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Perspective
EXPERT INSIGHTS ON A TIMELY POLICY ISSUE

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Incentivizing Solar

Catalyzing Solar Energy Technology Adoption to Address the Challenge of Climate Change

The United States emerged from the energy crisis of the 1970s with a strong motivation to enhance energy security and develop nonpolluting sources of energy. Renewable energy (RE), particularly solar energy, was seen as a potential pathway toward a more diverse and sustainable energy portfolio. The Solar Energy Research Institute, later the National Renewable Energy Laboratory, was established in 1975 to facilitate more intensive research and development of solar technologies (National Academy of Sciences, 1975). In 1982, the world's first megawatt (MW)-scale solar power station was turned on in San Bernardino County, California (Office of Energy Efficiency & Renewable Energy, undated-b). This was quickly followed by additional facilities, which experimented with the early solar technologies available at the time. These pioneering facilities met a negligible fraction of the nation's energy demand. However, with expansion of RE considered to be in the national interest, the federal government subsidized their construction, along with ongoing research and development programs (Hart, 1983).

More than 40 years later, the U.S. energy landscape has changed markedly. In 2020, RE sources—such as hydro, wind, and solar power—were responsible for approximately 15 percent of total U.S. electricity generation (U.S. Energy Information Administration, 2021b). This RE expansion has been driven by significant reductions in cost that make RE competitive with fossil fuels and by expanded federal and state mandates to address climate change and other impacts of fossil fuel use. RE technologies are often a preferred choice for replacing capacity losses from retiring fossil fuel power plants and meeting new energy demands from the growing U.S. population and economy.

Abbreviations

C&I	commercial and industrial
CES	clean energy standard
DVC	disadvantaged and vulnerable community
FIT	feed-in tariff
GCAM	Global Change Analysis Model
GW	gigawatt
IRS	Internal Revenue Service
ITC	investment tax credit
kW	kilowatt
MW	megawatt
NEM	net metering
PPA	power purchase agreement
PUC	public utility commission
PV	photovoltaics
RE	renewable energy
REC	renewable energy credit
RPS	renewable portfolio standard
SEIA	Solar Energy Industries Association
SREC	solar renewable energy credit

Solar power, in the form of solar photovoltaics (PV) and concentrating solar-thermal power, comprises 3 percent of the nation's electricity generation capacity (Office of Energy Efficiency & Renewable Energy, undated-c). However, solar power is rapidly growing as a sector: In 2021, solar power is expected to make up 39 percent of new installed generation capacity, making it the dominant form of new power generation in the nation this year (Ray, 2021). With the Biden administration positioning the United States to reemerge as an international leader on climate change, including setting aggressive new targets for climate action, some policymakers and solar developers are reviewing federal incentives to ensure that they are appropriately structured to enable solar power to contribute to meeting the administration's policy goals over the next decade.

In this Perspective, we provide an overview of the U.S. solar energy market, the rapid changes that it has undergone over the past decade, and the challenges that lie ahead as the broader energy system evolves. We highlight the roles that different stakeholders, particularly the federal government, play in incentivizing solar markets. We provide commentary on the Section 25D and Section 48 solar federal investment tax credit (ITC) extensions and the parity of these extensions in the context of recent net-zero climate and energy targets. We explore the potential implications of incentives for different solar technologies and private-sector business models and identify characteristics of federal incentives that are consistent with the Biden administration's policy objective of achieving deep decarbonization of the U.S. economy. We also explore the reliability and resiliency of solar power, its co-benefits for the jobs market, and its availability to disadvantaged and vulnerable communities (DVCs).

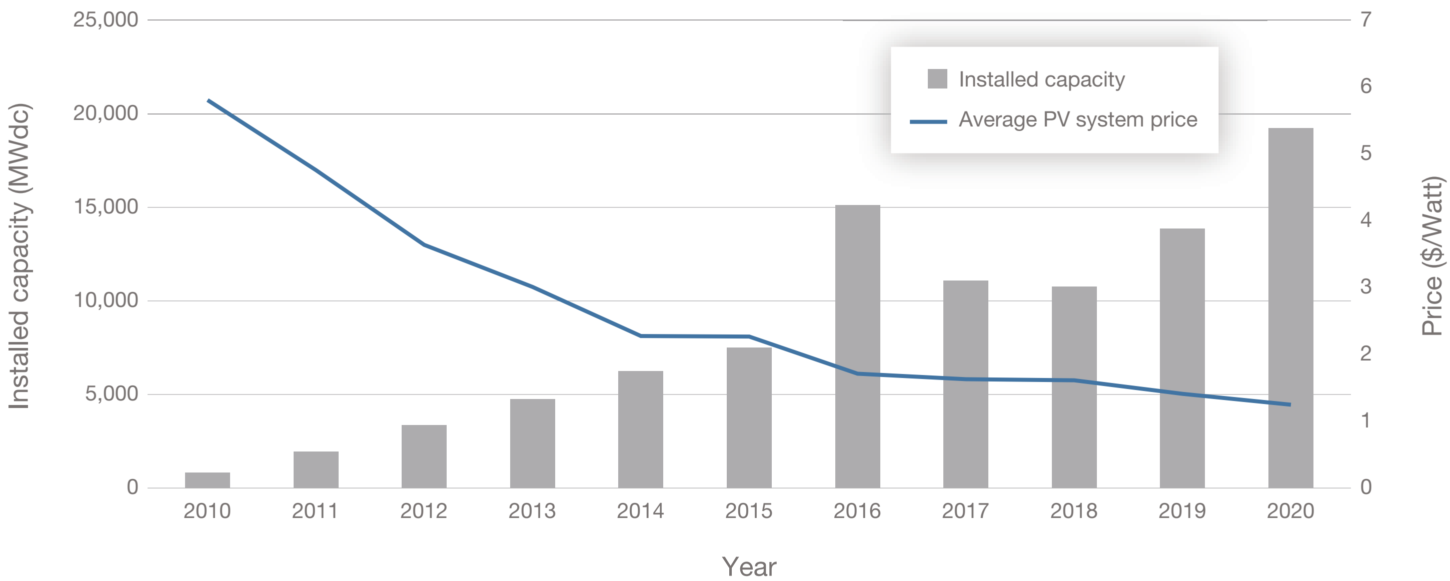
Drivers of Demand for Solar Power

The U.S. solar industry has experienced unprecedented growth in recent years. The domestic solar industry has grown an average of 49 percent per year for the past ten years (Solar Energy Industries Association [SEIA], 2021b; see Figure 1). Even as the coronavirus pandemic created an uncertain financing environment throughout the energy sector, new solar installations remained strong, surpassing all other generation technologies (Dickson, 2021). A record 19.2 gigawatts (GW) direct current of solar electricity capacity was installed in 2020.[1] This was a 43-percent increase over 2019 (SEIA, 2021a).

Much of this growth is a function of dramatic improvements in solar PV technologies; solar power is increasingly cost-competitive with other sources of energy, such as coal and natural gas. The unsubsidized levelized cost of electricity from utility-scale solar PV technologies ranged from $29 to $42 per megawatt-hour (MWh) in 2020—comparable with natural gas combined cycle generation technologies (Lazard, 2020).

FIGURE 1

U.S. Solar Photovoltaic Price Declines and Deployment Growth



SOURCE: SEIA, 2021b. Used with permission.

NOTES: The curve represents the blended average price (in dollars per watt) of a solar PV system between 2010 and 2020. Vertical bars represent the annual installed capacity of solar PV in MWdc over the same time period. Data reflect an order of magnitude increase in installed capacity in conjunction with a 75-percent reduction in system price. MWdc = megawatts direct current.

For more than 40 years, surveys have indicated that a majority of Americans favor renewable sources of electricity and would be willing to pay more per monthly utility bill for power from renewable sources (Farhar, 1999). In addition, the increasing affordability of solar power also has increased its accessibility to whole new classes of developers and consumers. Recent surveys show increased interest in installing residential solar, matching patterns of solar PV market growth. Approximately 53 percent of U.S. adults reported that they would be willing to invest in residential or community solar panels if they could recoup the investment in five years (Consumer Reports Advocacy, 2018). Among U.S. homeowners, 46 percent have seriously considered installing residential solar panels, and 6 percent already have done so (Kennedy and Thigpen, 2019). Of homeowners who have demonstrated or acted on this interest, the primary reasons were to save money on utility bills (96 percent), help the environment (87 percent), use the solar ITC (67 percent), and better the health of the individual or their family (60 percent) (Kennedy and Thigpen, 2019). Strong consumer interest reflects a sizeable market for distributed solar generation at the household level—if barriers, such as the upfront costs of solar systems, interconnection policies and tariffs, and the need for energy storage, can be overcome.

In addition to its popularity, solar power is increasingly seen as an important enabling technology for the nation's transition to a low- or net-zero-carbon economy. Decarbonizing the U.S. economy will necessitate large-scale deployment of a number of technologies, including RE (wind and solar), energy storage, bioenergy, and carbon capture (Masson-Delmotte et al., 2018).

