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Solar Photovoltaics (PV): Status and Issues for Congress

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Solar Photovoltaics (PV): Status and Issues for Congress

SUMMARY

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Over the last 15 years, solar photovoltaics (PV) has developed from a niche electricity generation technology to the most rapidly expanding renewable energy (RE) resource. During this period, major developments have occurred in the solar PV industry and in related policy areas including (1) a greater than 80% reduction in component and systems costs; (2) enactment of laws modifying federal support for solar PV, including tax incentives; (3) changes in conditions relating to international trade policies; and (4) modifications of state solar energy policies.

Cost improvements have been driven by several factors. These factors include research, development, and demonstration of improved manufacturing equipment and processes; improved solar PV system designs and efficiencies; and investment in manufacturing that has resulted in greater capacity, economies of scale, and other cost benefits.

Congress passed the Infrastructure Investment and Jobs Act (IIJA; P.L. 117-58) and P.L. 117-169 (commonly referred to as the Inflation Reduction Act, or IRA). The IIJA appropriated funding for various energy-related research programs, grant programs, federal procurement initiatives, loans, and loan guarantees. The IRA modified and extended tax incentives such as the Advanced Manufacturing Production Credit, the Investment Tax Credit, and the Production Tax Credit.

Since 2012, the United States has imposed various import restrictions on solar PV components and systems. These include antidumping and countervailing duties on solar PV components made in China; "safeguard" tariffs on solar cells and modules issued under Section 201 of the Trade Act of 1974; and tariffs on cells, modules, and other components, issued under Section 301 of the Trade Act of 1974 in response to violations of trade agreements or actions burdening U.S. commerce.

State and local policies and regulations have encouraged greater solar PV deployment in their jurisdictions. Examples include financial incentives (e.g., tax credits, rebates), renewable portfolio standards, and net metering policies.

These developments in solar industry conditions and policies have affected U.S. manufacturing capacity, solar PV installations, component imports, and workforce needs. Solar PV manufacturing has five main stages: silicon/polysilicon, ingots, wafers, cells, and modules. In 2024, U.S. silicon/polysilicon manufacturing capacity increased to 34.5 gigawatts (GW), and module capacity increased to 33.9 GW—both substantial increases over the average capacities of the previous 10 years. U.S. manufacturers have announced planned capacity expansions of 8.0 GW of silicon/polysilicon, 8.3 GW of ingots, 19.3 GW of wafers, 42.0 GW of cells, and 41.5 GW of modules.

The United States installed 137.2 GW of solar PV electricity generation capacity between 2015 and 2024, with 68.4% of that capacity in utility-scale installations (1 megawatt or larger), 22.7% in residential installations, and 8.9% in commercial and industrial installations. The U.S. Energy Information Administration anticipates that utility-scale installations will continue to supply the majority of new solar PV capacity in future years.

Domestic manufacturing capacity has not been able to supply all the U.S. demand for solar PV components, so the United States has had to import components. The quantities of solar PV components imported at each manufacturing stage have varied over the years—with modules being the largest import category overall (by capacity), increasing from 9.9 GW in 2015 to 56.5 GW in 2023. Six nations have been the largest sources of solar PV modules, supplying 91.7% of capacity. The six nations are (with their total fraction of import capacity since 2015) Vietnam (32.2%), Malaysia (23.0%), Thailand (18.1%), Cambodia (7.1%), South Korea (6.5%), and India (4.8%). China, which dominates worldwide manufacturing of these components, was the country of origin for 1.2% of U.S. imports since 2015.

Congress could consider conducting oversight of federal energy laws or federal energy tax credits to determine if they are having the intended impact. Congress could revise or repeal those laws or credits, as has been proposed in bills in the 118th Congress. Congress could review and revise federal programmatic funding supporting deployment of solar PV or promoting other goals such as grid resilience. Congress could provide policy guidance on trade issues and evaluate whether current trade policies are achieving their desired effects, including protecting U.S. interests, promoting U.S. solar PV manufacturing, or supporting solar PV deployment. Congress could conduct oversight of federal solar PV workforce initiatives or revise tax credits that potentially impact workforce issues, including issues related to the transition to greater RE deployment.

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Over the last 15 years, solar photovoltaics (PV) has developed from a niche electricity generation technology to the most rapidly expanding renewable energy (RE) source in the United States. During this period, a number of major developments have occurred in the solar PV industry and in related state and federal policy areas. Many of the policies have been intended to support the development and deployment of solar PV. Concurrent factors may have influenced the effectiveness of these policies. This report summarizes and contextualizes some of those major developments, describes how they may have contributed to solar PV deployment in the United States, and highlights some of the areas in which Congress has taken actions, or could consider actions, to affect these developments or federal policy.

Outside of these major developments, a variety of other topics that affect solar PV are not addressed in this report. One example of such a topic is the specifics of component and systems costs.[1] These critical hardware components for solar PV generation and deployment—known as the *balance-of-system* components—are necessary for constructing a solar PV installation and connecting it to the grid.[2] Another example is energy storage systems, which may be deployed alongside solar panels to increase the productivity and value of the electricity generation. The domestic manufacturing capacity, supply chain issues, and import levels of these other system components are not included in this report. Additionally, energy permitting and the interconnection process are critical issues affecting solar PV deployment that are beyond the scope of this report.

Component and System Costs

The Department of Energy (DOE) models and tracks the cost of solar PV components and systems. The main solar PV component is the module (also called a *panel*). The module manufacturing process consists of five major stages: bulk polysilicon, silicon ingots, wafers, cells, and completed modules, as shown in **Figure 1**.[3] Complete solar PV systems include modules, physical infrastructure (such as foundations and steel trusses), and balance-of-system components (such as inverters). DOE has found solar PV system costs have decreased by more than 80% over the last 15 years, as depicted in **Figure 2**.[4]

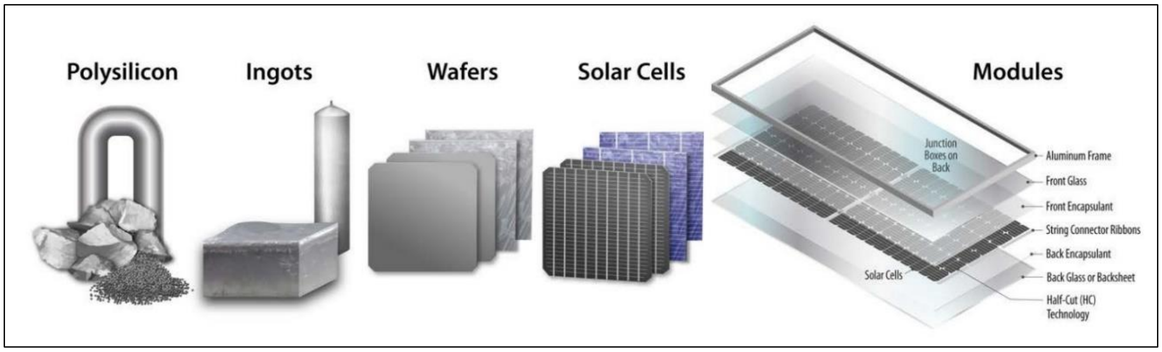
[1] See Vignesh Ramasamy et al., *U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, with Minimum Sustainable Price Analysis: Q1 2023*, National Renewable Energy Laboratory (NREL), September 2023, https://www.nrel.gov/docs/fy23osti/87303.pdf.

[2] *Balance-of-system* components are the non-solar-PV components—the other electrical and structural system components (including inverters) that connect the panels to the grid, condition the electricity for transmission, and store electricity for later transmission. U.S. Department of Energy (DOE), "Balance-of-System Equipment Required for Renewable Energy Systems," https://www.energy.gov/energysaver/balance-system-equipment-required-renewable-energy-systems.

[3] These stages apply to crystalline silicon-based solar PV panels, the dominant type of solar PV technology deployed in the United States. Alternative chemistries and designs—such as cadmium telluride thin films—contribute a small fraction of total installed capacity. For more information about these technologies and stages, see CRS Report R47093, *U.S. Solar Photovoltaic Manufacturing*, by Manpreet Singh. For further information, congressional clients may contact Morgan Smith.

