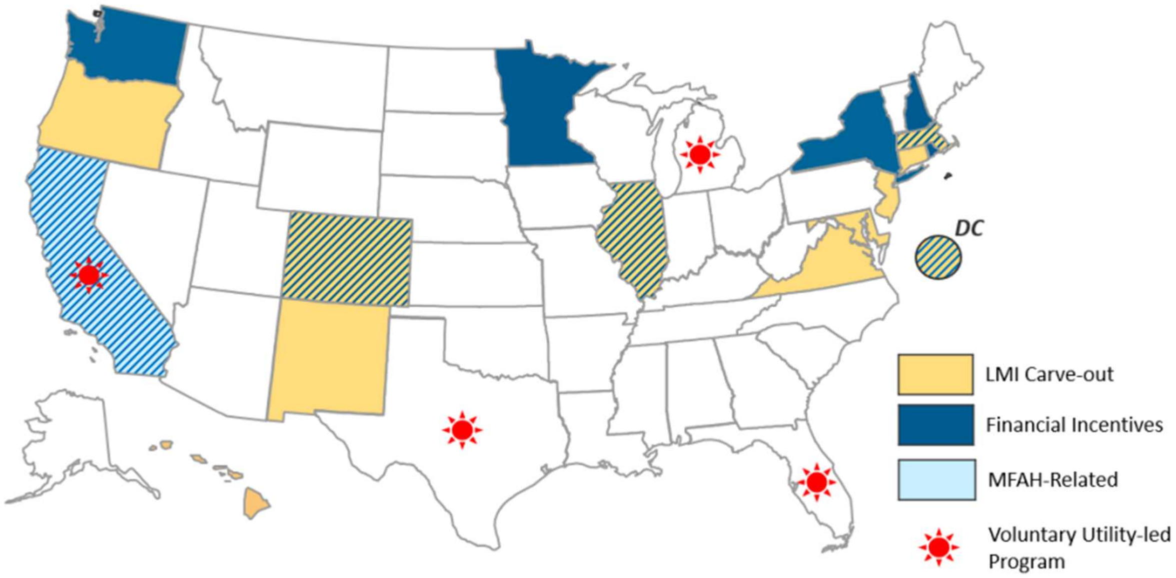

Figure 6 Types of LMI community solar mandates and voluntary efforts.[95] LMI = Low- and moderate-income, MFAH = multifamily affordable housing, DC = District of Columbia

3.8 Retroactive Measures Applied to PV

No retroactive measures were applied in 2022.

[95] Xu, Kaifeng, Jenny Sumner, Emily Dalecki, and Robin Burton. Expanding Solar Access: State Community Solar Landscape (2022). National Renewable Energy Laboratory. March 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.[96] While the United States consistently ranks with greater than 99% of the population having access to electricity,[97] according to initial data compiled by the U.S. Department of Energy Office of Indian Energy, 47% of American Indian/Alaskan Native respondents in 2022 reported their homes were not connected to a centralized grid or local microgrid.[98] 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.

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 3.2.1) to include various types of energy storage, as well as including battery technologies in the list of those incentivized by the manufacturing-related tax credits.

At the state level, several states are implementing time-of-use net billing rates, encouraging both storage and demand-response behaviour[99]. Building on its current requirements for new single-family homes and multifamily buildings up to three stories high to have storage, California became the first U.S. state to require PV and battery storage on newly constructed non-residential and high-rise multifamily buildings that meet certain criteria in 2022.[100]

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

[97] The World Bank. Access to electricity (% of population) – United States. Accessed July 2023

[98] U.S. Department of Energy Office of Indian Energy. Tribal Electricity Access and Reliability Congressional Report – Listening Session II. July 28, 2022.

[99] North Carolina Clean Energy Technology Center, The 50 States of Solar: 2022 Policy Review and Q4 2022 Quarterly Report, January 2023.