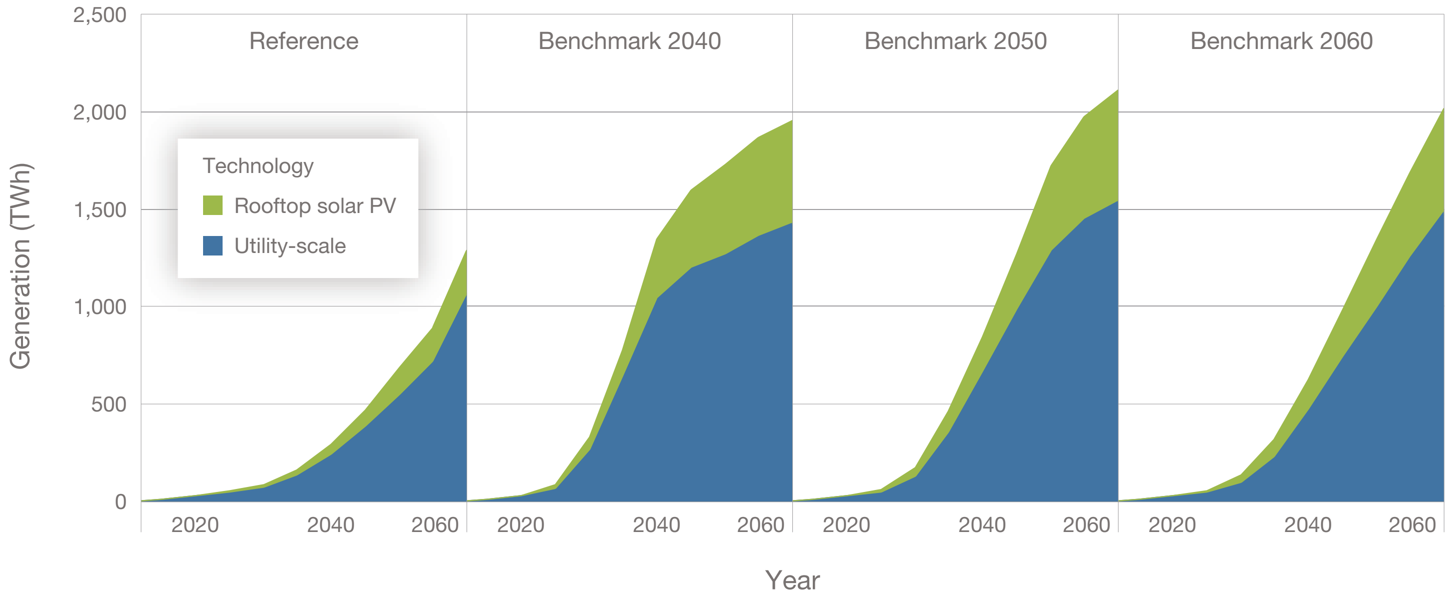
To explore alternative scenarios in which technological change, the economy, and policy interventions shape the future energy landscape, researchers often rely upon integrated assessment models. One such model, the Global Change Analysis Model (GCAM), has seen extensive use in modeling pathways toward deep decarbonization of the U.S. economy (The White House, 2016). Recent GCAM modeling undertaken by Pacific Northwest National Laboratory generated estimates of future deployment of solar generation capacity (both utility-scale and rooftop) for a variety of policy scenarios. The scenarios assume that the United States achieves a net-zero emissions benchmark target by 2040, 2050, or 2060 (Kaufman et al., 2020; see Figure 2). These scenarios are compared with a reference "do-nothing approach" that assumes that no specific policy interventions are made to address climate change.

All scenarios imply that significant growth in utility-scale and rooftop solar generation will be needed to get to net-zero emissions, indicating that both technologies, despite their inherent cost differences, are likely to be major contributors to net-zero emissions pathways. Even under the reference scenario, solar generation increases for several decades into the future. However, the net-zero scenarios outpace the reference scenario by a factor of four to eight. Meanwhile, total utility-scale generation consistently exceeds that of rooftop solar.

These results represent just one set of scenarios from a single model and are sensitive to assumptions within GCAM. Therefore, the absolute magnitude of generation and the relative contribution of rooftop and utility-scale solar projects to future generation remains uncertain. Nevertheless, these results highlight the potential for aggressive climate targets to boost demand for solar power.

FIGURE 2

Utility-Scale and Distributed Rooftop Growth Trend Effects by Net-Zero Year



SOURCE: Authors' analysis of data created by the Pacific Northwest National Laboratory and supplied to the authors by Noah Kaufman, Alexander R. Barron, Wojciech Krawczyk, Peter Marsters, and Haewon McJoen. See Kaufman et al., 2020, for additional analysis.

NOTES: Utility-scale (blue) and rooftop solar (green) generation growth scenarios are consistent with a straight-line path to net-zero carbon in the target year. Scenarios were derived from the 50-state version of GCAM-USA and data available as of 2019. TWh = terawatt-hour.

Different Models for Solar Power Deployment

Despite a large and growing demand for solar power, incentivizing further expansion of solar power in the United States likely will be necessary to meet decarbonization goals. Designing such incentives requires an appreciation for the different business models through which solar projects are financed and developed. Generally, the industry and individual solar projects can be divided into three market segments: residential, commercial and industrial (C&I), and utility-scale (see Table 1).

Residential solar projects account for 20 percent of total solar generation; their installed capacity is usually under ten kW (SEIA, undated-b). These projects tend to be installed on individual households. They are designed to generate power that is consumed on-site, but opportunities often exist for excess power to be sold back to a utility through the electricity grid.

TABLE 1

Example Solar Power Projects by Scale, Ownership, and Acquisition Model

Segment	Percentage of Installed Capacity	Approximate Size	Often Associated with On-Site Consumption	Ownership Options and Key Characteristics	Example Firms
Residential	20	<10 kW	Yes	• Owned by homeowner – Monetizes tax benefits directly • PPA/Own-leaseback model – Third-party financier monetizes tax benefits	• Private homeowners • Sunrun • Tesla • Google • SunPower
C&I	17	50 kW to >1 MW	Yes	• Owned by commercial entity – Monetizes tax benefits directly • PPA/Own-leaseback model – Third-party financier monetizes tax benefits	• Google • Facebook • Tesla • SunPower
Utility-scale	63	>1 MW	No	• Owned by utility or independent power producer	• NextEra Energy Partners • Dominion Energy • Berkshire Hathaway Energy • Cypress Creek Renewables • AES Clean Energy

NOTE: kW = kilowatt.

C&I projects, although highly varied, typically are larger than residential solar projects. C&I projects comprise 17 percent of installed capacity and usually exceed 50 kW in capacity (SEIA, undated-a). Utility-scale solar projects are generally the largest-scale solar projects, exceeding one MW, and constitute 63 percent of installed capacity (SEIA, undated-b). Unlike residential and C&I projects, which are distributed forms of generation, the electricity produced by centralized, utility-scale projects is *not* used on-site and is usually sold to a wholesale electricity market. This makes utility-scale projects more like conventional power plants.

Although this segmentation of solar projects is a useful convention, the industry has become more complex because of the emergence of varied and multifaceted ownership structures for solar assets. This complexity has emerged partly because of the structuring of federal financial incentives. These incentives shape whether and how different stakeholders can invest in and benefit from solar projects.

A variety of acquisition models can be used with the three project scales. Two common models are (1) *direct ownership* of the solar equipment through purchase and (2) *nonownership* through a lease or a power purchase agreement (PPA). Direct ownership occurs through the traditional sales model, in which the project owner finances the solar project through a combination of equity and debt. The owner directly receives the benefits of the project: the use or sale (or both) of the electricity generated and any additional financial incentives. In contrast, nonownership models offer financial flexibility by not requiring upfront investment. Instead, the customer makes a monthly payment for the equipment (a solar lease) or is charged a per-unit price for each unit of electricity generated as per a PPA. Financial incentives meant to promote solar development are then received by the third party that provided the upfront financing for the project. There are a variety of reasons why this third party may opt to retain some or all of the incentive. Tax equity financing or the securitization of bundled ITCs are associated with higher administrative costs; therefore, the third party might opt to withhold a greater fraction of the incentive benefits as compensation.

Policy Incentives Relevant to Solar Deployment

Since the federal government started investing in solar power in the 1970s, a variety of policy approaches and incentives have been used to encourage the development and uptake of solar technologies, including basic and applied research and development and incentives aimed at increasing deployment of solar generation capacity. Federal efforts have been complemented by a number of important state incentives and mandates—such as renewable portfolio standards—that vary significantly from one state to another. Collectively, these interventions in the solar market have contributed to bringing down the costs of the technology and expanding the installation of solar capacity throughout the United States. The Biden administration's plan to significantly accelerate decarbonization of the U.S. economy, including 100 percent carbon-free electricity by 2035, creates new demands for continued expansion of renewables (The White House, 2021a).

Under status quo policies, projections for renewable electricity fall short of what is needed, reaching only 42 percent of total installed capacity by 2050 (U.S. Energy Information Administration, 2021a). This indicates a need to continue to incentivize investment in RE, including solar technologies, not only to meet growth in electricity demand but to accelerate the retirement of existing fossil fuel power plants (The White House, 2021c). Such market interventions must be carefully designed and evaluated to ensure that they are effective in achieving policy objectives and that their benefits are fairly allocated. This includes considering who is eligible to receive incentives and the downstream impacts of different incentive structures.

Incentives are often described as either "carrots"—rewards (often financial rewards, such as tax credits or rebates) for behavior consistent with a desired objective—or "sticks"—punishments (e.g., fees, fines, taxes) for behavior that runs counter to the policy objective. Such incentives can be directed at specific technologies or can focus on broader outcomes, such as pollution emissions. Incentives for renewables are typically paid to stakeholders and are based on the upfront investment in the energy asset (e.g., during project development and construction) or based on the per-unit value of electricity produced over time. Unlike conventional power systems, the cost of wind and solar projects primarily involves upfront capital and installation, not fuel and operations and maintenance. Incentives should reflect these differences in the structure of costs.

We examine various incentives that have been used by the federal government to support U.S. solar markets in recent years; incentives that have featured prominently in U.S. energy and climate debates but have yet to be enacted at the federal level; and state-level policies that interact, or could interact, with federal incentives (see Table 2). Understanding how these incentives work, both as originally intended and as currently implemented, and their typical

TABLE 2

Policy Incentives to Mitigate Climate Change and Increase Solar Deployment

Incentive Type	Incentive Method	Scale of Implementation
Nonrefundable tax credits	Investment subsidy for eligible RE equipment relying on the project owner's tax liability	Federal/state
Refundable tax credits	Investment subsidy for eligible RE equipment	Federal
Clean energy standards	Generation threshold standard for RE production	State
Carbon pricing	Greenhouse gas (GHG)–associated per-unit price	State/region
Renewable energy credits (RECs)	Generation certificate credit for per-unit RE power generation	State
Net energy metering (NEM)	Generation payment tariff program for net power purchased from utility (typically subtracting a customer's power production from power consumed over a set billing cycle)	State
Feed-in tariffs (FITs)	Generation guaranteed payment program for RE power generation	State

market effects is important for considering any changes in the structure of solar incentives.