[4] Michael Woodhouse et al., "Reflections on 15 Years of PV Module and System Price Declines and Where Things Go from Here," workshop presentation, NREL, July 29, 2024, https://www.nrel.gov/docs/fy24osti/90639.pdf.

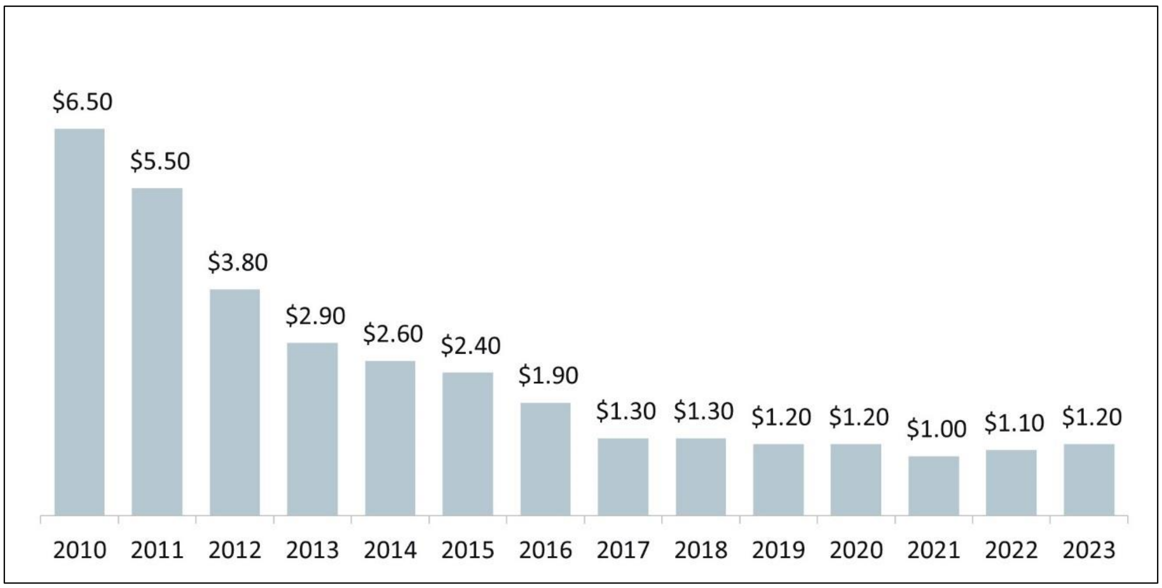
Figure 1. Major Manufacturing Stages of Solar PV Modules



Source: Michael Woodhouse et al., *Research and Development Priorities to Advance Solar Photovoltaic Lifecycle Costs and Performance*, National Renewable Energy Laboratory, October 2021, https://www.nrel.gov/docs/fy22osti/80505.pdf.

Figure 2. U.S. Utility-Scale Solar PV System Costs

(U.S. 2022 $ per W_{DC}, adjusted for inflation)



Source: Figure created by CRS using data from Michael Woodhouse et al., "Reflections on 15 Years of PV Module and System Price Declines and Where Things Go from Here," workshop presentation, National Renewable Energy Laboratory, July 29, 2024, https://www.nrel.gov/docs/fy24osti/90639.pdf.

Note: W_{DC} = watts-direct current.

These cost declines have been driven by research and development into improved manufacturing equipment and processes; improved solar PV system designs and efficiencies (including solar conversion efficiency and energy efficiency of the supporting electronics); and investment in manufacturing that has resulted in greater capacity, economies of scale, and other cost benefits. These reductions in costs have greatly affected the manufacturing of solar PV components in China and the United States.

China leveraged these recent decreases in solar PV manufacturing costs and its own domestic advantages to become the world leader in solar PV manufacturing.[5] Some of China's internal cost advantages include lower costs for energy, labor, investment, and overhead compared with competitors such as India, the United States, and Europe.[6] Between 2011 and 2022, China invested more than $50 billion in its domestic solar PV manufacturing, which has enabled it to expand production. China produced approximately 74.7% of all solar PV modules worldwide in 2021, 85.1% of cells, 96.8% of wafers, and 79.4% of polysilicon.[7] This boom in China's manufacturing has caused a number of challenges affecting worldwide supply, trade issues, and U.S. domestic solar manufacturing.

The United States was a pioneer in developing and manufacturing solar power technologies in the 1980s and 1990s. A variety of global and domestic factors led to the United States losing most of its manufacturing capacity and increasingly relying on imports to satisfy U.S. demand.[8] In addition to the rise of Chinese solar manufacturing, market and policy forces leading to this outcome include increasing domestic capital and labor costs, manufacturing industry movement toward just-in-time manufacturing and similar business models to reduce costs of overhead, and inconsistent federal incentives for manufacturing and RE development.[9]

Recent events such as the COVID-19 pandemic and related global supply chain disruptions have moved the United States to focus on onshoring solar PV manufacturing (among other industries) and supporting domestic industries. The United States has implemented several policies that seek to onshore solar PV manufacturing by offsetting the cost advantages China and other overseas suppliers have had. These policies include trade restrictions, tariffs, and federal tax incentives. Investments in related fields, such as semiconductor manufacturing and battery manufacturing, may also benefit solar manufacturing by creating regional synergies in workforce, energy supply, and data technologies. For example, investments through funding in P.L. 117-167, known as the CHIPS and Science Act, may create regional effects supporting solar PV development.[10]

Recent Federal Laws and Incentives

In 2021 and 2022, Congress passed several laws with the potential to impact solar PV manufacturing and development in the United States. These include the Infrastructure Investment and Jobs Act (IIJA; P.L. 117-58) and P.L. 117-169 (commonly referred to as the Inflation Reduction Act; IRA). The IIJA appropriated funds for solar activities detailed in the Energy Act

[5] Some critics of China's industrial policies contend that government subsidies and other factors, such as potentially forced labor, allow China's manufacturers to operate at a loss, which artificially suppresses prices and results in overcapacity. Ed Crooks, "China's Solar Growth Sends Module Prices Plummeting," *Energy Pulse* (blog), Wood Mackenzie, April 5, 2024, https://www.woodmac.com/blogs/energy-pulse/chinas-solar-growth-sends-module-prices-plummeting/; Michael Shellenberger, "China Helped Make Solar Power Cheap Through Subsidies, Coal and Allegedly, Forced Labor," *Forbes*, May 19, 2021, https://www.forbes.com/sites/michaelshellenberger/2021/05/19/china-made-solar-cheap-through-coal-subsidies—forced-labor-not-efficiency. For more information, see CRS In Focus IF11284, *U.S.-China Trade Relations*, by Karen M. Sutter, and CRS In Focus IF11667, *China's Economy: Current Trends and Issues*, by Karen M. Sutter and Michael D. Sutherland.

[6] International Energy Agency (IEA), *Solar PV Global Supply Chains*, July 2022, https://www.iea.org/reports/solar-pv-global-supply-chains (hereinafter IEA, *Solar PV Global Supply Chains*).

[7] IEA, *Solar PV Global Supply Chains*.

[8] Mary Sagatelova and Ryan Fitzpatrick, "Status Report: America's Competitive Advantage in Solar Energy," Third Way, July 23, 2024, https://www.thirdway.org/memo/status-report-americas-competitive-advantage-in-solar-energy.

[9] For more information on U.S. solar PV manufacturing, see CRS Report R47093, *U.S. Solar Photovoltaic Manufacturing*, by Manpreet Singh.

[10] Aaron Brickman and Ben Feshbach, "How Semiconductor Leadership Could Boost US Solar Manufacturing," RMI, August 12, 2024, https://rmi.org/semiconductor-solar-manufacturing-us-chips/.

of 2020 (42 U.S.C. §16238 (b)(2-4)), including $40 million for solar energy research and development, $20 million for an advanced solar manufacturing initiative, and $20 million for solar technology recycling development through FY2025. In addition to new funding for various energy-related grant programs, federal procurement initiatives, loans, and loan guarantees, the IRA created or updated several federal tax incentives for low-emissions energy sources.

