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State and Local Climate and Energy Program

State Energy and Environment Guide to Action:

Interconnection and Net Metering

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Preface and Acknowledgments

The U.S. Environmental Protection Agency (EPA) *State Energy and Environment Guide to Action* offers real-world best practices to help states design and implement policies that reduce emissions associated with electricity generation and energy consumption. First published in 2006 and then updated in 2015, the *Guide* is a longstanding EPA resource designed to help state officials draw insights from other states' policy innovations and implementation experiences to help meet their own state's climate, environment, energy, and equity goals.

As part of the 2022 update, each chapter reflects significant state regulatory and policy developments since the 2015 publication. *Guide* chapters provide descriptions and definitions of each featured policy; explain how the policy delivers energy, climate, health, and equity benefits; highlight how states have approached key design and implementation issues; and share best practices based on state experiences.

Unlike earlier *Guide* editions, which were released as a complete set of chapters comprising a single document, the 2022 update is being released in phases of collected chapters. This chapter is one of seven addressing state-level utility policies that support clean energy and energy efficiency:

- Overview of Electric Utility Polices
- Electricity Resource Planning and Procurement
- Electric Utility Regulatory Frameworks and Financial Incentives
- Interconnection and Net Metering
- Customer Rates and Data Access
- Maximizing Grid Investments
- Energy Efficiency Programs and Resource Standards

Guide chapters are available online on the *Guide to Action* webpage.

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Policy Description and Benefits

Summary

States use interconnection and net metering policies to integrate customer-sited, distributed energy resources (DERs) into the electric grid or to encourage greater investment in these resources. DERs are electric generation, demand response, or energy storage systems located on the distribution system, typically close to load, used individually or aggregated to provide more value. These resources can help meet electricity needs, reduce emissions, enable customer cost-savings, and improve energy security and resiliency. Interconnection standards and net metering rules can support the development of DERs by providing clear and reasonable requirements for connecting clean energy systems to the electric utility grid for both the utility and the customer and by compensating participants hosting DERs for the electricity they export back to the grid.

Interconnection standards are processes and technical requirements that specify for electric utilities and customers the system requirements and procedures to connect energy projects to the electricity grid.

Net metering, also referred to as net energy metering (NEM), is a method of compensating a utility customer that hosts a grid-connected DER system for the electricity generated at the customer site that is more than their own consumption – essentially giving customers credit for the excess power they send back to the grid. Depending on the individual state or utility rules, net excess generation may be credited to the customer's account or carried over to the future.

This chapter describes state experience in using interconnection standards and net metering policies to facilitate or encourage the adoption of DERs, such as rooftop solar photovoltaic (PV), energy storage, and combined heat and power (CHP). These resources can reduce generation and transmission infrastructure costs, stimulate economic growth, reduce customer bills, improve outdoor air quality, enhance energy resiliency, and reduce health impacts from fossil fuel generation. The chapter focuses on state-level actions by state utility regulators and legislatures. It covers the distinct but complementary components of interconnection standards and net metering rules and how policy design and implementation can create incentives, reduce uncertainty, and prevent excessive delays and costs associated with connecting DERs to the grid. This chapter reviews why net metering policies were initially created and discusses why many states are studying, updating, adjusting (e.g., increasing program size or reserving program capacity for low-income customers), or replacing their original programs. The chapter also briefly examines complementary state and federal policies.

The following are several examples of action steps states use to realize the benefits of DERs:

- Review existing interconnection standards and net metering rules while considering state priorities and other state examples.
- Engage DER stakeholders and gather community input from customers with DER systems and non-participants.
- Approach the design of interconnection standards in a way that balances requirements for grid reliability and safety, flexibility for DER technology, and compensation for DER customers.
- Make interconnection accessible for a broad range of customers by adopting application processes that are streamlined for smaller, simpler projects and more robust for larger, more complex projects.
- Ensure equitable access to DER benefits through net metering by engaging with communities and providing options such as virtual net metering to allow program participation of community shared solar for groups of customers.

- Monitor and evaluate net metering and interconnection programs to inform policy adjustments as economic costs, technology, and grid needs evolve, and in response to participation levels and customer needs.
- When reviewing established net metering programs, study options for ensuring costs and benefits are distributed fairly among participants and non-participants, such as through value-of-solar studies.
- As DER penetration increases, verify that compensation for net metering program participants reflects system needs.