Tax Credits

A variety of tax credit incentive programs for solar assets exist throughout the United States. They can be divided into two categories: nonrefundable and refundable. A *nonrefundable tax credit* cannot be used to create or increase a tax refund and therefore cannot exceed the amount of tax an individual or business owes the Internal Revenue Service (IRS). As a consequence, they tend to be more valuable to those with large tax burdens, such as wealthy homeowners or large businesses and investors. The federal solar ITC is a nonrefundable tax credit and is one of the most important incentives for the solar power industry; it is credited for the 52-percent average annual growth rate on a capacity basis since 2006 (SEIA, undated-c). The modern version was first signed into law in the Energy Policy Act of 2005 and modified in subsequent legislation (see Table 3). The solar ITC is regulated under two provisions of the Internal Revenue Code of 1986: Section 25D for individual homeowners and Section 48 for commercial entities (IRS, 2021a and 2021b).

Under these two provisions, homeowners and companies receive the same tax credit rate (currently a 26-percent deduction of the value of an eligible, solar energy system from federal income tax liability). The eligible system must be placed in service (for the Section 25D credit) or must have started construction (for the Section 48 credit) by the end of the year corresponding to the tax credit rate.

A key feature of the solar ITC is its sunset provisions. An incremental phasing out of the ITC was scheduled to begin at the end of 2020. However, in December 2020, the ITC was extended with a new sunset schedule (see Table 4). The phasing out of federal support for industries and

TABLE 3

History of Solar Investment Tax Credits

Year Enacted	Public Law	Description
2005	The Energy Policy Act	• Established a 30-percent tax credit for investments in eligible solar energy property through Section 25D for individuals and Section 48 for commercial entities in the Internal Revenue Code of 1986
2006	The Tax Relief and Health Care Act	• Extended the residential and commercial ITC through December 31, 2008
2008	Emergency Economic Stabilization Act	• Extended the residential and commercial ITC through December 31, 2016 • Removed residential solar project monetary eligibility constraint • Allowed commercial organizations paying the alternative minimum tax to qualify for the ITC
2015	Omnibus Appropriations Act	• Extended the Residential and Commercial ITC through December 31, 2023 • Replaced the "placed-in-service" standard to "commence construction" for completed project ITC qualification by December 31, 2023
2017	Tax Cuts and Jobs Act	• Preserved the residential and commercial ITC for projects completed by December 31, 2023
2020	Consolidated Appropriations Act	• Extended the phasedown of the ITC until December 31, 2023 • Changed the placed-in-service date to January 1, 2026

SOURCE: SEIA, undated-d.

technologies as they mature is common practice; however, because of the additional growth needed in renewables, such sunsets may be premature. Moreover, the ITC's renewal periods have become shorter and shorter; renewal periods are now shorter than the average development cycle of a solar energy project. This causes uncertainty, which, in turn, suppresses investment (Dewey, 2011). The Biden administration's Made in America Tax Plan recommends a ten-year extension of the solar ITC (U.S. Department of the Treasury, 2021). However, the plan does not stipulate whether Sections 25D and 48 will both be extended for ten years.

Another idiosyncrasy of the solar ITC is that provisions differ among market segments. The ITC rate for commercial entities under Section 48 will fall from 26 percent to 10 percent but then remain at that level indefinitely. However, it drops to zero in 2024 for individual homeowners using Section 25D. This subtle nuance in the ITC has significant implications for stakeholders' future benefits and, therefore, for the contributions that different market segments will make to decarbonization and other energy policy goals.

In contrast to nonrefundable credits, *refundable tax credits* can be monetized without any tax liability. They have been referred to as *direct pay* tax credits because the Department of the Treasury effectively pays eligible participants the difference if the value of the credit exceeds the tax liability, even if the liability is zero. Although currently inactive, these tax credits were first used in the solar industry when Congress passed the Section 1603 program as a

TABLE 4

Solar Investment Tax Credit Sunset Timeline

Year	Section 25D	Section 48
2021 and 2022	26%	26%
2023	22%	22%
2024 and beyond	0%	10%

component of the American Recovery and Reinvestment Act in 2009; at the time, the number of tax equity investors willing to make investments had decreased by 75 percent (Mendelsohn and Harper, 2012). Between 2009 and the program's end in 2011, Section 1603 funded 84,162 residential projects (which incentivized 462 MW of capacity) and 19,889 nonresidential solar projects (which incentivized 8,976 MW of capacity) through approximately $9.82 billion of direct payments. Under Section 1603, the Department of the Treasury made direct matching payments in lieu of the solar ITC to eligible applicants (U.S. Department of the Treasury, 2017). These direct payments were treated as an overpayment of taxes and were able to be monetized as cash refunds after filing a federal tax return.

The Made in America Tax Plan recommends reinstating direct pay solar tax credits, but it does not state whether Sections 48 and 25D will receive the same treatment or which agency should manage the program. This latter point—whether the Department of Treasury or the IRS will manage a new direct pay program—is a matter of ongoing debate. Traditionally, the Department of the Treasury has administered such tax credits while the IRS focuses on enforcement. However, this was not the case with the Section 1603 program, with the Department of the Treasury requiring grant awardees to submit system performance reports for five years (U.S. Department of the Treasury, undated). Meanwhile, the management of the ITC program has consistently been the responsibility of the IRS, which can use its existing tax filing processes and has provided public advice related to the solar ITC's use and function.

Clean Energy Standard and Renewable Portfolio Standard Programs

Clean energy standard (CES) programs (also known as clean electricity standard programs) and *renewable portfolio standard* (RPS) programs use "stick" approaches to increase renewable use. They mandate minimum RE thresholds for electricity generation in particular markets.

Compliance with a CES or an RPS program can be achieved through multiple mechanisms: electricity suppliers owning a RE facility and its power generation, the purchase of RECs or solar RECs (SRECs) from other entities, or the purchase of bundled renewable electricity (a combination of RECs, SRECs, and electricity) (Cox and Esterly, 2016; SRECTrade, undated). RECs and SRECs can reduce barriers to solar market entry by reducing the cost to operate a solar installation and enabling utilities to meet annual RPS quotas by purchasing SRECs.

RPS and CES programs also typically include legislative mandates that penalize noncompliance. Approximately half of U.S. RE generation between 2000 and 2018 was associated with a state RPS program (Barbose, 2019). Thirty-four states and U.S. territories have enacted their own RPS requirements, and eight states and U.S. territories have passed voluntary RPS programs or targets (Shields, 2021). These policies are often accompanied by long-term emissions reduction targets. As of September

2020, 14 states and the District of Columbia had targets of 100-percent clean or renewable electricity by 2050 at the latest (Database of State Incentives for Renewables and Efficiency, 2020). In terms of specifically encouraging solar power use, some RPS programs have included solar set-asides that prioritize solar deployment (Cox et al., 2015).

Federal incentives for solar energy can complement state RPS programs. In states with an RPS, solar power developers can use the solar ITC to offset the costs of deploying additional renewables, lowering the overall cost of compliance. Meanwhile, state RPS programs have been models for potential federal programs. A federal CES has been a topic of debate in Congress since the late 1990s, but no such program has been enacted to date (Lawson, 2021). Draft legislation for a federal CES—the Clean Energy Act—was introduced into Congress in early 2021 in support of the American Jobs Plan. By requiring 100 percent clean energy by 2035, this policy would fundamentally reshape the U.S. energy economy by either retiring carbon-based power plants or outfitting them with carbon capture technologies.[2]

A federal CES with targets exceeding state levels might eliminate the need for state-specific RPS programs and also could reduce the need for other market incentives (such as the solar ITC) for clean energy. Similarly, continued declines in the costs for renewables could lead to a diminishing role for state or federal CES and RPS programs. Nevertheless, CES and RPS programs' specific targets and timetables make them more effective at achieving decarbonization goals than market forces alone. Additionally, the need to achieve aggressive CES targets still would create strong market demands for financing.

Carbon Pricing

A *carbon price* is a general incentive mechanism that assigns a cost to carbon-based pollution, such as GHGs. This price is meant to reflect the external cost of this pollution. The carbon price can be fixed or can fluctuate (e.g., based on demand for reductions in carbon emissions; based on the estimated social, economic, and environmental impact of carbon).

The primary mechanism for instituting a carbon price is a *cap-and-trade system* that places a cap on total allowable emissions and then distributes emissions permits among a group of participating entities. Participants can then trade emissions allowances as needed. Those economically capable of reducing their emissions generate excess allowances that can be sold to other program participants. This ability to monetize emissions reductions creates financial incentives to reduce emissions and comes from the *cap* on emissions.

The approach has been successfully applied to conventional pollutants, but despite several attempts to pass federal cap-and-trade legislation over the past two decades, it has never been enacted nationally for GHGs. However, regional cap-and-trade systems exist among groups of states, such as the Regional Greenhouse Gas Initiative in the New England region and the Western Climate Initiative between California and the Canadian province of Quebec (Regional Greenhouse Gas Initiative, 2021; Western Climate Initiative, Inc., undated).

A more direct mechanism for establishing a price on carbon is a *carbon tax*, which is attached to carbon pollution on a per-unit basis. *Carbon emissions trading* allows carbon emitters to trade emission units to meet emission targets, typically on an economy-wide, national basis.

These methods are generally considered to be economically efficient, comprehensive, and effective policies for reducing carbon emissions (Howard and Sylvan, 2015). Despite consensus on the effectiveness of the carbon tax method, carbon taxes are uncommon, likely because they "impose costs on customers" and therefore can be difficult political propositions (Hagmann, Ho, and Loewenstein, 2019). Additionally, a carbon tax is technically challenging to implement across an economy, especially for industries that do not have a cost-effective replacement technology available to significantly curb carbon emissions—such as air travel, long-haul trucking, and steel and aluminum production.

Just as with cap-and-trade, a federal carbon tax has never been enacted by Congress, nor has such a tax been proposed by the Biden administration to date. In particular, carbon taxes and other pricing schemes have been labeled as regressive policies that disproportionately impact lower-income households, which spend a greater proportion of their income on energy than wealthier households. Mitigating these regressive impacts is often contingent on using the revenue generated by the tax.