The IRA created the Advanced Manufacturing Production Credit (AMPC; Internal Revenue Code section 45X), which subsidizes the manufacturing of certain energy components.[11] Eligible components used in solar energy production include qualifying PV cells, PV wafers, polymeric backsheets, torque tubes, structural fasteners, and solar modules.[12] Solar grade polysilicon is also eligible for the AMPC, as are various critical minerals used in solar electricity generation and different types of inverters.[13]

The IRA revised existing incentives including the Investment Tax Credit (ITC) and the Production Tax Credit (PTC). The ITC supports investments in selected RE technologies, and the PTC provides credits for the generation of electricity from selected sources. The ITC and PTC may be claimed for facilities beginning construction before 2025. These credits have been important to the growth and development of renewable electricity resources, particularly solar PV. Both credits have expired and been revived, extended, or modified many times over their existence. The inconsistent availability and status of these credits has affected the levels of investment in credit-eligible technologies and their relative deployment over time.[14]

The IRA created new versions of the ITC and PTC—the Clean Electricity Investment Tax Credit (CEITC) and the Clean Electricity Production Tax Credit (CEPTC). Both of these new credits are scheduled to go into effect in 2025 and are to be technology neutral. They are designed to provide tax credits for energy investments where the technology's greenhouse gas emissions are not greater than zero. Solar PV meets this criterion and is eligible for the CEITC and CEPTC. These new tax credits may be claimed for facilities placed in service in 2025 or later years (facilities beginning construction before 2025 but placed in service in 2025 or later are eligible for any of the credits). Taxpayers may claim one of the four credits for a single facility. Final regulations for the CEITC and the CEPTC had not been issued as of November 20, 2024.

The IRA established the CEITC and CEPTC through 2032 and regularized the incentive structure—compared with the earlier ITC and PTC—providing the same credit amounts for all qualifying energy types. The CEITC and CEPTC include a higher base credit for meeting wage and apprenticeship requirements, a bonus credit for investing in specified energy communities, and another bonus credit for meeting domestic content requirements.[15] Additional bonus credits exist under the CEITC (but not under the CEPTC) for constructing facilities on Indian land, in low-income communities, as part of low-income residential building projects, or as part of qualified low-income economic benefit projects.[16]

The IRA also modified and expanded the Residential Clean Energy Credit (RCEC), which subsidizes the cost of certain RE equipment installed at taxpayers' homes.[17] Between 2023 and

[11] 26 U.S.C. §45X.

[12] 26 U.S.C. §45X.

[13] 26 U.S.C. §45X.

[14] A. Will Frazier et al., "Wind and Solar PV Deployment After Tax Credits Expire: A View from the Standard Scenarios and the Annual Energy Outlook," *Electricity Journal*, vol. 32, no. 8, (October 2019), article no. 106637, https://doi.org/10.1016/j.tej.2019.106637.

[15] 26 U.S.C. §45, 26 U.S.C. §45Y, 26 U.S.C. §48, and 26 U.S.C. §48E.

[16] CRS Report R47202, *Tax Provisions in the Inflation Reduction Act of 2022 (H.R. 5376)*, pp. 8, 20.

[17] CRS Insight IN12423, *Preliminary Data on the IRA Residential Clean Energy Credit*, by Nicholas E. Buffie.

2032, taxpayers may receive an RCEC equal to 30% of the cost of purchasing, assembling, and installing solar electric panels, solar water heaters, and other RE equipment. The credit phases down to 26% in 2033 and 22% in 2034 and is eliminated thereafter.[18] Preliminary Internal Revenue Service (IRS) data released in August 2024 indicate that at least 1.2 million taxpayers claimed the credit in 2023, with approximately 752,000 taxpayers claiming the RCEC for solar electricity panel installations and 139,000 claiming it for solar water heater installations.[19]

Finally, the IRA provided $10 billion of new funding for the competitively awarded Qualifying Advanced Energy Project Credit (QAEPC).[20] The QAEPC subsidizes a wide array of energy-related activities, including the reequipment, expansion, or establishment of "property designed to be used to produce energy from the sun, water, wind, geothermal deposits ... or other renewable resources."[21] The credit is equal to 30% of qualifying costs for firms meeting wage and apprenticeship requirements and 6% of qualifying costs for firms not meeting such requirements.[22]

Trade Conditions

Since 2012, the United States has imposed various import restrictions on solar PV components and systems. These components include solar PV cells and modules, laminates, and panels. Components go through multiple processing stages (see **Figure 1**). A country may import a solar PV component, process it, and export it, only to reimport similar components at later stages, until the final panel stage when it is ready for installation. It may be difficult to determine the origin point of a component or whether a country has contributed significantly to the manufacturing of the component (or has passed the component through).

U.S. import restrictions include antidumping (AD) tariffs and countervailing duties (CVDs) on solar PV components made in China.[23] AD tariffs are "punitive tariffs placed on countries that sell below cost to gain market share," and CVDs are "punitive tariffs placed on countries that receive government subsidies believed to be unfair."[24] Starting in 2018, the United States imposed "safeguard" tariffs on solar cells and modules. A *safeguard tariff* is a "temporary import restriction…that a country is allowed to impose on a product if imports of that product are increasing so as to cause, or threaten to cause, serious injury to a domestic industry that produces

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[18] CRS Insight IN12423, *Preliminary Data on the IRA Residential Clean Energy Credit*, by Nicholas E. Buffie.

[19] Internal Revenue Service (IRS) clean energy tax credit statistics can be found at https://www.irs.gov/statistics/soi-tax-stats-clean-energy-tax-credit-statistics. CRS Insight IN12423, *Preliminary Data on the IRA Residential Clean Energy Credit*, by Nicholas E. Buffie.

[20] 26 U.S.C. §48C.

[21] 26 U.S.C. §48C(c)(1)(A)(i)(I).

[22] 26 U.S.C. §48C(e).

[23] International Trade Administration (ITA), "Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled into Modules, from the People's Republic of China: Amended Final Determination of Sales at Less Than Fair Value, and Antidumping Duty Order," 77 *Federal Register* 73018, December 7, 2012, https://www.federalregister.gov/documents/2012/12/07/2012-29668/crystalline-silicon-photovoltaic-cells-whether-or-not-assembled-into-modules-from-the-peoples; ITA, "Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled into Modules, from the People's Republic of China: Countervailing Duty Order," 77 *Federal Register* 73017, December 7, 2012, https://www.federalregister.gov/documents/2012/12/07/2012-29669/crystalline-silicon-photovoltaic-cells-whether-or-not-assembled-into-modules-from-the-peoples.

[24] Brittany Smith et al., *Solar Photovoltaic (PV) Manufacturing Expansions in the United States, 2017–2019: Motives, Challenges, Opportunities, and Policy Context*, NREL, April 2021, https://www.nrel.gov/docs/fy21osti/74807.pdf (hereinafter Smith et al., *Solar PV Manufacturing Expansions*).

a similar or directly competitive product."[25] The tariffs were to provide temporary relief to U.S. manufacturers harmed by increased imports (known as Section 201 tariffs under that section of the Trade Act of 1974) and to respond to violations of trade agreements or actions that are unjustifiable and a burden on U.S. commerce (known as Section 301 tariffs). Since their initial imposition, these tariffs have been adjusted by federal agency administrative action and following federal court rulings. The tariffs have been adjusted regarding the types of solar materials and cells to which the restrictions apply, the countries of origin to which the tariffs apply, the quota levels for exceptions to the import tariffs, and the tariff rates.

The Section 201 tariffs were imposed on imports of solar PV cells and panels from all countries except for certain developing countries. The tariffs included a quota exception—the tariff is not applied on the first 2.5 GW of capacity of cells imported annually (there was no quota for panels). The quotas were established to allow sufficient supply to meet domestic solar PV demand while also allowing the build-out of additional domestic manufacturing capacity. Total annual U.S. imports exceeded the quota for a limited amount of time (39 days from December 30, 2021, to February 6, 2022). In June 2019, the U.S. Trade Representative exempted bifacial panels from these Section 201 tariffs. After this exemption took effect, imports of bifacial panels grew to account for the majority of total annual solar PV panel imports.[26] The quota on cells was increased to 5.0 GW in 2022 when the tariff was extended until February 2026.[27] Section 201 tariffs are statutorily time-limited and may not exceed eight years from the initial imposition date.[28] In 2024, the exclusion for bifacial panels was removed.