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

Table 17 Energy storage procurement policies (as of mid-2022)[101]

State	MW_{ac}/Year	Originating Source	Mandate/Goal/Target
California	1 825 by 2020. Carve-out of 500 for behind-the-meter	Legislative and regulatory	Mandate
Connecticut	1 000 by 2030. Carve-out of 580 for behind-the-meter	Legislative	Goal
Maine	400 by 2030	Legislative	Goal
Massachusetts	1 000 by 2025	Legislative	Target
Nevada	1 000 by end of 2030	Regulatory	Target
New Jersey	2 000 by 2030	Legislative	Mandate
New York	6 000 by 2030	Legislative with increase set by governor	Mandate
Oregon	5 by 2020	Legislative	Mandate
Virginia	3 100 by 2035. Carve-out of 10% for behind-the-meter	Legislative	Mandate

3.9.3 Support for Encouraging Social Acceptance of PV Systems

At the national level, 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,[102] 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,[103] 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 several international trade issues. 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

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[101] 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.

[102] 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.

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

Act – delayed and/or halted module shipments until adequate documentation could be produced attesting to 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 ongoing investigation. These headwinds were somewhat mitigated by President Biden declaring an emergency with respect to the electric grid reliability and waiving the imposition of duties resulting from the AD/CVD circumvention investigation for two years, as well as clarification from U.S. Customs and Border Protection on what documentation was required to confirm compliance with forced labour laws. Module imports rebounded in the latter half of 2022, but developers and installers reported that supply chain issues were the dominant cause of PV deployment shortfalls within the U.S. market in 2022.[104] The majority of PV modules deployed within the United States are imported.[105]

[104] National Renewable Energy Laboratory. Summer 2022 Quarterly Solar Industry Update. July 2022.

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

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, while thirteen states have not adopted state-wide procedures.[106]

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.[107]

According to a Lawrence Berkeley National Lab study, at approximately 950 GW_{ac} in the interconnection queue in 2022, solar projects account for largest share of the 1,35 TW_{ac} of generation capacity in the queue (see Figure 7).[108] A further 680 GW_{ac} of storage is also in the queue, with solar and storage projects together representing about 80% of new additions to the queue in 2022. Only 14% of proposed solar projects entering queues from 2000 to 2017 have reached commercial operations and only 10% of solar capacity entering the queue in that time reached operation (see Figure 8). As the number of projects in the queues have grown, the average time spent in queues has increased over time. The typical projects built in 2022 took 5 years from interconnection request to commercial operation. This compares to 3 years in 2015 and less than 2 years in 2008.

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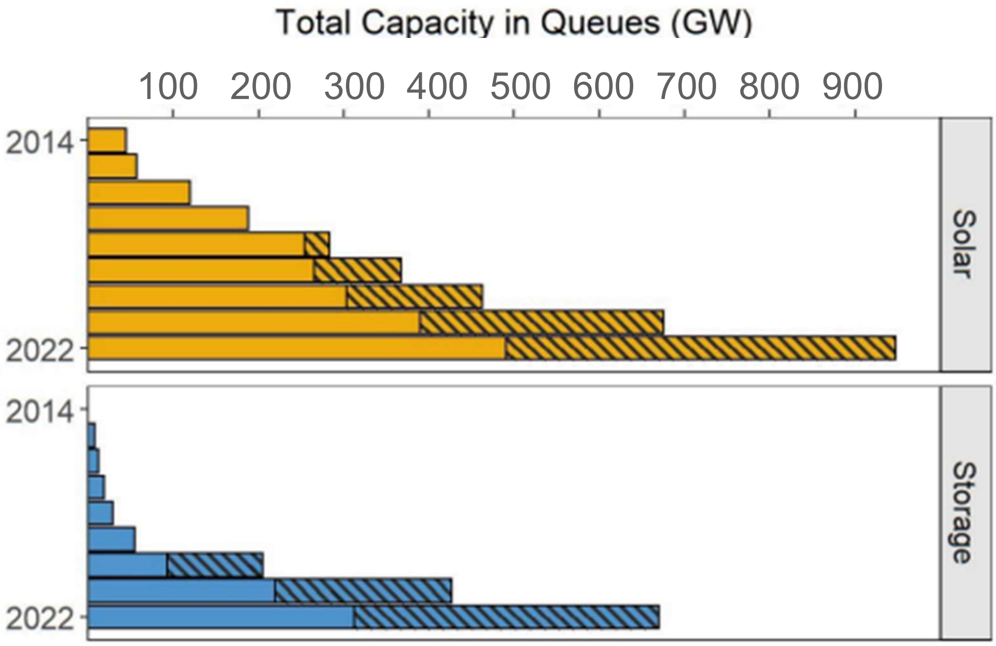
[106] Freeing the Grid. Interconnection Key Takeaways. Accessed July 2023.