Tariff Policies and Structures

A variety of *tariffs*—pricing structures used by a power utility to charge customers for consumption—can be used to incentivize solar power. We examine two categories of tariffs that are commonly used by American utilities and regulatory bodies: (1) NEM and (2) FITs. *NEM* is a financial instrument that enables power customers to be credited for the power that their distributed generation systems supply to the power grid by subtracting it from their grid-consumed power. The policy is regarded as a fundamental tool for deploying distributed solar generation, and its presence or absence can severely impact solar energy deployment (Lawson, 2019b). Program details vary by state and local jurisdiction, but typically, electric utilities bill the net consumption of customers over a defined period. In some states, customers may sell their excess generation and credit the sale against their bill. Some states have included provisions to require time-of-use rates to reflect changes in the demand for (and therefore value of) power during different parts of the day.

The rate compensation method for NEM has been a point of contention among NEM customers, non-NEM customers, and their utilities. As NEM use rates increase within a utility's service area, the power grid maintenance costs may shift disproportionately to non-NEM customers, raising concerns over rate payment fairness. Studies examining the inequities of NEM have shown mixed results, primarily because of state-by-state market variance (National Association of Regulatory Utility Commissioners, 2016; Tanton, 2018).

FITs are complementary instruments to NEM; they are rates paid to power generators above market price to encourage development of certain technologies, such as renewables. FITs are often fixed-price generation incentives that are a component of PPAs, providing a more stable form of market incentives to customers. The rate structure of FITs varies by utility service region and state, depending on the underlying program objectives.

Although NEMs and FITs have been used at the national level and for large power projects in other countries, they have been confined to state-level initiatives in the United States, partly because of constraints on federal interventions in state energy markets. Federal law does not require NEM (16 U.S.C. 46). However, the Energy Policy Act of 2005 does require that states consider the policy's adoption (Pub. L. 109-8, 2005). As of June 2020, 35 states and the District of Columbia have developed mandatory NEM for certain utilities, five states have non-NEM statewide distributed generation compensation rules, and five states are in transition to non-NEM statewide distributed generation compensation rules (U.S. Energy Information Administration, 2020). Idaho and Texas do not have statewide rules, but some utilities in those states allow NEM.

Similarly, there is currently no federal policy for FITs. As of December 2020, Vermont, Washington, New York, Indiana, Hawaii, and California have FITs, totaling 1.1 GW in installed capacity that involves a variety of small-scale renewable projects, such as PV, micro wind, and fuel-cell technologies (Database of State Incentives for Renewables and Efficiency, undated).

Comparing Costs and Benefits of Solar Incentives

Given the expansion of RE—and solar generation specifically—needed to enable the United States to meet aggressive new decarbonization goals, critical reflection on the effectiveness of existing and proposed incentives is needed. In assessing the different incentives introduced previously, we consider the following five elements and their implications for solar deployment via their effect on solar project scales and acquisition models:

1. alignment of incentives with policy objectives
2. how solar projects contribute to system reliability and resiliency
3. potential co-benefits of solar technologies
4. the fairness with which incentives are implemented across market segments
5. the equity of access to solar incentives and technologies among different populations.

Each element is discussed further in the following sections.

Ensuring Incentive Alignment with Climate and Energy Policy Objectives

Existing incentives have played an important role in catalyzing solar deployment. For example, the solar ITC is regarded as a major market catalyst that has accelerated adoption throughout the United States. Meanwhile, RPS mandates in U.S. states and regional cap-and-trade programs have been central drivers of solar technology deployment, particularly of utility-scale projects that benefit from economies of scale and can be readily integrated into the grid.

The expansion of solar deployment has contributed to the rapid reduction in costs to the point of some utility-scale systems being competitive with fossil generation, but projections suggest that this might not be sufficient to scale-up solar deployment to the levels that are needed to pursue a net-zero target within a few decades. Solar costs need to decrease to a point where they are not only a competitive option for new generation capacity but also incentivize replacement of existing fossil fuel generation. As solar capital costs decline amid flat-to-increasing commercial and retail electricity prices, installing on-site solar power increasingly becomes a more attractive investment option to offset electricity costs (Center for Climate and Energy Solutions, undated; U.S. Energy Information Administration, 2021c).

Meeting energy and climate policy objectives will also require supporting technologies to accompany solar generation capacity expansion, particularly storage technologies. This creates additional downward cost pressures for solar technologies. Moreover, maximizing the deployment of solar technologies means boosting not only utility-scale generation but also residential and commercial systems (see Figure 2). Financial incentives that address capital costs of deployment, such as the solar ITC, have been credited with catalyzing increased market share for residential and C&I solar. Such incentives as FITs, NEM, and SRECs (via CES) can complement the ITC and lead to even greater adoption of distributed solar generation. The ability to pay for net electricity use improves the return on the initial capital investment in residential and C&I solar systems. In addition, the emergence of leasing options for solar systems that capitalize on the ITC has expanded the range of financing options available to customers, which boosts adoption and generation by reducing barriers to market entry.

Ensuring incentive alignment to policy objectives also means addressing barriers that limit these objectives' effectiveness. Such challenges often arise disproportionately in the residential and C&I segments of the market. Some states still lack NEM, creating a fundamental barrier to capitalizing on the opportunities for solar generation in the distributed generation market. The federal government has not intervened in state energy markets to mandate NEM rules.

Meanwhile, many utilities recently have been lobbying their respective public utility commissions (PUCs) to increase distributed generation capacity fees, increase residential electricity fixed charges, reduce distributed generation rate minimum charges, or reduce NEM payouts (Proudlove, Lips, and Sarkisian, 2021). These fees can negatively impact the return on investment of smaller solar power projects. Utilities argue that distributed generation customers are using the grid but not paying for it, which shifts the costs of maintaining the grid to those not participating in the distributed generation market. Although such assertions have been studied, the results are inconclusive (Bird et al., 2013; Lawson, 2019b). However, many utilities agree that the state rate policies for distributed generation tariff structures should be updated to ensure fair cost sharing for power grid use and the maintenance of electric service reliability (Edison Electric Institute, 2013). Although this example is not wholly representative of all relevant market participants, this presents an opportunity for the federal government to provide additional clarity, as Congress did in the Energy Act of 2005, or provide incentives to promote these state-owned market mechanisms so they align with federal strategies on climate change, grid modernization, and energy security.

Congress's first attempt at promoting distributed generation through NEM was through the Energy Policy Act of 2005, which stated that distributed generation "may" be used to offset utility-provided electricity by adding it to the list of "states-must-consider" standards of the Public Utility Regulatory Policies Act of 1978 (Pub. L. 109-58, 2005). Because of limits on federal involvement in state-level power markets, the Federal Energy Regulatory Commission has historically remained agnostic to NEM and FIT policies. However, establishing clearer, more coherent federal guidance on tariff incentive structures and federally incentivizing the NEM and FIT policies, rather than simply relying on regulatory encouragement, can increase the utility of such federal incentives as the solar ITC or a clean energy standard.

Maintaining Reliability and Resilience

Solar power has both benefits and liabilities for reliability and resilience. Without an integrated power storage solution and demand response, solar power cannot meet fluctuating power demand, making it a *nondispatchable* power source (a source that cannot be "turned on" or "turned off" to meet demand) (Afework et al., 2018). Furthermore, as solar power deployment becomes a larger share of electricity generation portfolios, electricity systems could experience difficulty providing an adequate amount of power to satisfy demand, particularly at night or during times of reduced sun (Lawson, 2019a). Power markets with high levels of solar penetration will require integrated storage solutions, expanded transmission systems, increased demand response, and complementary renewable or conventional power generation assets to balance the market's instantaneous supply and demand requirements.

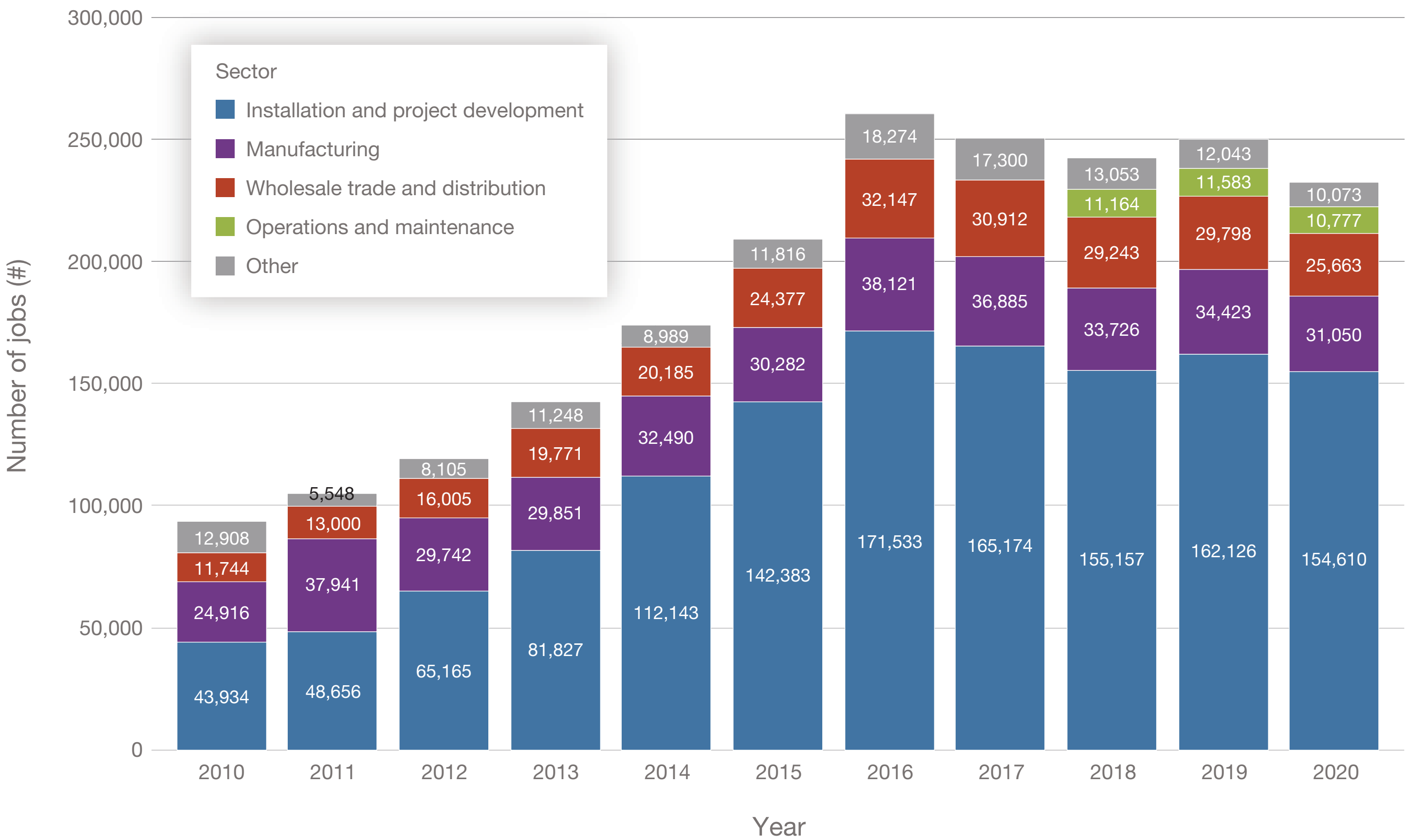
Conversely, because C&I and residential solar are often interconnected with the power grid and an on-site load, allowing for two-way power flow, these projects may contribute to further reliability issues stemming from high system renewables penetration without sufficient storage (Office of Energy Efficiency & Renewable Energy, 2020). Furthermore, the two-way flow of power can complicate the interconnection process because most electric distribution systems were not originally designed to accommodate two-way flow in either an engineering or market sense. Moreover, when a gridwide power outage occurs, electricity utilities often limit power dispatch from these systems; this is done to protect workers responding to grid outages and other power grid equipment from feedback damage. Electricity utilities are making progress toward developing more-robust distribution networks to accommodate distributed generation feedback during power outages but have thus far been resistant to reconfiguration (New York Department of Public Service, 2016). For the United States to reach its power grid decarbonization rates, these technical obstacles will have to be mitigated, allowing higher C&I and residential solar power market penetration.