In 2018, the United States placed Section 301 tariffs of up to 25% on a variety of imports from China including solar PV cells, panels, and related materials (e.g., *balance-of-system* components such as inverters). Some of these restrictions were later expanded to include imports from Taiwan to prevent circumventions of the tariffs. Section 301 of the Trade Act of 1974 (Title III of the Trade Act of 1974 [Sections 301-310, 19 U.S.C. §§2411-2420], titled "Relief from Unfair Trade Practices") provides for U.S. sanctions on countries that violate trade agreements or engage in "unjustifiable" or "unreasonable" acts that burden U.S. commerce.[29] Certain solar cell and wafer manufacturing equipment are excluded from the Section 301 tariff.[30]

In 2022, the U.S. Department of Commerce (Commerce) found that Cambodia, Malaysia, Thailand, and Vietnam had been circumventing existing AD and CVD orders on Chinese solar products. In June 2022, the Biden Administration initiated a 24-month duty-free "solar bridge" on solar imports from those countries to facilitate imports. In June 2024, the solar bridge ended, thus

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[25] ITA, "Trade Guide: WTO Safeguards Agreement," https://www.trade.gov/trade-guide-wto-safeguards.

[26] Bifacial panels are capable of generating electricity from sunlight absorbed on both sides of the panel. White House, "Fact Sheet: Biden-Harris Administration Takes Action to Strengthen American Solar Manufacturing and Protect Manufacturers and Workers from China's Unfair Trade Practices," May 16, 2024, https://www.whitehouse.gov/briefing-room/statements-releases/2024/05/16/fact-sheet-biden-harris-administration-takes-action-to-strengthen-american-solar-manufacturing-and-protect-manufacturers-and-workers-from-chinas-unfair-trade-practices/ (hereinafter White House, "Biden-Harris Administration Takes Action to Strengthen American Solar Manufacturing").

[27] Applicable tariff rates on cells in excess of the quota and on modules started at 14.75% in 2022 and decreased 0.25% each year thereafter. U.S. Customs and Border Protection, "QB 22-507 Solar Cells and Modules 2022," February 4, 2022, https://www.cbp.gov/trade/quota/bulletins/qb-22-507-solar-cells-and-modules-2022.

[28] CRS In Focus IF10786, *Safeguards: Section 201 of the Trade Act of 1974*, by Liana Wong.

[29] For more information on Section 301, see CRS In Focus IF11346, *Section 301 of the Trade Act of 1974*, by Andres B. Schwarzenberg.

[30] David E. Bond et al., "United States Finalizes Section 301 Tariff Increases on Imports from China," White & Case, September 17, 2024, https://www.whitecase.com/insight-alert/united-states-finalizes-section-301-tariff-increases-imports-china.

reimposing the duties on solar imports from those countries.[31] In May 2024, Commerce initiated a separate AD/CVD investigation on solar PV cells and modules from these same four countries.[32]

It is unclear what effect the various tariffs have had on domestic solar component manufacturing capacity. In surveys, domestic panel producers cite multiple reasons why domestic solar PV manufacturing has not grown at the same pace as domestic demand since 2018.[33] Cited factors include the exclusion of bifacial modules from duties at different times within the tariff period, stockpiling of imports prior to tariff impositions or changes, and circumvention by China.[34] For example, from 2020 to 2021, tariffs were applied to less than half of all solar PV panel imports due to various exemptions. To prevent stockpiling, Commerce required that panels imported under this duty-free exemption be installed within 180 days after the expiration of the proclamation.[35]

State Energy Policies

State and local laws, regulations, and policies are major drivers of solar PV deployment.[36] Key types of policies and regulations include financial incentives (including tax credits or rebates), renewable or clean energy targets and goals (e.g., renewable portfolio standards [RPSs]; or clean energy standards [CESs]), and net metering policies. The differences between RPSs and CESs largely come down to definitions—RPSs can include renewable energy sources that emit greenhouse gases, such as biomass-fired power plants, whereas CESs may include nonrenewable carbon-free sources, such as nuclear power. [37] Net metering is a policy that allows electricity customers with their own generation capacity to be financially compensated for the electricity they produce but do not consume.[38] These policies, among others, have been contributing factors encouraging greater solar PV deployment in state and local jurisdictions.

State energy goals and energy portfolio targets are drivers of solar deployment. State RPSs or CESs require or encourage utilities to supply a minimum amount of electricity from renewable or clean energy sources—either supplying their own generation or purchasing it from others. Some

[31] White House, "Biden-Harris Administration Takes Action to Strengthen American Solar Manufacturing."

[32] ITA, "Commerce Initiates Antidumping and Countervailing Duty Investigations of Crystalline Silicon Photovoltaic Cells from Cambodia, Malaysia, Thailand, and the Socialist Republic of Vietnam," May 15, 2024, https://www.trade.gov/commerce-initiates-antidumping-and-countervailing-duty-investigations-crystalline-silicon (hereinafter ITA, "Commerce Initiates Antidumping and Countervailing Duty Investigations").

[33] Smith et al., *Solar PV Manufacturing Expansions*.

[34] World Trade Organization member developing countries with less than a 3% share of solar cell and panel imports to the United States are exempt from the Section 201 tariffs. Suniva and Auxin Solar claim that imports from Cambodia, excluded from tariffs, have risen rapidly since 2019 due to Chinese companies using Cambodia as an export platform. U.S. International Trade Commission (USITC), *Crystalline Silicon Photovoltaic Cells, Whether or Not Partially or Fully Assembled into Other Products*, Investigation no. TA-201-75 (Extension), Publication no. 5266, December 2021, https://www.usitc.gov/publications/other/pub5266.pdf.

[35] For more details relating to these tariffs, the Trade Act of 1974, and solar imports, see CRS In Focus IF11346, *Section 301 of the Trade Act of 1974*, by Andres B. Schwarzenberg; CRS In Focus IF11582, *Section 301 Tariff Exclusions on U.S. Imports from China*, by Andres B. Schwarzenberg; CRS Insight IN10856, *Section 201 Safeguards on Solar Products and Washing Machines*, by Vivian C. Jones (for further information, congressional clients may contact Liana Wong); and CRS In Focus IF10786, *Safeguards: Section 201 of the Trade Act of 1974*, by Liana Wong.

[36] Eric O'Shaughnessy, "State and Local Policy Impacts on the Residential Solar PV Installation Industry," NREL, January 2019, https://www.nrel.gov/docs/fy19osti/72149.pdf; Christine L. Crago and Eric Koegler, "Drivers of Growth in Commercial-Scale Solar PV Capacity," *Energy Policy*, vol. 120 (September 2018).

[37] For more information on these standards, see CRS Report R45913, *Electricity Portfolio Standards: Background, Design Elements, and Policy Considerations*, by Ashley J. Lawson.

[38] For more information, see CRS Report R46010, *Net Metering: In Brief*, by Ashley J. Lawson.

RPSs and CESs may explicitly call for a certain percentage of electricity to come from a specific technology such as distributed solar PV, and they may have interim and ultimate targets.[39] As of December 2023, 28 states and the District of Columbia had renewable or clean energy standards.[40]

State and local financial incentives—including tax credits, rebates, or net metering policies—have been widely implemented to support solar PV deployment.[41] Many states have grant or loan programs (often with funding from federal programs such as DOE's State Energy Program) that support solar deployment, and many states have sales or property tax exemptions or tax rebates for solar equipment and installations. The Database of State Incentives for Renewables & Efficiency (DSIRE) from the N.C. Clean Energy Technology Center at North Carolina State University compiles state incentives (and policies) supporting RE and energy efficiency.[42]

Net metering policies determine how electricity customers with distributed solar PV generation are compensated for electricity they deliver to the grid.[43] A variety of policy configurations attempt to balance the costs of the utility with the value of the electricity supplied while incentivizing customers to invest.[44] All states, U.S. territories, and the District of Columbia have some programs and access to some kind of compensation, though an individual's access to net metering depend upon their utility's details.[45] Some programs are established by the state or jurisdiction, and some are available through individual utilities as in, for example, Alabama, Texas, and Tennessee. The U.S. Energy Information Administration reported more than 4.7 million customers participated in net metering programs in the United States in July 2024.[46] In regions with significant distributed electricity generation, the compensation rates and policies may undergo reconsideration—due to the total impact of costs and claims from the utilities and others that the policies are resulting in cost shifting from net metering participants to non-net metering customers.[47] The ongoing debates around the existence and degree of cost shifting has

[39] NREL, "Renewable Portfolio Standards," https://www.nrel.gov/state-local-tribal/basics-portfolio-standards.html; and CRS Report R45913, *Electricity Portfolio Standards: Background, Design Elements, and Policy Considerations*, by Ashley J. Lawson.