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

[108] Rand, Joseph et al. Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2022. Lawrence Berkeley National Laboratory. April 2023.



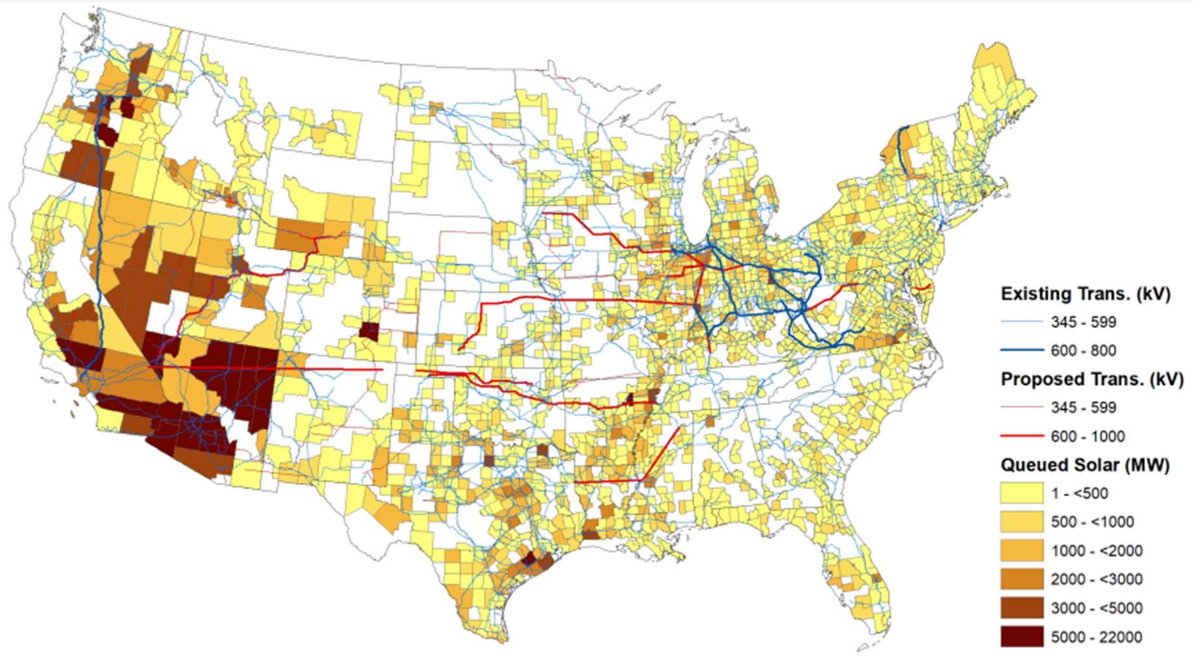


Figure 7 (top) Total solar and storage capacity in U.S. electric system operator interconnection queues over time. Stripes indicate hybrid systems. (bottom) Solar capacity currently in queues by U.S. county.[109]

[109] Id.