These and other state practices are discussed in the Designing Effective Interconnection Standards and Net Metering Rules section and in the Implementation and Evaluation section. This chapter concludes by highlighting state policy examples from Massachusetts, Virginia, California, and Utah.

Benefits

Interconnection standards and net metering rules are inextricably linked, and together they can spur DER adoption, providing benefits to the energy system, customers, and society. This section summarizes many but not all of these benefits. For more details on DER benefits, the National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources (NSPM for DERs) catalogs the many types of potential benefits of DERs and presents principles and guidelines for analyzing their cost-effectiveness (NESP 2020).

Electricity System Benefits

Interconnection and net metering policies have the potential to encourage customer DER adoption. DER benefits vary by the time of day the resource is deployed and its location on the distribution system. With sufficient adoption, grid planning, and integration, DER deployment can reduce demand for, and costs associated with, centralized fossil-fired power generation and new generation capacity, fossil fuel supply resource extraction and delivery, and the construction of new transmission and distribution infrastructure.

For a perspective on the scale of solar DER adoption levels, one example is small-scale solar PV relative to U.S. installed capacity and generation. In 2021, small-scale solar PV accounted for 30.4 gigawatts (GW) or 11 percent of summer renewable energy capacity and 5 percent of the nation's total renewable energy generation (EIA 2021a). In California, a state with an active net metering program, small-scale, customer-owned (behind-the-meter) solar generation is forecasted to increase by 260 percent from 15,800 to 41,200 gigawatt-hours (GWh) from 2019 to 2030, and customer-owned energy storage capacity is forecasted to increase 770 percent from 2019, reaching 2.6 GW by 2030 (CPUC 2021b).

DERs can benefit the electricity system by reducing the amount of energy and peak capacity a utility needs to purchase. When aggregated, some DER technologies can provide ancillary services and help grid operators balance supply and demand in real time. DER investments that help meet capacity needs reduce the need for and associated costs of large-scale investment in new fossil fuel power generation units. Distribution system planning (DSP)[1] and energy demand management are ways to ensure that DERs support grid balancing, offset higher-emission generation, and provide overall benefits. Encouraging DER siting in locations that most benefit the grid can help maximize DER benefits (AEE 2018).

[1] One type of DSP (also called integrated distribution system planning or IDSP) is hosting capacity analysis (HCA). For more on IDSP and HCA, refer to the Maximizing Grid Investments chapter in the *Guide*.

Customer Benefits

For the residential or commercial DER host customer, DERs can provide a source of recurring revenue or electricity cost-savings, depending on usage, rate design, and government tax incentives. In many cases, the upfront financial costs to the host customer are offset by the ongoing financial benefits of recurring revenue or electricity credit generated by the DER. DERs can be used by commercial or industrial host customers to manage their peak demand and reduce the demand charge owed to the utility. To the extent aggregated and flexible DER support grid balancing and reduce utility capacity needs, they lower utility costs and ultimately benefit all ratepayers.

Economic Benefits

DERs provide economic benefits associated with local job creation, which has ripple effects on economic development in a community. DER systems such as rooftop PV and energy storage spur local job creation in energy system design and installation, and some DERs are manufactured in the United States. By the end of 2020, over 231,000 U.S. workers had a job primarily dedicated to solar energy, and another 86,000 U.S. employees spent some (less than half) of their working hours on solar projects (NREL 2021c). Residential PV accounted for over half of the solar installation jobs in 2020. Within the solar workforce, union members, veterans, and non-African American minorities have higher representation than the national average (NREL 2021c).

Environmental Benefits

Environmental benefits from DERs vary with the type of technology, fuel, timing, and location of DER deployment; but environmental benefits typically include pollution reduction, improved outdoor air and water quality, and reduced environmental health impacts associated with fossil fuel power generation. DERs have the potential to reduce pollution in communities with environmental justice concerns. Research has shown that exposures to and health impacts of air pollution from electricity generation is higher for low-income and Black communities than other demographic groups (Maninder et al. 2019). Moving generation to locations where load exists can reduce plant operations and the resulting air emissions at the site of a larger central facility. Policies and programs, including interconnection and net metering, that help to avoid or reduce the use of fossil fuel energy and criteria air pollutants can benefit public health by reducing incidences of premature death, asthma attacks, and respiratory and heart disease; avoiding related health costs; and reducing the number of missed school and workdays due to illnesses.