[40] N.C. Clean Energy Technology Center, "Renewable and Clean Energy Standards," map, December 2023, https://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2023/12/RPS-CES-Dec2023-1.pdf.

[41] Andrea Sarzynski et al., "The Impact of State Financial Incentives on Market Deployment of Solar Technology," *Energy Policy*, vol. 46 (July 2012), https://doi.org/10.1016/j.enpol.2012.04.032; Sadie Cox, "Financial Incentives to Enable Clean Energy Deployment: Policy Overview and Good Practices," NREL, February 2016, https://www.nrel.gov/docs/fy16osti/65541.pdf.

[42] Available at https://www.dsireusa.org/.

[43] Not all distributed generation compensation policies are called *net metering*, but for the purposes of this discussion all related policies are grouped within this term. Alternative terms include *solar buy-back programs* and *net billing*.

[44] "Buy-all, sell-all" and "net billing" are two such configurations. In "buy-all, sell-all," the utility buys all of the customer's generated electricity at a defined rate (which may be different from the standard consumer rate) and also sells all of the customer's electricity consumption to the customer at the standard consumer rate. In "net billing," the utility tracks the net difference between the customer's generation and consumption in a given time frame (for example, monthly) and charges or pays that customer for the net electricity used or generated. NREL, "Energy Compensation Mechanisms for Distributed Generation," https://www.nrel.gov/state-local-tribal/energy-compensation-mechanisms.html.

[45] Mary-Elisabeth Combs, "Does Your State Have Solar Net Metering?" *CNET*, https://www.cnet.com/home/energy-and-utilities/new-to-solar-net-metering-heres-what-you-need-to-know-for-your-state/.

[46] U.S. Energy Information Administration, "Monthly Electric Power Industry Report," Form EIA-861M, https://www.eia.gov/electricity/data/eia861m/.

[47] While some cost shifting is inherent to rate design, the degree and importance of cost shifting can vary by application and region. Some critics argue that compensating net metering customers at the standard consumer rate for their generated electricity reduces or eliminates the amount of the utility's fixed costs those customers support, unfairly (continued...)

resulted in changes to net metering policies in some locations—for example, California has altered its policies on compensation rates and qualifications and Hawaii has eliminated new participant sign-ups. The resulting policies are sometimes known as Net Metering 2.0 and 3.0.[48]

Domestic Solar Photovoltaics Industry Status

Domestic Production Capacity

Some of the federal financial incentives and solar trade policies discussed above are aimed at supporting increases in domestic manufacturing. DOE has concluded that domestic solar PV manufacturing capacity increases supply chain resilience, supports jobs and economic development, keeps more capital available in local and national economies, improves energy security, promotes U.S. decarbonization, and simplifies shipping and logistics.[49]

While domestic manufacturing capacity in 2023 was able to supply enough assembled modules to meet approximately one-third of U.S. demand, domestic capacity for the other segments of the solar PV module supply chain was more limited. **Table 1** lists U.S. solar PV component historical production capacity from 2015 to 2024. The majority of U.S. manufacturing capacity has been in polysilicon production and module manufacturing (i.e., final panel assembly from individual cells), and capacities in both of these stages increased substantially in 2024.

Table 1. Annual U.S. Solar PV Manufacturing Capacity by Stage, 2015-2024

(GW_{DC})

Stage	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024[a]
Silicon/Polysilicon	2.9	2.7	2.75	1.8	1.35	1.2	1.2	1.25	1.3	34.5
Ingots	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Wafers	0	0	0	0	0	0	0	0	0	n/a
Cells	0.6	0.7	0.2	0.1	0.05	0	0	0	0	n/a
Modules	0.55	0.6	0.25	0.3	1.8	2.4	2.1	2.4	2.7	33.9

Sources: David Feldman et al. "Summer 2024: Solar Industry Update," presentation, National Renewable Energy Laboratory (NREL), August 20, 2024, https://www.nrel.gov/docs/fy24osti/91209.pdf; U.S. Department of Energy, "U.S. Domestic Solar Photovoltaic Manufacturing Map Data," September 6, 2024, CSV file downloadable at https://www.energy.gov/eere/solar/articles/us-domestic-solar-photovoltaic-manufacturing-map-data.

Notes: GW_{DC} = gigawatts-direct current; n/a = not available. Polysilicon values have been converted to GW using NREL's assumption of 2.0 grams per watt.

a. The 2024 data are through September 6, 2024.

A significant amount of new U.S. manufacturing capacity has been announced since the enactment of the IIJA and IRA; however, it is not clear how much can be attributed to the effects

shifting those costs to non-net metering customers. Fixed costs are those the utility must pay to maintain the electrical grid and supply power to all customers and are independent of the actual amount of electricity a customer consumes. The rates charged and paid in the net metering programs, and decisions about how to value the electricity supplied, are points of contention among policymakers, consumers, utilities, and other stakeholders. Brittany Smith, "U.S. Net Metering Value and Grid Cost," NREL, presentation at the IEA-PVPS Grid Cost Workshop at the Photovoltaic Specialists Conference, June 18, 2019, https://www.nrel.gov/docs/fy19osti/74198.pdf.

[48] For more information on net metering, see CRS Report R46010, *Net Metering: In Brief*, by Ashley J. Lawson.

[49] DOE, "Building a Bridge to a More Robust and Secure Solar Energy Supply Chain," https://www.energy.gov/eere/solar/building-bridge-more-robust-and-secure-solar-energy-supply-chain.

of those laws and how much can be attributed to other market forces and trends. **Table 2** depicts current or planned manufacturing capacity additions, by component stage and construction status, as reported by the trade group Solar Energy Industries Association (SEIA).[50] These data may not represent actual final capacity: Not all announced projects begin construction, and not all projects that begin construction are completed. Completion of projects depends on project economic viability and a variety of changing market conditions such as financing availability, labor costs, interest rates, permitting timelines, tax incentives, raw materials, and energy prices (current or projected).

Table 2. Planned U.S. Solar PV Manufacturing Capacity Additions by Stage

(GW_{DC})

Stage	Under Construction	Announced
Silicon/Polysilicon	0	8.0
Ingots	3.3	5.0
Wafers	3.3	16.0
Cells	8.8	33.2
Modules	22.0	19.5

Source: Solar Energy Industries Association, "Solar and Storage Supply Chain Dashboard," August 2024, https://seia.org/research-resources/solar-storage-supply-chain-dashboard/.

Notes: GW_{DC} = gigawatts-direct current. Polysilicon values have been converted to GW using the National Renewable Energy Laboratory's assumption of 2.0 grams per watt.

Solar Photovoltaic Installations

Solar PV installations can be divided into market segments based on a variety of characteristics. One approach is to segment installations according to the customers they typically serve: utility-scale (generally installations of 1 megawatt [MW] or larger, where the electricity generated is delivered to the grid), residential (typically small-scale [<1 MW] installations on rooftops), and commercial and industrial (installations may be utility- or small-scale). There is also a market subset called *community solar*, in which residential customers can access a share of a utility-scale project; this subset of customers is not represented separately in this analysis but is grouped with utility-scale projects.[51]

Table 3 provides data on annual U.S. solar PV installations (i.e., added electricity generation capacity) from 2015 to 2024. The majority of U.S. deployment as measured by capacity has been utility-scale installations, followed by residential installations. DOE anticipates that utility-scale installations will continue to supply the majority of new solar PV capacity in future years.[52]

[50] DOE has a clean energy investment tracker, which—as of September 24, 2024—lists 122 projects (announced after the enactment of the IRA) to increase domestic manufacturing of solar panels, solar panel parts, and balance-of-system hardware. The tracker does not report manufacturing capacity of projects. The tracker is available at https://www.energy.gov/invest.