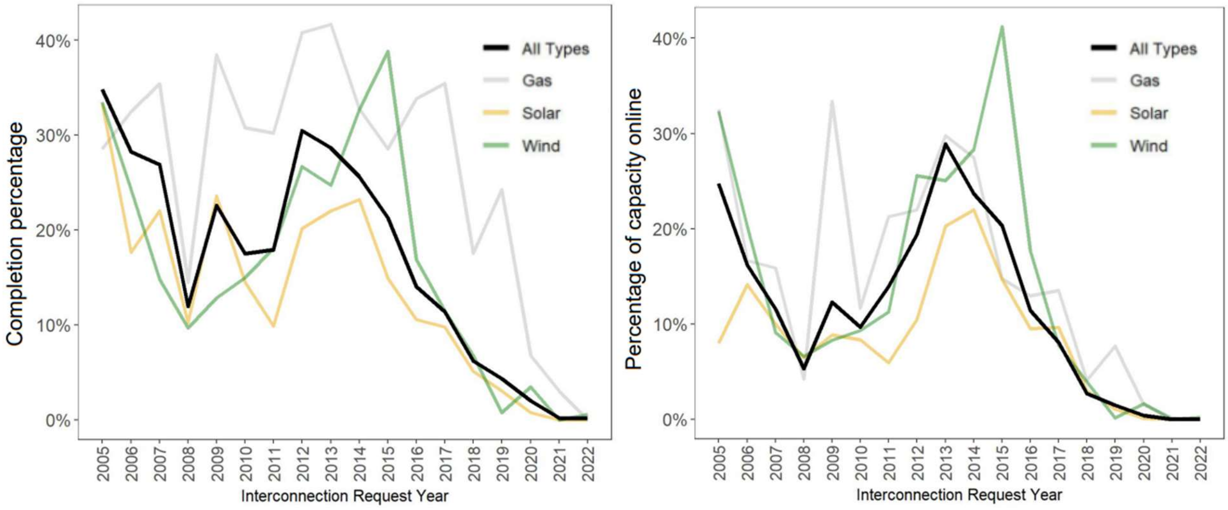


Figure 8 (left) Completion percentage by generator type for projects within U.S. electric system operator interconnection queues over time. (right) Percentage of capacity online by generator type for projects within U.S. electric system operator interconnection queues over time.[110]

Many states' utility commissions have established mandates that limit the maximum number of days allowed for utility review and approval of interconnection for certain small, often residential applications. According to one Lawrence Berkeley National Lab study in 2020, state-level median approval timelines ranged from 0 to 23 days across 24 states with mandates.[111]

Interconnections costs in the United States are paid by generators wishing to connect to the grid and have been rising across all regions and request types over the last decade. Costs are occasionally shared across multiple generators who contribute to upgrades and paid for by project developers.[112]

At the federal level, the U.S. Federal Energy Regulatory Commission began the process of rulemaking to improve generator interconnection procedures in 2022.[113] At the regional and state level, multiple similar reforms are also underway.[114]

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[110] Id.

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

[112] Seel, Joachim et al. Generator Interconnection Costs to the Transmission System. Lawrence Berkeley National Lab. June 2023.

[113] U.S. Federal Energy Regulatory Commission. Notice of Proposed Rulemaking Improvements to Generator Interconnection Procedures and Agreements. July 2022.

[114] Seel, Joachim et al. Generator Interconnection Costs to the Transmission System. Lawrence Berkeley National Lab. June 2023.

4 INDUSTRY

As discussed in Section 3.2.1, the Inflation Reduction Act contained significant incentives for domestic manufacturing across the PV supply chain. As of April 2023, there had been nearly 110 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 14 states. 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 LONGi, Meyer Burger, Enphase, and Maxeon.[115]

4.1 Production of Feedstocks, Ingots, and Wafers (Crystalline Silicon Industry)

Table 18: Silicon feedstock, ingot, and wafer producer's production information for 2022[116]

Manufacturers	Process & technology	Total Production [Tonnes]	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
Wacker Polysilicon	Polysilicon (Siemens)	19 000	Not Available	Not Available
REC Silicon	Silanes	2 000	Not Available	Not Available
CubicPV	c-Si Wafers	Not Available (20 MW_{dc}/yr capacity)	Not Available	Not Available

[115] Feldman, D.; Dummit, K.; Zuboy, J.; and Margolis, R. Spring 2023 Solar Industry Update. National Renewable Energy Lab. April 2023.

[116] U.S. Department of Energy. Solar Manufacturing Map. Accessed July 2023.

Wacker Polysilicon and Hemlock Semiconductor Corporation both produce polysilicon for both the solar and semiconductor industries. Total production values within Table 18 refers to both solar and semiconductor polysilicon production. Production values are estimates based on previously published capacities and publicly available data.[117] Wacker also has significant polysilicon production capacity in Germany.

CubicPV is currently the only domestic wafer manufacturer in the United States. See Figure 9 for the locations of the facilities listed in Table 18.