Quantifying and Communicating the Benefits

Environmental regulators, state energy office officials, consumer advocates, utilities, and utility regulators (called in some states a public utility commission or public service commission) all have their own roles in shaping and implementing interconnection standards and net metering programs. Each group has unique interest in the impacts of these policies (for more on participants and their roles, refer to the Participants section in this chapter). To help states and stakeholders analyze and quantify these impacts, EPA has a range of tools highlighted in the text box.

State air agency staff may focus on how DER adoption and load shifting can reduce air emissions and contribute to meeting each jurisdiction's air quality goals. State energy and air office staff can use EPA's AVoided Emissions and geneRation Tool (AVERT) to evaluate the emission impacts of policies that increase the participation rate in net metering programs or other targeted energy policies. EPA's Co-Benefit Risk Assessment (COBRA) model can then be used to evaluate and quantify the health impacts of these emissions changes. With these tools, state environmental regulators can quickly evaluate the impacts of one or more policies and their associated changes to load and emissions at different temporal (hourly to annual) and spatial (county to region) scales.

EPA Environmental Impacts and Health Benefits of Clean Energy Tools

EPA has a range of free tools available to support states and stakeholders with analyzing and quantifying the environmental impacts and health benefits of clean energy, including but not limited to the following:

- **AVoided Emissions and geneRation Tool (AVERT)** is a tool designed to meet the needs of state air quality planners and other interested stakeholders. Non-experts can use AVERT to evaluate county, state, and regional emissions displaced at fossil fuel power plants by policies and programs that support efficiency, clean DER, and utility scale renewable energy.
- **CO–Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool** is a tool that helps state and local governments estimate and map the air quality, human health, and related economic benefits of clean energy policies and programs at the national, state, and county levels. Analysts assessing the impacts of changes in rate design can enter corresponding changes in emissions from the electric utility sector and use the results from COBRA to inform cost-benefit analyses and other decision-making processes.
- **Health Benefits Per Kilowatt-Hour (BPK)** is a set of values that help state and local government policymakers and other stakeholders develop screening-level estimates of the outdoor air quality-related public health benefits of investments in energy efficiency and other clean DER.
- **Energy Savings and Impacts Scenario Tool (ESIST)** is a customizable and transparent Excel-based planning tool for analyzing the energy savings and costs from customer-funded energy efficiency programs and their impacts on emissions, public health, and equity. ESIST enables users to develop, explore, and share energy efficiency scenarios between 2010 and 2040.
- **Emissions & Generation Resource Integrated Database (eGRID)** is a comprehensive source of data on environmental characteristics of electric power plants in the United States. The interactive eGRID Explorer dashboard offers data, maps, and graphs on electric power generated, emissions, emission rates, heat input, resource mix, and more.
- **Quantifying the Multiple Benefits of Energy Efficiency and Renewable Energy** describes methods, tools, and steps analysts can use to quantify these benefits so that they can compare costs and

Each jurisdiction conducts cost benefit assessments for their programs differently. Understanding the benefits and how to quantify those benefits enables stakeholders to develop, implement, and justify programs and policies like net metering. For jurisdictions that consider or account for health impacts in their decision-making processes, EPA's COBRA tool and health benefits per kilowatt-hour (BPK) values give health officials, utilities, and utility regulators the ability to quantify and monetize the health benefits from the reduced operation of fossil fuel generation that results from DER interconnection and net metering. Utilities and utility regulators can use the BPK values to incorporate the public health impacts of power generation into DER value assessments that get included in compensation rates for excess energy. For example, an analysis of BPK applications from the Regulatory Assistance Project suggests ways BPK values can inform how a utility sets time varying rates[2] and rates to incentivize economic development (RAP 2021). In addition to tools, EPA offers the detailed resource Quantifying the Multiple Benefits of Energy Efficiency and Renewable Energy: A Guide for State and Local Governments (EPA 2018).

[2] A time varying rate (TVR) is a rate that varies by the hour the electricity is used to reflect higher costs of providing electricity service during peak periods in the day. Some states are evaluating or implementing TVRs within their net metering programs. For example, South Carolina incorporated time-of-use rates in its net-metering successor program (NREL 2021c). Refer to the Customer Rates and Data Access chapter in the *Guide* for more information.

Current Regulatory Landscape

This section first provides an overview of the regulatory landscape for state interconnection standards and net metering, followed by a discussion of the changing landscape for state net metering policies. This section describes state efforts to update and streamline interconnection processes for DERs and to improve the equitable distribution of grid upgrade costs.