Employment Co-Benefits of Solar Technologies

Promoters of solar technologies often argue that large investments in solar energy, and public subsidies in particular, are justified by potential co-benefits. One major co-benefit is job creation. The Biden administration has made green jobs a prominent focal point of its climate and energy policy (The White House, 2021b). Industry data indicate that between 2010 and 2019, solar employment grew 167 percent to approximately 250,000 jobs (The Solar Foundation, 2020); between 2014 and 2019, it accounted for one of every 150 new U.S. jobs (U.S. Bureau of Labor Statistics, 2020). The largest solar supply chain segment by employment—installation and project development—accounted for approximately 65 percent of solar employment and grew 269 percent between 2010 and 2019 (Figure 3). Solar installation and project development jobs include activities throughout the entire solar project construction life cycle.

However, a closer look at this job category reveals significant disparities among market segments. Of the

FIGURE 3
Solar Employment by Solar Supply Chain Segment



SOURCE: The Solar Foundation, 2020 and 2021. Used with permission.
NOTES: The data represent total number of solar jobs from 2010 to 2020 for different elements of the supply chain. Data are based on the Solar Jobs Census, a collaborative effort of SEIA, The Solar Foundation, and the Interstate Renewable Energy Council.

162,126 installation and project development jobs created in 2019, 56 percent were residential, 25 percent were nonresidential, and 19 percent were utility-scale jobs (The Solar Foundation, 2020). The residential and nonresidential distributed solar generation market segments represent more than 80 percent of installation and project development jobs and more than 52 percent of total solar jobs in the United States. These jobs tend to be high quality; they receive an 11-percent salary premium and are 11 percent more likely to include health care benefits over parallel industry occupations (E2, 2020). However, the distributed generation solar market segment has lower labor productivity and economies of scale because of the high transaction costs compared with utility-scale solar generation. Although they are less economically efficient, studies show that distributed generation solar jobs have a positive effect on induced jobs (jobs that are created when the wealth generated by the RE industry is spent elsewhere in the economy) (International Renewable Energy Agency, 2011).

Although difficult to measure, this effect demonstrates the co-benefits that distributed generation solar power can produce in terms of employment. At the same time, expansion of employment translates into growth in labor costs. Recent estimates indicate that achieving a net-zero target translates into approximately $200 billion in wages that must be paid during the 2020s and $200 billion to $500 billion during the 2040s (Mayfield et al., 2021). Therefore, when assessing net costs and benefits of incentives, the employment effects of increased deployment across different market segments should be considered.

Ensuring Fair Competition

The incentives that federal and state governments use to promote the deployment of solar power have different implications for different solar projects. Differences in incentive access may arise naturally and make policy sense because of intrinsic differences between market segments, but the ability for some actors to capitalize on incentives more effectively than others raises questions regarding the fundamental fairness of those incentives—particularly when there is misalignment between how an incentive is currently being used and its original intentions.

One clear example is the proliferation of tax equity financing in solar markets. Because of the solar ITC, tax equity financing is now the most common method of third-party financing on a power capacity basis. Tax equity financing requires investors with enough tax liability—typically the most profitable and financially secure banks, insurance companies, or large corporations—to contribute investment capital in a partnership with the project developer in exchange for the ITC tax credits. Tax equity investors benefit from the use of the Modified Accelerated Cost-Recovery System depreciation schedule in addition to the benefits that they receive from the ITC (provided that the investor has a positive 704(b) capital account) ("Inside Capital Account (704(b))," undated). With Modified Accelerated Cost-Recovery System accelerated depreciation, companies can claim higher expenses earlier in the equipment's design life and thus lower their short-term taxable income. This earlier deduction allows companies to reap higher interest savings or investment returns, making the investment more tax-efficient. When combined with the solar ITC, this accelerated depreciation can return up to 44 percent of a solar project's costs to an efficient tax equity investor in the first year of operation (Weaver, 2020).

This scale of tax equity financing is not economically efficient for an individual residential solar project because utility-scale and C&I solar power systems receive more favorable financing terms and because of the administrative burden associated with the piecemeal financing of residential solar power projects (Feldman and Schwabe, 2017). The difference in the ease of ITC application does not preclude residential projects from the variety of financing options available, but it inadvertently provides Section 48 users a distinct advantage over firms relying on homeowners using Section 25D to finance solar projects.[3] A variety of third-party financing opportunities for residential solar projects exist, but they rely primarily on traditional loans or the securitization of bundled Section 48 solar ITC tax credits from solar leases and PPAs to the same tax equity institutional investors.

The early sunsetting of the Section 25D ITC (compared with that of Section 48) provides an advantage to commercial developers, who can outcompete and consolidate residential solar installation market share. This might create future barriers to market entry for private individuals looking to capitalize on the residential tax credit. This exclusionary provision in the federal tax code undercuts the United States' ability to deploy solar power at greater rates by selectively incentivizing a particular market participant type. Commercial installers, who primarily use Section 48, can enter more leases or PPAs with residential homeowners and outcompete installers who relied on residential owner project financing and Section 25D.

Already, commercial solar installers are leveraging economies of scale cost efficiencies and using Section 48 to enter the residential solar market, consolidating a 40-percent market share of small, distributed solar generation (U.S. Energy Information Administration, 2021b). Alternative third-party financing is an important method of offering access to those without sufficient upfront capital the opportunity to participate in the market. However, Sections 25D and 48 sunsetting at different times inadvertently incentivizes the market share consolidation of the residential market and reduces options for market access. Additionally, the higher Section 48 incentive for third-party solar projects can potentially induce a higher system price because tax credits are being used to supplement project soft costs (e.g., permits, labor, supply chain costs) rather than equipment. There is no existing congressional commentary that explains why commercial entities are allowed to continue receiving Section 48 in perpetuity while private individuals cannot receive Section 25D. Maintaining equal sunset provisions between Section 25D and Section 48 ITCs could help to preserve a competitive marketplace, increase market participation for private individuals, and allow more direct, efficient, and flexible use of a federal tax credit. However, such benefits of the deployment of solar generation capacity should be weighed against the costs. The amount of forgone revenue associated with Section 48 alone has been estimated at $34.9 billion between 2020 and 2024 (Joint Committee on Taxation, 2020).

The inequities created by the ITC could be ameliorated by reverting to an expired version of the ITC, specifically the refundable solar tax credit (also called direct pay). If the original intention of the ITC was to decrease solar installation costs, spur industry growth, and reduce barriers to market entry, reenabling the refundable provisions would eliminate dependence on tax equity financing and tax credit rollover. Direct pay is a more efficient project finance option, eliminating the premium paid to tax equity and third-party investors for project financing and ensuring that project installers receive the full benefit. There are other benefits that the refundable tax credit provides besides effective financial utilization and equity. Between 2009 and 2011, the refundable solar tax credit program allowed 110,000 projects to monetize the credit. The largest number of projects were residential solar systems. Additionally, the program was attributed with the creation of

75,000 direct and indirect jobs (Steinberg, Porro, and Goldberg, 2012). However, the refundable solar tax credit proved expensive because of the high uptake. Therefore, expanding access to the ITC for more individuals ultimately results in the federal government bearing a greater burden of solar generation deployment costs.

Another method to achieve net-zero emissions and ensure a fairer market is implementing a CES and a complementary carbon price. A *carbon price* provides an economic signal to equate the marginal abatement costs across pollution sources and often can incentivize carbon reduction across an entire economy at the lowest possible overall cost (Schmalensee and Stavins, 2017). A carbon price is a more systematic approach to decarbonization but can be considered less intrusive than more-prescriptive incentives because it allows market participants the choice in how to approach decarbonization. When paired with other incentives, a carbon price can be a potent policy lever that can further motivate the expansion of particular RE technologies. However, because carbon pricing has such wide-ranging effects on an economy and typically gives market participants a diverse set of options in how to approach decarbonization strategies, it can be difficult to fully determine the effects of other decarbonization incentives and policies as they may be masked by the variety of options (Somanathan et al., 2014). However, "it is rare that carbon pricing is the only lever that policy makers pull" (Best, Burke, and Jotzo, 2020).

Electricity in the United States is not sold like other commodities because of its market regulatory structure. Consideration should be given to how and who benefits from incentive program expansion. U.S. electric utilities are given monopolies over their service regions to provide electricity at a fair rate in exchange for being regulated by PUCs, which exist to ensure fair market pricing. Nevertheless, electric utilities have a history of anticompetitive and antitrust behavior (Gross, 1979; Turetsky, 1996). As the capital costs of distributed solar generation have fallen and the technology has become more ubiquitous, issues of market competition have arisen between utilities and distributed solar companies. This has occurred whether or not utilities own distributed generation assets and threatens to usurp fair and competitive power markets through consolidation of distributed generation market share.