[51] Community solar customers, including renters or apartment owners, can gain the advantages of utility-scale solar PV installations, such as lower-cost and carbon-free electricity, when they might not otherwise be able to develop their own small-scale installation. DOE, "About the National Community Solar Partnership+," https://www.energy.gov/communitysolar/about-national-community-solar-partnership.

[52] Joachim Seel et al., "Utility-Scale Solar, 2024 Edition," presentation, Lawrence Berkeley National Laboratory, (continued...)

Table 3. Annual U.S. Solar PV Installations by Market Segment, 2015-2024

(GW_{AC} of capacity)

Market Segment	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024[a]	Total	Percent of Market
Utility-scale	3.24	8.29	5.02	4.93	5.6	10.6	13.8	11.3	18.4	12.7	93.9	68.4%
Residential	1.84	2.34	2.09	2.09	2.5	2.9	4.0	5.1	6.6	1.6	31.1	22.7%
Commercial and Industrial	0.59	0.65	1.29	1.31	1.1	1.5	1.5	1.7	1.3	1.2	12.2	8.9%
Total	5.68	11.28	8.40	8.33	9.3	15.0	19.3	18.1	26.3	15.6	137.2	

Source: U.S. Energy Information Administration, "Electric Power Monthly: July 2024," September 24 2024, Tables 6.1.A and 6.1.B, https://www.eia.gov/electricity/monthly/.

Notes: GW_{AC} = gigawatts-alternating current. Utility-scale includes installations of size 1 megawatt or larger. Residential includes small-scale installations of size less than 1 megawatt. Commercial and Industrial includes both small-scale and utility-scale installations. Numbers for small-scale installations are estimated values, while the utility-scale numbers represent a census of all large projects.

a. The 2024 data are through June 2024.

Solar Photovoltaic Imports

As discussed above, the solar PV manufacturing supply chain can be divided into five main stages for the photovoltaic elements: silicon/polysilicon, ingots, wafers, cells, and modules. Since the United States does not have sufficient domestic manufacturing capacity to meet domestic demand, these materials must be imported. **Table 4** displays solar imports between 2015 and 2024 for each of the stages. The United States International Trade Commission (USITC) reports the quantity of the silicon, ingots, and wafers by their weight (in metric tons [MT]) and the quantity of cells and modules by their electricity generation capacity (in gigawatts-direct current [GW_{DC}]).[53]

Table 4. U.S. Solar PV Imports by Stage, 2015-2024

(by weight or capacity)

Stage	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024[a]
Silicon/Polysilicon (MT)	11,779	8,186	10,949	6,134	5,243	1,914	3,354	3,750	2,537	3,650
Ingots (MT)	2,661	2,152	2,419	2,974	2,506	2,619	2,833	2,985	2,489	1,174
Wafers (MT)	0	0	562	778	19,882	5,626	489	1,869	3,497	2,195
Cells (GW_{DC})	n/a	n/a	n/a	1.057	2.575	2.218	2.673	2.657	3.863	5.224
Modules (GW_{DC})[b]	9.943	13.451	10.865	5.731	18.611	26.731	23.535	29.435	56.469	32.576

Sources: U.S. Census Bureau, as available on USITC DataWeb, U.S. International Trade Commission, https://dataweb.usitc.gov/; U.S. Department of Energy (DOE), "Annual Solar Photovoltaic Module Shipments Report," https://www.eia.gov/renewable/annual/solar_photo/.

Notes: MT = metric tons; GW_{DC} = gigawatts-direct current; n/a = not available. Data collected using the following Harmonized Tariff Schedule of the United States (HTS) codes: 2804.61.0000, 3824.99.1100,

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Energy Markets and Policy Department, October 2024, https://emp.lbl.gov/sites/default/files/2024-10/Utility%20Scale%20Solar%202024%20Edition%20Slides.pdf.

[53] USITC also tracks other import characteristics, such as the dollar value of imports.

3818.00.0090, 8541.40.6025, 8541.42.0010, 8541.42.0080, 8541.40.6015, 8541.40.6035, 8541.43.0010, 8541.43.0080.

a. The 2024 data are values through June 2024.

b. Module data for 2015-2017 are from DOE. All other data in the table are from USITC DataWeb.

Given the various trade conditions discussed above, country of origin can be an important consideration for solar PV component imports. The majority of U.S. imports come from a small set of nations. While the majority of solar PV component manufacturing capacity is located in China, the various international trade policies related to tariffs and trade findings have reduced direct imports from China. **Table 5** depicts U.S. imports of solar PV modules, listed by country of origin.

Table 5. U.S. Solar PV Module Imports by Country of Origin, 2015-2024

(GW_{DC} of capacity)

Country of Origin	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024[a]	Total, 2019-2024	Percentage, 2019-2024
Cambodia	n/a	n/a	n/a	n/a	0.055	0.548	0.799	2.365	7.152	2.426	13.346	7.1%
China	3.288	2.670	0.741	n/a	0.364	1.160	0.214	0.304	0.090	0.025	2.156	1.2%
India	n/a	0.002	n/a	n/a	0.331	0.183	0.406	0.648	4.874	2.573	9.016	4.8%
Malaysia	2.322	3.789	3.254	2.631	7.447	9.088	7.332	4.638	10.041	4.574	43.120	23.0%
South Korea	0.468	1.869	1.899	n/a	1.358	2.252	1.749	3.255	3.263	0.308	12.185	6.5%
Thailand	n/a	0.889	n/a	n/a	1.462	4.301	4.199	4.981	11.473	7.564	33.981	18.1%
Vietnam	0.361	0.930	1.028	n/a	5.846	7.541	7.518	10.555	15.691	13.159	60.309	32.2%
ROW	n/a	2.630	n/a	n/a	1.748	1.659	1.316	2.689	3.885	1.947	13.244	7.1%
Worldwide	9.756	12.777	9.997	7.238	18.611	26.731	23.535	29.435	56.469	32.576	187.357	

Sources: Data for 2015-2018 are from U.S. Department of Energy, "Annual Solar Photovoltaic Module Shipments Report," https://www.eia.gov/renewable/annual/solar_photo/. Data for 2019-2024 are from U.S. Census Bureau, as available on USITC DataWeb, U.S. International Trade Commission, https://dataweb.usitc.gov/.

Notes: Table lists top six countries of origin by total imports, plus China. Prior to 2019, data by country of origin are less uniform. GW_{DC} = gigawatts-direct current; ROW = "rest of world" (i.e., worldwide excluding the seven countries listed above); n/a = not available. Percentage is each country's imports as a share of imports worldwide during 2019-2024. Data collected from the following Harmonized Tariff Schedule of the United States (HTS) codes: 8541.40.6015, 8541.40.6020, 8541.40.6035, 8541.43.0010, 8541.43.0080.

a. The 2024 data are through June 2024.

Projections of the imports of solar components in future years are difficult to make. Complicating factors include the end of the bifacial panel exemption; pending federal decisions on antidumping and countervailing duties on Cambodia, Malaysia, Thailand, and Vietnam; and domestic supply chain and workforce issues.[54]

[54] ITA, "Commerce Initiates Antidumping and Countervailing Duty Investigations"; SEIA, *Solar Market Insight Report Q2 2024*, June 5, 2024, https://seia.org/research-resources/solar-market-insight-report-q2-2024 (hereinafter SEIA, *Solar Market Insight Q2 2024*).

Considerations for Congress

Effects of Recent Incentives and Related Regulations

The modifications the IRA made to the ITC, PTC, and other tax credits, the transition to the new technology-neutral clean electricity tax credits, and the implementation of other new credits might increase solar PV deployment compared with what would have happened without the IRA. It is difficult to determine the causal impacts of any given tax credit and clearly distinguish those effects from other policy reforms implemented at the same time. Aldy (2024) notes that "considerable uncertainty characterizes the economic, emissions, energy, and fiscal implications of the law," due in part to the many separate legal requirements for receiving the various credits.[55] As of November 4, 2024, the IRS and the Treasury Department had finalized fewer than half of the regulations called for under the IRA.[56] Various regulations that could impact the solar industry, including regulations for the CEITC, the CEPTC, and the IRA's modifications to the existing ITC, had not been issued as of November 20, 2024.