Overview

Interconnection standards and net metering rules are developed and overseen by state utility regulators[3] or by the Federal Energy Regulatory Commission (FERC). State regulators typically regulate interconnections that send excess power back to the local utility (small utility-scale and DER projects), whereas FERC regulates interconnections where power is exported outside state boundaries.[4] State regulators have jurisdiction to approve the standards used for most interconnections, which are for smaller DER systems that serve the local utility, such as residential rooftop solar. To initiate new policy or updates, legislators can pass bills or utility regulators can open a docket.

State regulators have developed interconnection standards that enable customers to connect to a utility's distribution network. Excessive or expensive interconnection procedures can increase project timelines and costs, potentially making clean DERs uneconomical.

State legislatures initially created net metering policies as a simple way to compensate early adopters of solar PV. The rules developed for net metering have allowed PV and other DER systems to receive credit for electricity generated on site that is exported to the utility grid. In effect, customers that generate and export more electricity to the grid than they consume, usually on a billing cycle basis, have been able to offset the cost of future electricity use.

Traditional net metering rules compensated DER owners for their excess electricity at the retail electricity price, which is much higher than the wholesale price that utilities pay large generators for their electricity.[5] When making initial decisions about net metering compensation, many policymakers accepted that the retail rate was a reasonable approximation for the value of distributed generation. When the number of participating customers and amount of total energy being credited is relatively small, the potential effect of retail rates overcompensating for the value of the distributed generation, and consequently affecting customer rates or utility revenues, is also assumed to be small (NRRI 2019).

Net metering often relies on the use of a single bidirectional utility meter to measure, or "net" out, the use and flow of electricity to and from the electric grid. Net metering rules have generally placed limitations on eligible onsite generators, including maximum system size restrictions and the period that customers can roll over net metering credit into the future (e.g., year-to-year). Many net metering policies are designed with a cap on the total metered generating capacity that can be installed in the state or utility service area, for example measured as a percentage of peak demand.

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3 A state legislature grants authority to a utility regulator, commission, agency, board, or authority within each state to regulate electricity rates and reliability. The entity is often named public utility commission (PUC) or public service commission (PSC) but is referred to as "utility regulator" in the *Guide*.

4 FERC does not have jurisdiction in Texas, Hawaii, or Alaska (FERC 2018).

5 When DER owners are compensated for excess generation at rates other than the retail rate (e.g., at the wholesale rate), some refer to the program structure as "net billing" instead of net metering. In this chapter, the term net metering encompasses both structures, consistent with how some states define it in statute.

Most states have interconnection standards and a net metering policy in place (NRRI 2019). The DER market has grown substantially since the first state net metering policies were established. Solar PV efficiency has increased, and costs for hardware and installation have decreased, improving the overall economics (Kavlak, McNerneya, and Trancik 2018). From 2010 to 2020, solar PV system costs declined 64 percent for residential rooftop and 82 percent for commercial rooftop systems (NREL 2021a). State net metering policies, technical advancements, and declining costs have helped to accelerate the adoption of DERs and the development of utility-scale solar projects.

The total installed capacity of DER systems enrolled in state net metering programs as of 2020 was at least 28 GW (EIA 2021b). Solar PV accounts for over 90 percent of the net-metered DER capacity (EIA 2020). The national average customer PV system capacity was approximately 12 kW and the national average customer wind generator was approximately 36 kW (EIA 2020). The U.S. Energy Information Administration (EIA) tracks and reports monthly on state electric power data, including net metered capacity, generation, and number of customers by technology type.

A Changing Landscape for State Net Metering

States, federal officials, stakeholders, and energy system experts are working to understand and potentially reshape the role of net metering in the changing electricity system landscape.[6] As DER penetration rates increase, many states are in various stages of studying, updating, or replacing their original net metering policies, with some moving away from a static, retail rate of compensation (NCCETC 2021). Others are increasing the size of their programs by raising program capacity caps or adjusting their programs by reserving capacity for low-income customers. Examples of various approaches are presented in the State Examples section at the end of this chapter.

In some regions, the increased penetration of PV has shifted net demand—the difference between predicted demand and expected generation from variable sources like PV—in ways that lowers the value of additional solar generation (NREL 2018a). This happens when there is more solar electricity generation during daylight hours than needed to meet demand. In some oversupply cases, negative real-time electricity prices can occur on the wholesale market for some hours of the day (CAISO 2016). Traditional net metering compensation structures generally do not reflect this widely variable value of PV.