Utilities have asserted issues of socioeconomic equity to defend their practices—such as concerns over wealthier ratepayers taking advantage of the benefits of distributed generation assets and leaving ratepayers least able to afford it to cover fixed costs of the grid (SEIA, 2016). In California, which has the most distributed solar generation in the United States, the California PUC found that participants benefited—to the detriment of nonparticipants (Verdant, 2021). This is a critical example of designing competitive markets in which the benefits of distributed generation are balanced with their contribution to the grid to prevent costs shifting to those who cannot afford solar.

Distributed solar generation companies have been identified as "substantially disadvantaged" compared with vertically integrated power utilities, which have positioned themselves as the arbiters of their power market jurisdictions (SEIA, 2016). The Department of Justice has also identified these anticompetitive behaviors in utility practices, making distributed solar generation uneconomical and forcing customers to exclusively purchase retail, utility-provided electricity (*Ellis*, 2020). When regulated electric utilities do not own distributed generation assets, a host of regressive distributed generation market methods have been used, including increasing fixed charges, demand charges, solar taxes, and standby charges and delaying permission to operate or applications for distributed generation interconnection. Moreover, electric utilities have received support from regional, state, and local authorities to prevent competition (*SZ Enterprises,* 2014).

Enhancing the Equity of Access to the Benefits of Solar

Various federal and state incentives will continue to play a role in stimulating solar technology deployment, but the ability of different groups to capitalize on the benefits of these incentives varies significantly. This ultimately contributes to inequities in incentive structures and their social impacts. Despite its elegant use in project financing solar projects, the ITC was not originally designed as a mechanism for tax equity financing of large solar projects: Structurally, the tax credits were intended to assist residential homeowners and commercial solar developers (Keightley, Marples, and Sherlock, 2019). However, many homeowners and commercial solar developers generally do not pay sufficient federal taxes to take full advantage of the ITC in offsetting the significant costs of system installation (SEIA, undated-e; Wuebben, 2019).

For DVC households that own their homes, the average residential rooftop solar system could generate an ITC benefit of approximately $4,600 using Section 25D (Fu, Feldman, and Margolis, 2018). The bottom 50 percent of U.S. income earners pay an average of $626 per year for electricity, requiring an average of more than seven years to realize the full monetization of the tax credit (York, 2021). Additionally, rolling over the tax credit year-over-year means losing the value of the ITC to the time value of money. Meanwhile, the average income taxpayer in the top 50 percent will, on average, realize the ITC's full value in the project's first year of operation because of their higher tax liabilities.

This has real-world effects: In California, DVC households have less than half the distributed solar in their communities than those in the wealthiest neighborhoods (Lukanov and Krieger, 2019). This is after considering the increased C&I solar in lower-income communities. These same households also face an electricity bill burden three times higher than non-low-income households and would reap outsized health and environmental benefits from solar power because natural gas- or oil-burning power plants are more likely sited in DVCs (Krieger, Casey, and Shonkoff, 2016; Office of Energy Efficiency & Renewable Energy, undated-a).

Reducing the tax burden of the top 50 percent of earners using the ITC while increasing residential property value directly contributes to the widening wealth gap in the United States (Lei, 2017; Sunrun, 2021). By changing the nonrefundable tax provision back to a refundable tax credit for at least lower-income earners, the federal government could increase participation in the solar market. Lower-income earners could realize the full value of the ITC within the first year of the project's operation like their higher-income counterparts.

DVCs also face challenges in adopting distributed solar generation because the high rate (59 percent) of low-income households that are renters (Office of Energy Efficiency & Renewable Energy, undated-a). Incentives to improve energy efficiency and install distributed generation are often misaligned with renters, depending on who is responsible for utility costs. Multifamily residences, whether owned at the individual unit level or rented, create additional challenges for making use of the ITC.

However, there are good examples of expanding access to solar power without using individual ITC residence applications. Existing programs in California, such as the Disadvantaged Communities–Single-Family Affordable Solar Homes and Solar on Multifamily Affordable Housing programs, are in the nascent stages. These programs evaluate the availability of financial incentives and resources for homeowners and property owners in DVCs who might want distributed solar power for their properties. Community solar could be an attractive policy lever for increasing access for rural DVCs or urban DVCs with significant industrial or commercial rooftop capacity.

Conclusions and Policy Implications

By renewing commitments to international climate change compacts, setting ambitious domestic policy goals, and initiating a whole-of-government approach, the Biden administration has taken an aggressive stance on climate change. Fully implementing this vision and achieving climate and energy objectives will require the strategic harmonization of government interventions in the energy sector. With administration efforts still in the early stages of development, policymakers should reflect critically on the existing portfolio of incentives to determine if they remain both necessary and sufficient for catalyzing the requisite levels of RE while satisfying other policy objectives, such as energy reliability and equity.

Accordingly, we identify the following courses of action for consideration:

- Solar power is a core technology for transitioning away from fossil fuel-based electricity. Energy pathways that lead to decarbonization of the U.S. energy system imply rapid increases in the rate of deployment of solar generation, even relative to the growth seen over the past decade. As demonstrated by energy and economic modeling, this growth will likely be needed across all solar market segments—residential, C&I, and utility-scale. Therefore, aligning incentives to stimulate growth of solar across all these fronts can enhance the ability of solar technologies to contribute to achieving the administration's net-zero goals.
- Given the diversity of federal and state incentives for solar technology deployment and the rapid evolution of the solar market in recent years, policymakers should consider revisiting various incentives to determine whether each is appropriately structured to achieve policy objectives and to evaluate potential consequences and interactions among them. The potential impact of extending the federal ITC is undermined by the absence of NEM and FITs for distributed resources in a number of states, and the observed increase in distributed generation capacity fees is eroding revenue from the sales of surplus electricity by owners of distributed electricity systems.
- Extending the Section 25D and 48 provisions for an extended period of time and offering parity in credit size and the eventual elimination of the credits would enable longer-term investment planning and facilitate more equitable market participation

for residential, C&I, and utility-scale customers and developers. Meanwhile, particular attention is also needed for incentives that are accessible to DVCs, which have had limited opportunities to enter solar energy markets. Reverting the nonrefundable tax credit to a refundable one would help a broader spectrum of Americans access incentives, thereby enabling the benefits to be received by those directly installing distributed energy resources. However, although refundable credits catalyze deployment of distributed solar generation, they reduce tax revenue to the federal government and therefore should be periodically evaluated to determine whether there is an ongoing need for their use.

- Increased levels of solar deployment can yield co-benefits, such as increased employment and system resiliency. However, the size and distribution of such co-benefits is highly contingent on the design and implementation of policies. Furthermore, too much solar power deployment in the absence of complementary technologies, such as energy storage, can reduce system reliability and cost savings. The design of incentives should consider the technical and economic trade-offs when planning to incentivize a particular technology.
- Clarifying federal guidance and providing additional incentives for distributed generation tariffs can contribute to the national decarbonization agenda on a regional scale. Federal regulations already allow states flexibility in power market design, limiting the ability of the federal government to dictate changes from the top down. However, federal agencies can provide enhanced guidance on the value of NEM for increasing deployment of solar power systems and on pricing structure for solar FITs and their alignment with other energy policies and targets.
- If policymakers want an economywide approach to incentivizing rapid deployment of RE, then the implementation of a national clean energy standard is a technology-neutral approach to decarbonization that makes use of all available technologies and allows for custom market solutions based on regional differences in existing policies and generation portfolios. Coupling a clean energy standard with a carbon price can be an economically efficient and effective mechanism for reducing emissions, motivating both the public and private sectors toward a common goal. Nevertheless, these are complex policy structures that generate both costs and benefits for different stakeholders.

Galvanizing the low-carbon energy sector with this combination of policies has the potential to accelerate the ongoing energy transition toward renewables and yield employment, social, and environmental benefits for future generations of Americans. If the costs and benefits are shared fairly, the energy transition also can contribute to reducing the disproportionate financial burden placed on DVCs with respect to energy costs.

Endnotes

[1] Direct current (DC) is the rating of the solar capacity before it is converted to alternating current (AC) to be exported to the power grid.

[2] Although the federal CES would force early retirement of many fossil fuel power plants throughout the country, Grubert has shown that it would only financially strand approximately 15 percent of fossil capacity-years and 20 percent of job-years (Grubert, 2020). (A *stranded asset* is a resource or job that has lost its value or ability to produce income because of external changes; Makower, 2019.) This level of stranded assets is very low on a global energy economy basis (Kefford et al., 2018).

[3] There are many financing options available to residential projects, including traditional loans, solar leases, and Property Assessed Clean Energy financing.

References

Afework, Bethel, Jordan Hanania, Kailyn Stenhouse, and Jason Donev, "Non-Dispatchable Source of Electricity," University of Calgary Energy Education, webpage, last updated June 25, 2018. As of June 23, 2021: https://energyeducation.ca/encyclopedia/Non-dispatchable_source_of_electricity

Barbose, Galen L., *U.S. Renewable Portfolio Standards: 2019 Annual Status Report*, Lawrence Berkeley National Laboratory, July 2019. As of June 21, 2021: https://emp.lbl.gov/publications/us-renewables-portfolio-standards-2

Best, Rohan, Paul J. Burke, and Frank Jotzo, "Carbon Pricing Efficacy: Cross-Country Evidence," *Environmental and Resource Economics*, Vol. 77, 2020, pp. 69–94.