Congress could consider the implementation of the IRA tax credits to determine if they are having the intended impact and could provide additional oversight or revisions to the policies. The IRS has released guidance on the ITC, in particular expanding the applicability of the bonus credit for investing in specified energy communities.[57] The IRS has also finalized regulations for the "direct payments" and for the wage and apprenticeship requirements for receiving higher IRA base credits. Congress could evaluate these federal regulations (or other forthcoming regulations) and could decide whether they are achieving intended results and whether to modify or optimize the effects of federal incentives. Alternately, Congress could repeal the tax credits, as has been proposed in the 118th Congress (see discussion in "Activities in the 118th Congress").

Disbursement of Federal Program Funds

Many of the federal solar PV-related programs established, modified, or funded by the IRA and the IIJA are in the process of being deployed by DOE and other federal agencies. The IIJA appropriated approximately $75.8 billion for energy and minerals-related research, demonstration, technology deployment, and incentives.[58] Of those funds, $38.9 billion was appropriated for programs that could affect solar PV deployment, including RE, grid reliability, batteries, and critical minerals programs. These funds support new programs, existing programs that were reorganized or reoriented, and existing programs that received new funding or expanded applicability; all of the programs are complex, involving considerable technical-, social-, and policy-based challenges. As examples of expanded eligibilities, the IRA allowed nonprofits to access the ITC via direct payments. An example of a program implementing new and ongoing funding is DOE's Renew America's Schools program, which aims to improve school buildings

[55] Joseph E. Aldy, *How Big Is the "Biggest Climate Spending Bill Ever?" Key Factors Influencing the Inflation Reduction Act's Clean Energy Impacts*, National Bureau of Economic Research, Working Paper no. 33092, October 2024.

[56] The IRS maintains a website listing the finalized IRA regulations, available at https://www.irs.gov/newsroom/final-regulations-for-the-inflation-reduction-act-of-2022. The website lists two regulations for the Advanced Manufacturing Investment Credit—passed as part of P.L. 117-167, known as the CHIPS and Science Act—as finalized IRA tax regulations.

[57] IRS, "Energy Community Bonus Credit Amounts Under the Inflation Reduction Act of 2022," https://www.irs.gov/pub/irs-drop/n-24-30.pdf.

[58] For more information, see CRS Report R47034, *Energy and Minerals Provisions in the Infrastructure Investment and Jobs Act (P.L. 117-58),* coordinated by Brent D. Yacobucci.

with energy efficiency and RE projects. The program's 2024 Renew America's Schools Prize and Grant was funded by the IIJA.[59]

Congress could consider oversight activities to review the status of the solar PV-related programs. DOE (and its cooperating agencies such as Commerce, Treasury, and the IRS, among others) is in the process of creating programs, issuing rules and regulations, issuing funding opportunity notices, collecting and selecting projects, and providing fund disbursements and project reviews. Oversight of these programs could ensure timely and appropriate consideration regarding disbursement of IIJA and IRA funds and ensure the programs are having their intended impact on solar PV development and deployment. Many of the IIJA programs are funded through FY2026, so Congress might also consider whether such funding is necessary or sufficient.

Increasing Deployment of Solar Photovoltaics and Related Effects

Solar PV can be a distributed energy resource (DER) when installed and connected to local or regional distribution grids, and it can have many potential benefits that support grid resilience. Solar PV can support resilience by providing on-site electricity generation (for example, for farms or residences), including during grid-based generation or transmission disruptions, assuming the solar PV is properly configured to do so.[60] Solar PV can provide electricity generation to distribution networks—to potentially reduce stress on the long-distance transmission lines—and can provide limited electricity generation independent of fuel supplies, fuel transportation disruptions, or fuel prices.[61] Congress could consider the role of federal agencies relative to state and local authorities and electricity regulators in developing requirements, standards, and best practices for solar PV or other similar DERs. The requirements, standards, and best practices could support solar PV deployment where additional distributed generation could improve grid resilience. Congress could consider the extent to which federal programs might consider solar PV deployment as a means to improve grid resilience.

Increasing penetration of solar PV and the development and presence of supporting technologies can provide benefits to the electricity grid. The potential benefits include increased grid reliability for customers with properly configured DERs, reduced electricity costs, avoided negative environmental impacts of other electricity generation technologies, replacement of outdated or inefficient plants, increased supply to meet new electricity demand, and support for advanced grid elements and designs (such as microgrids or smart grids).[62] Congress could consider the role of federal programs or incentives to encourage greater deployment of solar PV (and integration with

[59] DOE, "Renew America's Schools," https://www.energy.gov/scep/renew-americas-schools; DOE, "Biden-Harris Administration Announces $180 Million Investment in School Energy Infrastructure as Part of Investing in America Agenda," press release, March 20, 2024, https://www.energy.gov/articles/biden-harris-administration-announces-180-million-investment-school-energy-infrastructure.

[60] In a typical configuration, residential solar PV systems turn off in the event of a grid disruption. Jacob Marsh, "Do Solar Panels Work During a Power Outage?" EnergySage, December 6, 2023, https://www.energysage.com/solar/do-solar-panels-work-during-a-power-outage.

[61] American Council for an Energy-Efficient Economy, "Distributed Energy Resources," https://www.aceee.org/topic/distributed-energy-resources.

[62] A *microgrid* is a system of interconnected demand and energy resources (such as solar PV) that can act as a single controllable entity. A *smart grid* is an electricity system integrated with communication and information technology—including advanced solar PV inverters and control technologies. Killian McKenna et al., *Preparing Distribution Utilities for the Future—Unlocking Demand-Side Management Potential*, report prepared by NREL for the U.S. Agency for International Development, July 2021, https://www.nrel.gov/docs/fy21osti/79375.pdf; NREL, "Microgrids," https://www.nrel.gov/grid/microgrids.html; Ben Kroposki, "Smart Grid Overview," presentation, NREL, https://www1.eere.energy.gov/femp/pdfs/fupwg_fall12_kroposki.pdf.

other RE and supporting technologies such as energy storage) where solar PV would provide benefits.

On the other hand, increasing penetration of solar PV (and other intermittent RE technologies) can—depending on its configuration—create reliability risks for the grid. The North American Electric Reliability Corporation (NERC) has identified risks related to high levels of intermittent RE deployment, including RE potentially not being able to provide voltage control, frequency support, and/or essential reliability services (ERS) during normal and disturbed grid operations. Additionally, although solar PV and other DERs can satisfy some demand and thus potentially reduce the loading on transmission lines, the operation of these DERs introduces additional complexities for managing and balancing transmission and distribution line use.[63] Since 2007, NERC has been studying the interaction of intermittent RE and DERs with the grid.[64] NERC has recommended standards and best practices for the operation of DERs (including advanced inverter standards) and has recommended state regulators consider DER risks, standards, and best practices in their interconnection rules.[65]

Congress could consider modifying or expanding the federal rules for NERC and their authority to develop new reliability standards, to incorporate deployment of and generation from solar PV, and to ensure compatibility with supporting technologies such as energy storage and other complementary RE technologies. The federal role is fairly limited. Under current law, states are responsible for the majority of grid deployment decisions, including approving new power plants, new transmission lines, and requirements relating to the share of electricity that should be generated from RE.

Deployment of rooftop solar PV can be significantly affected by net metering policy—as has been demonstrated by reduced rates of deployment of rooftop solar PV in California since 2023.[66] Congress directed the National Academies of Sciences, Engineering, and Medicine to study the challenges and impacts of net metering (Section 8015 of the Consolidated Appropriations Act, 2021; P.L. 116-260).[67] Congress could consider further studying issues like cost shifting (for example, determining the existence and/or severity of cost shifting) and best practices for net metering based on relevant energy market conditions (such as the presence of a competitive energy market or the degree of penetration of intermittent RE in that market).

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[63] North American Electric Reliability Corporation (NERC), *Distributed Energy Resources: Connection Modeling and Reliability Considerations*, February 2017, https://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/Distributed_Energy_Resources_Report.pdf (hereinafter NERC, *Distributed Energy Resources*).

[64] For more information, see CRS Report R45764, *Maintaining Electric Reliability with Wind and Solar Sources: Background and Issues for Congress*, by Ashley J. Lawson.