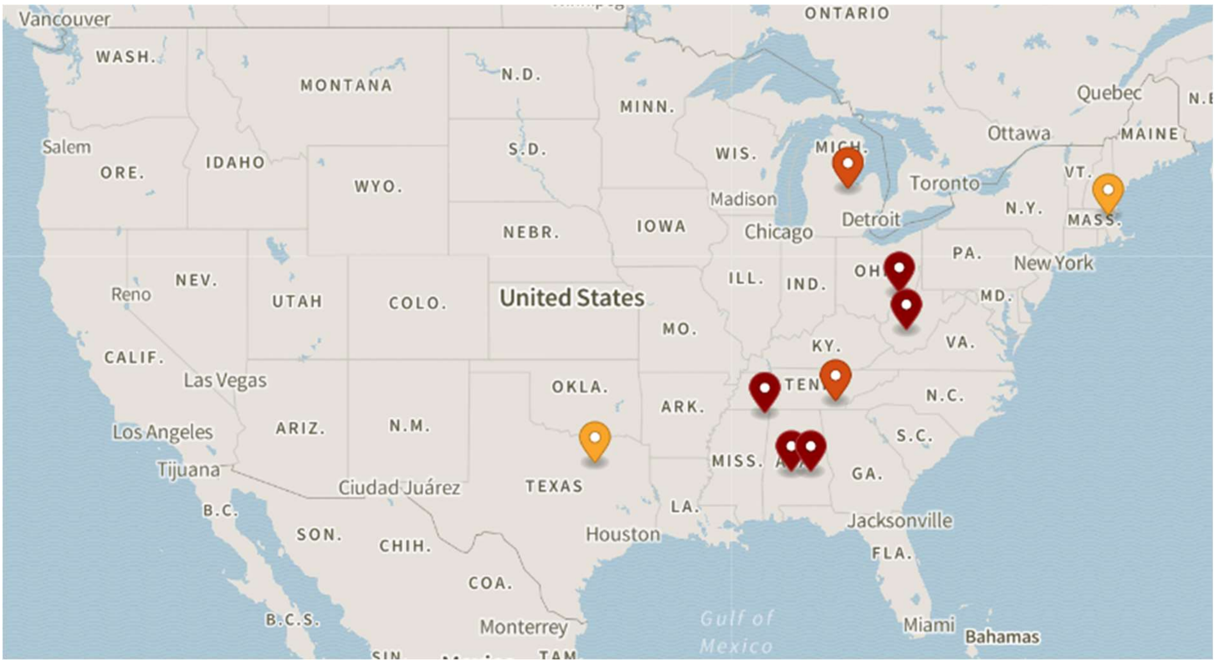

Figure 9 Domestic silicon feedstock (dark red), polysilicon (bright red), and wafer (orange) manufacturing facilities and company headquarters.

[117] Id.

4.2 **Production of Photovoltaic Cells and Modules (Including Thin Film)**

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

Total PV cell and module manufacture together with production capacity information is summarised in Table 19 below and depicted in Figure 10.