Bird, L., J. McLaren, J. Heeter, C. Linvill, J. Shenot, R. Sedano, and J. Migden-Ostrander, *Regulatory Considerations Associated with the Expanded Adoption of Distributed Solar*, Golden, Colo.: National Renewable Energy Laboratory, Technical Report NREL/TP-6A20-60613, November 2013. As of June 21, 2021: https://www.nrel.gov/docs/fy14osti/60613.pdf

Center for Climate and Energy Solutions, "Global Emissions," webpage, undated. As of May 4, 2021: https://www.c2es.org/content/international-emissions/#:~:text=China%2C%20the%20United%20States%2C%20and,the%20United%20States%20and%20Russia

Consumer Reports Advocacy, "Consumer Reports 2018 Energy Utilities Survey Report," 2018. As of May 4, 2021: https://advocacy.consumerreports.org/wp-content/uploads/2018/10/CR-2018-Energy-Utilities-Survey-Report-1.pdf

Cox, Sadie, and Sean Esterly, *Renewable Electricity Standards: Good Practices and Design Considerations*, Washington, D.C.: National Renewable Energy Laboratory, Technical Report NREL/TP-6A20-65507, January 2016. As of June 3, 2021: https://www.nrel.gov/docs/fy16osti/65507.pdf

Cox, Sadie, Terri Walters, Sean Esterly, and Sarah Booth, *Solar Power: Policy Overview and Good Practices*, Clean Energy Solutions Center, NREL/TP-6A20-64178, May 2015. As of June 3, 2021: https://www.nrel.gov/docs/fy15osti/64178.pdf

Database of State Incentives for Renewables and Efficiency, "Programs: Renewable Portfolio Standard," webpage, undated. As of May 4, 2021: https://programs.dsireusa.org/system/program?type=38&

———, "Renewable & Clean Energy Standards," infographic, September 2020. As of June 21, 2021: https://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2020/09/RPS-CES-Sept2020.pdf

Dewey, Erin, "Sundown and You Better Take Care: Why Sunset Provisions Harm the Renewable Energy Industry and Violate Tax Principles," *Boston College Law Review*, Vol. 52, No. 3, 2011, pp. 1105–1146.

Dickson, Duane, "2021 Oil and Gas Industry Outlook: Exploring Oil and Gas Trends and Impact of COVID-19," Deloitte, 2021. As of March 4, 2021: https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/oil-and-gas-industry-outlook.html

E2, *Clean Jobs, Better Jobs: An Examination of Clean Energy Job Wages and Benefits*, Washington, D.C., October 2020. As of June 21, 2021: https://e2.org/reports/clean-jobs-better-jobs/

Edison Electric Institute, "A Policy Framework for Designing Distributed Generation Tariffs," Washington, D.C., December 2013.

Ellis v. Salt River Project Agricultural Improvement and Power District, 432 F. Supp. 3d 1070, D. Ariz., January 10, 2020.

Farhar, Barbara C., *Willingness to Pay for Electricity from Renewable Resources: A Review of Utility Market Research*, Springfield, Va.: National Renewable Energy Laboratory, July 1999.

Feldman, David, and Paul Schwabe, *PV Project Finance in the United States, 2017*, Golden, Colo.: National Renewable Energy Laboratory, September 2017. As of June 21, 2021:
https://www.nrel.gov/docs/fy18osti/70157.pdf

Fu, Ran, David Feldman, and Robert Margolis, *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018*, Golden, Colo.: National Renewable Energy Laboratory, Technical Report NREL/TP-6A20-72399, November 2018. As of June 21, 2021:
https://www.nrel.gov/docs/fy19osti/72399.pdf

Gross, Jill, *Impact of the Antitrust Laws on the Commercialization of Solar Heating and Cooling*, Golden, Colo.: Solar Energy Research Institute, June 1979. As of June 21, 2021:
https://www.osti.gov/biblio/5950119-impact-antitrust-laws-commercialization-solar-heating-cooling

Grubert, Emily, "Fossil Electricity Retirement Deadlines for a Just Transition," *Science*, Vol. 370, No. 6521, December 4, 2020.

Hagmann, David, Emily H. Ho, and George Loewenstein, "Nudging Out Support for a Carbon Tax," *Nature Climate Change*, Vol. 9, June 2019, pp. 484–489.

Hart, Stuart L., "The Federal Photovoltaics Utilization Program: An Evaluation and Learning Framework," *Policy Sciences*, Vol. 15, No. 4, 1983, pp. 325–343.

Howard, Peter, and Derek Sylvan, *Expert Consensus on the Economics of Climate Change*, New York: New York University School of Law Institute for Policy Integrity, December 2015. As of June 21, 2021:
https://policyintegrity.org/publications/detail/expert-climate-consensus

"Inside Capital Account (704(b))," EdBodmer.com, webpage, undated. As of May 14, 2021:
https://edbodmer.com/inside-capital-account-704-account-book-basis-fmv-basis

Internal Revenue Service, "Instructions for Form 5695 (2020)," webpage, last updated January 26, 2021a. As of May 4, 2021:
https://www.irs.gov/instructions/i5695

———, "About Form 3468, Investment Credit," webpage, last updated February 26, 2021b. As of May 4, 2021:
https://www.irs.gov/forms-pubs/about-form-3468

International Renewable Energy Agency, *Renewable Energy Jobs: Status, Prospects & Policies*, Abu Dhabi, 2011. As of June 21, 2021:
https://www.irena.org/publications/2012/Jan/Renewable-Energy-Jobs-Status-Prospects--Policies-2012

IRS—*See* Internal Revenue Service.

Joint Committee on Taxation, *Estimates of Federal Tax Expenditures for Fiscal Years 2019–2023*, Washington, D.C., JCX-23-20, November 20, 2020. As of June 19, 2021:
https://www.jct.gov/CMSPages/GetFile.aspx?guid=ec4fb616-771b-4708-8d16-f774d5158469

Kaufman, Noah, Alexander R. Barron, Wojciech Krawczyk, Peter Marsters, and Haewon McJoen, "A Near-Term to Net Zero Alternative to the Social Cost of Carbon for Setting Carbon Prices," *Nature Climate Change*, Vol. 10, November 2020, pp. 1–5.

Kefford, Benjamin M., Benjamin Ballinger, Diego R. Schmeda-Lopez, Chris Greig, and Simon Smart, "The Early Retirement Challenge for Fossil Fuel Power Plants in Deep Decarbonisation Scenarios," *Energy Policy*, Vol. 119, August 2018, pp. 294–306.

Keightley, Mark P., Donald J. Marples, and Molly F. Sherlock, *Tax Equity Financing: An Introduction and Policy Considerations*, Washington, D.C.: Congressional Research Service, R45693, April 17, 2019. As of June 21, 2021:
https://www.everycrsreport.com/reports/R45693.html

Kennedy, Brian, and Cary Lynne Thigpen, "More U.S. Homeowners Say They Are Considering Home Solar Panels," Pew Research Center, December 17, 2019. As of May 4, 2021:
https://www.pewresearch.org/fact-tank/2019/12/17/more-u-s-homeowners-say-they-are-considering-home-solar-panels/

Krieger, Elena M., Joan A. Casey, and Seth B. C. Shonkoff, "A Framework for Siting and Dispatch of Emerging Energy Resources to Realize Environmental and Health Benefits: Case Study on Peaker Power Plant Displacement," *Energy Policy*, Vol. 96, September 2016, pp. 302–313.

Lawson, Ashley J., *Maintaining Electric Reliability with Wind and Solar Sources: Background and Issues for Congress*, Washington, D.C.: Congressional Research Service, R45764, June 10, 2019a. As of June 21, 2021:
https://fas.org/sgp/crs/misc/R45764.pdf

———, *Net Metering: In Brief*, Washington, D.C.: Congressional Research Service, R46010, November 14, 2019b. As of June 21, 2021:
https://crsreports.congress.gov/product/details?prodcode=R46010

———, *Clean Energy Standards: Selected Issues for the 117th Congress*, Washington D.C.: Congressional Research Service, R46691, updated March 26, 2021. As of June 3, 2021:
https://fas.org/sgp/crs/misc/R46691.pdf

Lazard, "Lazard's Levelized Cost of Energy Analysis—Version 14.0," October 2020. As of June 4, 2021: https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf

Lei, Serena, "Nine Charts About Wealth Inequality in America (Updated)," Urban Institute, February 2015, updated on October 5, 2017. As of May 5, 2021: https://apps.urban.org/features/wealth-inequality-charts/

Lukanov, Boris R., and Elena Krieger, "Distributed Solar and Environmental Justice: Exploring the Demographic and Socio-Economic Trends of Residential PV Adoption in California," *Energy Policy*, Vol. 134, November 2019.

Makower, Joel, "The Growing Concern over Stranded Assets," *GreenBiz*, September 10, 2019. As of June 22, 2021: https://www.greenbiz.com/article/growing-concern-over-stranded-assets

Masson-Delmotte, V., P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, et al., eds., *Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, Geneva: Intergovernmental Panel on Climate Change, 2018. As of June 21, 2021: https://www.ipcc.ch/sr15/download/#full

Mayfield, Erin, Jesse Jenkins, Eric Larson, and Chris Greig, "Labor Pathways to Achieve Net-Zero Emissions in the United States by Mid-Century," USAEE Working Paper No. 21-494, 2021.

Mendelsohn, Michael, and John Harper, *§1603 Treasury Grant Expiration: Industry Insight on Financing and Market Implications*, Golden, Colo.: National Renewable Energy Laboratory, Technical Report NREL/TP-6A20-53720, June 2012. As of June 4, 2021: https://www.nrel.gov/docs/fy12osti/53720.pdf

National Academy of Sciences, *Establishment of a Solar Energy Research Institute*, Washington, D.C., 1975. As of June 1, 2021: https://www.nap.edu/catalog/13356/establishment-of-a-solar-energy-research-institute

National Association of Regulatory Utility Commissioners, *Distributed Energy Resources Rate Design and Compensation*, Washington, D.C., 2016. As of June 21, 2021: https://www.naruc.org/rate-design/

New York Department of Public Service, "Joint Utility Anti-Islanding Position: Interconnection Technical Working Group," October 26, 2016.