[65] NERC, *Distributed Energy Resources*.

[66] Other markets—such as Hawaii, Nevada, South Carolina, and California—reportedly also experienced downturns in rooftop solar PV deployment after changing their net metering policies. Emma Foehringer Merchant, "Hawaii's Trailblazing Solar Market Continues to Struggle Without Net Metering," Greentech Media, August 7, 2019, https://www.greentechmedia.com/articles/read/hawaiis-solar-market-continues-to-struggle-without-net-metering; Kavya Balaraman, "California Rooftop Solar Had a Tough Year Following NEM 3.0. Can the Industry Bounce Back?" *Utility Dive*, January 2, 2024, https://www.utilitydive.com/news/california-rooftop-solar-nem-30-outlook/702498/; SEIA, "A New Reality: The Path Forward for California's Solar and Storage Industry," blog post, January 29, 2024, https://seia.org/blog/new-reality-path-forward-californias-solar-and-storage-industry/.

[67] National Academies of Sciences, Engineering, and Medicine, *The Role of Net Metering in the Evolving Electricity System* (National Academies Press, 2023), https://nap.nationalacademies.org/read/26704/chapter/1#xv.

Trade Issues

It is uncertain to what extent the existing trade restrictions and tariffs have affected the expansion of domestic solar PV manufacturing or the rate of solar PV deployment; a number of factors may be mitigating the impact of the restrictions and tariffs. These factors include circumvention actions by foreign nations, trade rule exceptions that lessen the impact of the tariffs, and other market responses to the trade restrictions. Examples of market responses include U.S. solar PV project developers importing components from countries not covered by the trade restrictions, importing solar PV panel types allowed under the exemptions, or importing components and stockpiling them when the restrictions or tariffs do not apply. Additionally, some industry stakeholders (such as SEIA, as noted in its June 2024 quarterly industry market report) have reported that uncertainty surrounding trade policy—particularly the investigations into circumvention actions and the potential resulting antidumping and countervailing duty responses—is another factor potentially limiting growth of solar PV deployment.[68]

Congress could consider providing guidance and conducting oversight on trade decisions relating to the types of tariff exceptions, the existence or levels of quotas, or the targets of tariffs. Congress could also consider modifying the relevant sections of the Trade Act of 1974 to broaden or narrow the scope of available tariff actions or to require actions be dependent on particular fact-findings or rulings, or to strengthen or weaken dependence on World Trade Organization (WTO) mechanisms. Congress could also consider legislation or oversight activities regarding the statutory time limits on some tariffs (e.g., the Section 201 tariffs), the five-year review cycle for AD/CVD orders, or the regular review cycle for tariffs (e.g., the Section 301 tariffs). Congress could also consider whether actions taken by an Administration should be dependent on judicial or administration determinations that harm to U.S. interests has occurred or that existing trade measures are or are not having their intended effects.

Workforce Issues

Workforce issues could affect the continued deployment of solar PV systems. Industry stakeholders (such as SEIA, in its June 2024 quarterly industry market report) note that a lack of labor availability is one factor likely to impede continuing growth in solar PV deployment.[69] The CEITC's energy communities bonus credit and the wage and apprenticeship multiplier requirements could support RE deployment in communities negatively impacted by the energy transition and could potentially leverage retrained energy industry workers in transitioning to new solar PV opportunities.

Congress could consider oversight of federal solar PV workforce initiatives. Congress could consider the role of workforce bonus credits or modifying existing wage and apprenticeship credits of the ITC (or other existing credits) to include requirements related to employing or contributing to retraining, certifying, or apprenticing energy industry workers on solar PV projects.

Activities in the 118th Congress

The 118th Congress has considered a variety of bills that address some elements of the topics covered in this report. For example, the American Tax Dollars for American Solar Manufacturing Act (S. 4873) would restrict the Advanced Manufacturing Production Credit from applying to

68 SEIA, *Solar Market Insight Q2 2024*.

69 SEIA, *Solar Market Insight Q2 2024*.

components sourced from "foreign entities of concern," while the Keep China Out of Solar Energy Act of 2023 (S. 968) would develop standards and guidelines for executive agencies to prohibit federal funds from being used to purchase solar PV panels from China or from entities influenced by China. In May 2023, Congress passed H.J.Res. 39, which would have ended the pause on tariffs on solar panels (the "solar bridge") from four Southeast Asian nations; President Biden vetoed this act and Congress failed to override President Biden's veto.[70]

Some legislation addressed the role of incentives and tax credits. The Limit, Save, Grow Act of 2023 (H.R. 2811), which passed the House, would remove the Advanced Manufacturing Production Credit, the Clean Electricity ITC, and the Clean Electricity PTC, along with other energy-related tax credit provisions. The Restoring Energy Market Freedom Act (H.R. 1562) would remove many of the energy tax credits related to solar energy.

Other legislation considered support of domestic manufacturing. The Reclaiming the Solar Supply Chain Act of 2023 (S. 1643 and H.R. 4990) would establish a DOE program of grants and loans to support the domestic solar PV manufacturing supply chain. The Renewable Energy Jobs Act (H.R. 2520) and the Protecting Workers for a Clean Future Act (H.R. 9651) would support workforce development and workforce transition for solar energy (among other RE types).

Congress has also conducted oversight on these topics. On May 23, 2023, the House Committee on Energy and Commerce held a hearing, *Growing the Domestic Energy Sector Supply Chain and Manufacturing Base: Are Federal Efforts Working?*, to examine recent federal efforts to increase the domestic energy sector supply chain and manufacturing.[71] On September 20, 2023, the Joint Economic Committee held a hearing, *Growing the Economy of the Future: Job Training for the Clean Energy Transition*, to explore clean energy workforce development and the effectiveness of federal support.[72] On June 12, 2024, the Joint Economic Committee held a hearing examining U.S. manufacturing investment following the IIJA, IRA, and CHIPS Act (and the earlier Tax Cuts and Jobs Act, P.L. 115-97) and debated which federal policies, if any, were responsible for increasing investment in solar manufacturing and related areas.[73] On September 20, 2023, the Joint Economic Committee held a hearing, *Growing the Economy of the Future: Job Training for the Clean Energy Transition*, to explore clean energy workforce development and the effectiveness of federal support.[74]

[70] A two-thirds majority is required: the vote count was 214-205 to override. White House, "Message to the House of Representatives—President's Veto of H.J. Res. 39," May 16, 2023, https://www.whitehouse.gov/briefing-room/presidential-actions/2023/05/16/message-to-the-house-of-representatives-presidents-veto-of-h-j-res-39/; Clerk of the House of Representatives, "Roll Call 233 | Bill Number: H. J. Res. 39," May 24, 2023, https://clerk.house.gov/Votes/2023233.

[71] U.S. Congress, House Committee on Energy and Commerce, Subcommittee on Oversight and Investigations, *Growing the Domestic Energy Sector Supply Chain and Manufacturing Base: Are Efforts Working?*, hearing, 118th Cong., 1st sess., May 23, 2023, https://democrats-energycommerce.house.gov/committee-activity/hearings/hearing-on-growing-the-domestic-energy-sector-supply-chain-and.

[72] U.S. Congress, Joint Economic Committee, *Growing the Economy of the Future: Job Training for the Clean Energy Transition*, hearing, 118th Cong., 1st sess., September 20, 2023, S.Hrg. 118-49, https://www.govinfo.gov/content/pkg/CHRG-118jhrg53818/pdf/CHRG-118jhrg53818.pdf.

[73] U.S. Congress, Joint Economic Committee, *Made in America: The Boom in U.S. Manufacturing Investment*, hearing, 118th Cong., 2nd sess., June 12, 2024, https://www.jec.senate.gov/public/index.cfm/hearings-calendar?ID=64634074-E9CF-4864-9400-E017645CC14B.

[74] U.S. Congress, Joint Economic Committee, *Growing the Economy of the Future: Job Training for the Clean Energy Transition*, hearing, 118th Cong., 1st sess., September 20, 2023, S.Hrg. 118-49, https://www.govinfo.gov/content/pkg/CHRG-118jhrg53818/pdf/CHRG-118jhrg53818.pdf.

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