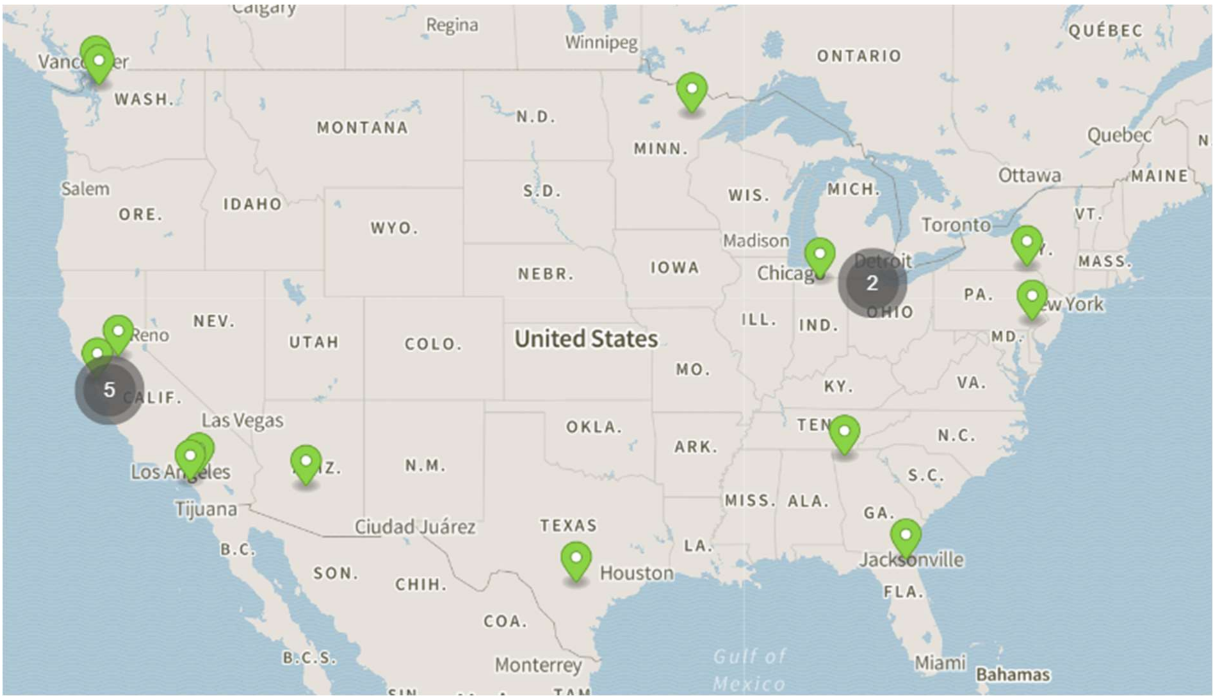

Figure 10 Domestic PV module manufacturing facilities and company headquarters.

Table 19: PV cell and module production and production capacity information for 2022

Cell/Module manufacturer	Technology	Total Production [MW]		Maximum production capacity [MW_{dc}/yr] [118]	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
Auxin Solar	c-Si	-	Not Available	-	150
CertainTeed	c-Si	-	Not Available	-	120
CrossRoads Solar	c-Si	-	Not Available	-	12
GAF Energy	c-Si	-	Not Available	-	50
Heliene	c-Si	-	Not Available	-	700
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	-	1700
Silfab Solar	c-Si	-	Not Available	-	800
Solaria	c-Si	-	Not Available	-	40
SPI Energy/ Solar4America	c-Si	-	Not Available	-	1100
Sunspark USA/SolarMax Technology	c-Si	-	Not Available	-	250
SunTegra	c-Si	-	Not Available	-	10
Sub-totals	**c-Si**	**-**	**2 521**[119]	**-**	**5 637**
Thin film manufacturers					
First Solar	CdTe	2 577[120]	2 577[121]	2 800	2 800
Toledo Solar	CdTe	Not Available	Not Available	100	100
Sub-totals	CdTe	Not Available	Not Available	2 900	2 900
Totals		**2 600 (est.)**	**5 100 (est.)**	**2 900**	**8 537**

[118] U.S. Department of Energy. Solar Manufacturing Map. Accessed January 2023.

[119] Value deduced from c-Si cell imports in 2022. U.S. Census Bureau. USA Trade Online. HTS code 8541420010. Accessed April 2023.

[120] PV Tech Research. PV Manufacturing & Technology Quarterly Report – Release 28 – February 2023.

[121] Id.

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 11).[122] Recycling facilities are also a growing part of the domestic solar supply chain, as more of an emphasis is being place on the life cycle of the solar panel.