Office of Energy Efficiency & Renewable Energy, "Low-Income Community Energy Solutions," webpage, undated-a. As of May 5, 2021: https://www.energy.gov/eere/slsc/low-income-community-energy-solutions#:~:text=According%20to%20the%20U.S.%20Department,which%20is%20estimated%20at%203%25

———, "Solar Achievements Timeline," webpage, undated-b. As of May 13, 2021: https://www.energy.gov/eere/solar/timeline/solar-achievements-timeline

———, "Solar Energy in the United States," webpage, undated-c. As of March 13, 2021: https://www.energy.gov/eere/solar/solar-energy-united-states#:~:text=Solar%20power%20is%20more%20affordable,United%20States%20than%20ever%20before.&text=Today%2C%20over%203%25%20of%20U.S.,panels%20has%20dropped%20nearly%2070%25%20

———, "The Road to Resilience with Rooftop Solar," webpage, June 30, 2020. As of May 4, 2021: https://www.energy.gov/eere/articles/road-resilience-rooftop-solar

Proudlove, Autumn, Brian Lips, and David Sarkisian, *50 States of Solar: Q4 2020 Quarterly Report & 2020 Annual Review*, Raleigh, N.C.: North Carolina Clean Energy Technology Center, January 2021. As of June 21, 2021: https://static1.squarespace.com/static/5ac5143f9d5abb8923a86849/t/601093095908283f619d1b34/1611698959121/Q4-20-Solar-Exec-Summary-Final.pdf

Public Law 109-8, Energy Policy Act of 2005, August 8, 2005.

Ray, Suparna, "Renewables Account for Most New U.S. Electricity Generating Capacity in 2021," U.S. Energy Information Administration, January 11, 2021. As of June 15, 2021: https://www.eia.gov/todayinenergy/detail.php?id=46416#

Regional Greenhouse Gas Initiative, "Elements of RGGI," webpage, 2021. As of May 4, 2021: https://www.rggi.org/program-overview-and-design/elements

Schmalensee, Richard, and Robert N. Stavins, "Lessons Learned from Three Decades of Experience with Cap and Trade," *Review of Environmental Economics and Policy*, Vol. 11, No. 1, 2017, pp. 59–79.

SEIA—*See* Solar Energy Industries Association.

Shields, Laura, "State Renewable Portfolio Standards and Goals," National Conference of State Legislatures, April 7, 2021. As of May 4, 2021: https://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx#nmi

Solar Energy Industries Association, “2019 Solar Means Business Report,” webpage, undated-a. As of May 4, 2021: https://solarmeansbusiness.com/

———, “Solar Industry Research Data,” webpage, undated-b. As of May 4, 2021: https://www.seia.org/solar-industry-research-data

———, “Solar Investment Tax Credit (ITC),” webpage, undated-c. As of June 21, 2021: https://www.seia.org/initiatives/solar-investment-tax-credit-itc

———, “Solar ITC 101: What is the Solar Investment Tax Credit?,” fact sheet, undated-d. As of June 21, 2021: https://www.seia.org/sites/default/files/2021-01/SEIA-ITC-Factsheet-2021-Jan.pdf

———, “Third-Party Solar Financing,” webpage, undated-e. As of May 5, 2021: https://www.seia.org/initiatives/third-party-solar-financing

———, *Competition Issues Between Solar Distributed Generation (DG) Firms and Regulated Utilities*, Washington, D.C., June 2016. As of June 21, 2021: https://www.ftc.gov/system/files/documents/public_comments/2016/06/00113-128285.pdf

———, *Solar Market Insight Report 2020 Year in Review*, Washington, D.C., March 16, 2021a. As of March 4, 2021: https://www.seia.org/research-resources/solar-market-insight-report-2020-year-review

———, “U.S. Solar Market Insight,” webpage, last updated June 15, 2021b. As of March 4, 2021: https://www.seia.org/us-solar-market-insight

The Solar Foundation, *10th Annual National Solar Jobs Census 2019*, Washington, D.C., February 2020. As of June 21, 2021: https://www.thesolarfoundation.org/wp-content/uploads/2020/03/SolarJobsCensus2019.pdf

———, *National Solar Jobs Census 2020*, Washington, D.C., May 2021. As of June 22, 2021: https://www.thesolarfoundation.org/national/

Somanathan, E., T. Sterner, T. Sugiyama, D. Chimanikire, N. K. Dubash, J. Essandoh-Yeddu, S. Fifita, L. Goulder, A. Jaffe, X. Labandeira, et al., “National and Sub-National Policies and Institutions. Contribution of Working Group III to The Fifth Assessment Report of The Intergovernmental Panel on Climate Change,” in O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, et al., eds., *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, New York: Cambridge University Press, 2014.

SRECTrade, “Solar Renewable Energy Certificates,” webpage, undated. As of May 4, 2021: https://www.srectrade.com/markets/rps/srec/

Steinberg, Daniel, Gian Porro, and Marshall Goldberg, *Preliminary Analysis of the Jobs and Economic Impacts of Renewable Energy Projects Supported by the §1603 Treasury Grant Program*, Golden, Colo.: National Renewable Energy Laboratory, Technical Report NREL/TP-6A20-52739, April 2012. As of June 21, 2021: https://www.nrel.gov/docs/fy12osti/52739.pdf

Sunrun, “Do Solar Panels Increase Home Value?” webpage, April 20, 2021. As of May 5, 2021: https://www.sunrun.com/go-solar-center/solar-articles/do-solar-panels-increase-home-value#:~:text=Yet%20recent%20studies%20show%20an,kilowatt%20of%20solar%20panels%20installed.&text=At%20%244%2C020%20per%20kilowatt%2C%20a,a%20mid%2Dsized%20U.S.%20home

SZ Enters. v. Iowa Utils. Bd, 850 N.W.2d 441, Iowa, July 11, 2014.

Tanton, Thomas, *Net Metering in the States: Moving Toward Equitable and Sustainable Policies for Electric Customers*, Washington, D.C.: State Government Leadership Foundation, April 2018. As of June 21, 2021: https://static1.squarespace.com/static/601df23633789301b053df7e/t/602b017cab0deb12bbbc5029/1613431166276/SGLF-Net-Metering-in-the-States.pdf

Turetsky, David, “Antitrust Enforcement in the Electric Industry,” U.S. Department of Justice, February 2, 1996. As of May 4, 2021: https://www.justice.gov/atr/speech/antitrust-enforcement-electric-industry

U.S. Bureau of Labor Statistics, “Quarterly Census of Employment and Wages,” webpage, last updated January 2, 2020. As of May 4, 2021: https://data.bls.gov/cew/apps/table_maker/v4/table_maker.htm#type=1&year=2017&qtr=2&own=0&ind=10&supp=0

U.S. Code, Title 16, Conservation; Chapter 46, Public Utility Regulatory Policies; Subchapter II, Standards for Electric Utilities; Sec. 2621, Consideration and Determination Respecting Certain Ratemaking Standards. As of June 23, 2021: https://www.govinfo.gov/app/details/USCODE-2011-title16/USCODE-2011-title16-chap46-subchapII-sec2621

U.S. Department of the Treasury, "1603 Program: Payments for Specified Energy Property in Lieu of Tax Credits," webpage, undated. As of June 3, 2021: https://home.treasury.gov/policy-issues/financial-markets-financial-institutions-and-fiscal-service/1603-program-payments-for-specified-energy-property-in-lieu-of-tax-credits

———, "Overview and Status Update of the §1603 Program," Washington, D.C., April 1, 2017. As of June 21, 2021: https://www.treasury.gov/initiatives/recovery/Documents/Status%20overview.pdf

———, *The Made in America Tax Plan*, Washington, D.C., April 2021. As of June 21, 2021: https://home.treasury.gov/system/files/136/MadeInAmericaTaxPlan_Report.pdf

U.S. Energy Information Administration, "Renewable Energy Explained: Incentives," webpage, last updated November 20, 2020. As of May 5, 2021: https://www.eia.gov/energyexplained/renewable-sources/incentives.php

———, "Electricity," briefing, 2021a. As of May 4, 2021: https://www.eia.gov/outlooks/aeo/pdf/04%20AEO2021%20Electricity.pdf

———, "Electricity Explained: Electricity Generation, Capacity, and Sales in the United States," webpage, last updated March 18, 2021b. As of June 3, 2021: https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php

———, "Short-Term Energy Outlook," webpage, released on April 6, 2021c. As of May 4, 2021: https://www.eia.gov/outlooks/steo/report/electricity.php

Verdant, *Net-Energy Metering 2.0 Lookback Study*, Berkeley, Calif.: January 21, 2021.

Weaver, John Fitzgerald, "This One Weird Solar Trick to Get Five Years of Taxes Back," Commercial Solar Guy, April 16, 2020. As of May 5, 2021: https://commercialsolarguy.com/2020/04/16/cares-act-tax-benefit

Western Climate Initiative, Inc., homepage, undated. As of May 4, 2021: https://wci-inc.org

The White House, "United States Mid-Century Strategy for Deep Decarbonization," Washington, D.C., November 17, 2016.

———, " FACT SHEET: The American Jobs Plan," Washington, D.C., March 31, 2021a. As of May 4, 2021: https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/

———, "Remarks by President Biden on the American Jobs Plan," Washington, D.C., April 7, 2021b. As of May 4, 2021: https://www.whitehouse.gov/briefing-room/speeches-remarks/2021/04/07/remarks-by-president-biden-on-the-american-jobs-plan-2/#:~:text=It's%20the%20single%20largest%20investment,in%20desperate%20need%20of%20repair

———, "FACT SHEET: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies," Washington, D.C., April 22, 2021c. As of May 4, 2021: https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/

Wuebben, Gabe, "Tax Equity Structuring and the Advantage of a Tax-Efficient Sponsor," Solsystems, April 4, 2019. As of May 5, 2021: https://www.solsystems.com/tax-equity-structuring

York, Erica, "Summary of the Latest Federal Income Tax Data, 2021 Update," Tax Foundation, February 3, 2021. As of May 5, 2021: https://taxfoundation.org/publications/latest-federal-income-tax-data

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About This Perspective

With climate and energy issues a pillar of the Biden administration's policy agenda, the United States is likely to see several regulatory actions and financial incentives introduced to catalyze an energy transition. This Perspective provides an overview of the U.S. solar energy market, the rapid changes that it has undergone over the past decade, and the challenges that lie ahead. The authors highlight the roles that different stakeholders, particularly the federal government, play in incentivizing solar markets. The authors also examine the implications of different incentives that are meant to encourage the completion of climate and energy policy objectives, the maintenance of reliability and resilience, and the promotion of equity in access to solar technologies.

The authors draw on a review of the literature on U.S. energy market trends, solar energy technoeconomic assessments, and renewable policy design evaluation. The conclusions should be of interest to industry stakeholders and policymakers seeking a timely primer on core solar policy and market developments that affect the future of the industry.

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