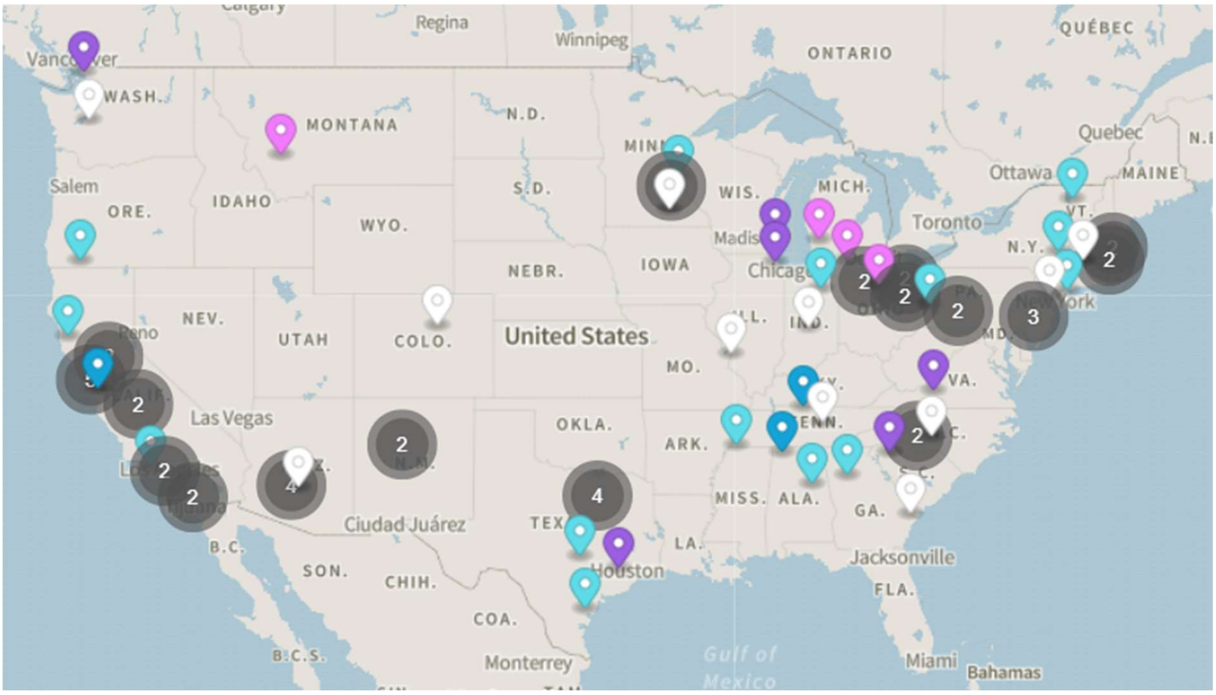

Figure 11 Domestic S-BOS (dark blue), E-BOS (light blue), inverter (purple), component (pink), and recycling (white) facilities and company headquarters. [123]

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 3, several 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.

[122] U.S. Department of Energy. Solar Manufacturing Map. Accessed July 2023.

[123] U.S. Department of Energy. Solar Manufacturing Map. Accessed July 2023.

5 PV IN THE ECONOMY

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

5.1 Labour Places

Table 20: Estimated PV-related full-time labour places in 2022[124]

Market category	Number of full-time labour places
Research and development (not including companies)	Not Segmented
Manufacturing of products throughout the PV value chain from feedstock to systems, including company research & development (R&D)	33 473
Distributors of PV products and installations	202 176
Other	28 233
Total	**263 883**

124 Interstate Renewable Energy Council. National Solar Jobs Census 2022. July 2023

5.2 Business Value

Table 21: Rough estimation of the value of the PV business in 2022 (sales tax is excluded)

Sub-market	Capacity installed [MW_{dc}]	Average price [$US\$/W_{dc}$]	Value	Sub-market
Off-grid	Not Available	Not Available	Not Available	Not Available
Grid-connected distributed	8 625	3,06	26 392 500 000	26 392 500 000
Grid-connected centralized	12 502	0,97	12 126 940 000	12 126 940 000
Value of PV business in 2022				38 591 440 000

6 HIGHLIGHTS AND PROSPECTS

6.1 Highlights

The U.S. PV market saw considerable changes this year, with international trade issues driving lower-than-expected deployment and high prices, changes to net metering incentivizing solar-plus-storage, growing interconnection queue timelines, and the most significant action the U.S. Congress has taken on clean energy and climate change in the nation's history all coming in 2022. While utility-scale solar projects faced trade headwinds, community solar, corporate solar, residential solar, and solar programs targeting low- and moderate-income households continued to grow.

6.2 Prospects

The Inflation Reduction Act (IRA) will shape PV manufacturing, financing, and deployment for the next decade at least within the United States. While big announcements have been made in solar manufacturing, it remains to be seen what sectors of the supply chain and business models will find success on U.S. shores.