With the growth in number of participants and amount of net metered generation, some stakeholders have raised concerns. For example, some have asserted that retail rates overcompensate for DER generation at the expense of ratepayers not participating in the program, and as a result, shift system costs from net metering participants to non-participants (FERC 2020a). Specifically, some argue that net metering could allow customers with DERs to reduce their utility bills to a level that they would not equitably contribute to utility fixed cost recovery (i.e., pay their share of grid infrastructure operation and maintenance costs) (NRRI 2019). If a utility serves a large number of net metering customers who pay monthly bills too low to cover operation and maintenance costs, non-participants might pay proportionately more for utility fixed costs (NCSL 2017).

Some state legislatures have requested studies to inform net metering policy proposals. In some states, utility company requests or preexisting legislative or regulatory requirements trigger the policy reviews. Some reviews and reforms were prompted by stakeholder concerns that retail rates overcompensate for DER generation at the expense of ratepayers not participating in the program. Some states saw sufficient interest in net metering programs that they reached statutory capacity limits, which has sometimes prompted actions to

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6 In 2020, U.S. Congress mandated a study for the U.S. Department of Energy on net metering and alternative mechanisms, impacts on the electricity grid and consumers, and potential contributions of net metering to decarbonization, equity, and resiliency. The study remains in progress at the time of *Guide* publication (National Academies of Sciences, Engineering, and Medicine 2022).

consider new alternatives and successor rates to net metering (NRRI 2019). A 2021 California Public Utility Commission (CPUC) study found that net metering policies in the state reduced revenue for the utilities, which resulted in increased rates for non-participating customers (CPUC 2021a; Verdant 2021). However, recent research finds that the effects of net metering[7] on retail electricity rates are likely to remain small or negligible at anticipated participation levels (LBNL 2017).

Understanding the value of distributed generation allows states to better align customer compensation with the value that their system provides to the grid. As discussed, the benefits of DERs can vary by time of day and location on the grid. Some states are opening proceedings or conducting “value of solar” studies to quantify the benefits and costs of the distributed solar generation to the grid. Reaching consensus on value of solar methodology and converting that into a compensation rate can be challenging. A small change in a compensation rate can result in large changes in the economics of DER systems. Studies on the values of solar have varied in their methodologies and results. For example, a comparison of studies completed by Montana and Maryland shows Montana valuing solar 88 percent less than Maryland, with much of the difference resulting from vastly different retail rates (Utility Dive 2018). The causes of disparities relate to choices about which costs and benefits should be monetized (ICF 2018). For example, a study in Maine found the value of solar to be five time more than the retail rate (ME PUC 2015).

Many states are considering to update or have updated net metering policies. In response to stakeholder concerns, value of solar studies, program reviews and other research, some states are adopting alternative incentive structures that credit customers at a lower rate than the full retail rate for energy passed back to the grid. Other state policy changes include basing export credit rates based on time of day, creating separate customer classes for DERs, changing periods when credits must be netted out, raising caps on existing programs, and adding provisions for virtual net metering to enable access from community solar projects.[8] To ensure customers with DER systems are still paying for the services they receive from accessing the grid, some states have implemented or increased fixed minimum bill charges or grid access charges. In nearly all states and the District of Columbia, state utility regulators and legislatures have formally explored alternatives to their respective system of net metering (NRRI 2019).

Making changes to net metering programs can be contentious. Some utility industry stakeholders argue that policy and program reforms are needed because with higher program participation rates, the cost of energy rises for utilities that purchase the excess energy at retail rates. Solar industry and environmental stakeholders often advocate to maintain compensation at retail rates or institute a slower, more gradual decline in the rates to prevent rapid disruptions to the industry. For example, when Hawaii implemented a policy change that ended net metering in 2015, permit applications for distributed solar PV systems on the island of Oahu decreased between 30 to 50 percent in the following three years (GTM 2019; 2017a).

Some states have introduced tariff structures to compensate customers with DER systems for the value of the energy based on time and location, rather than at the constant retail rate. For example, after Hawaii ended its net metering program, the Public Utilities Commission approved a Smart Export program for customers with both solar and storage systems. During the daytime hours of 9 a.m. to 4 p.m., when the islands’ grids typically

[7] This research specifies net metering of distributed solar PV systems (LBNL 2017). A majority of net metered capacity is solar PV (LBNL 2017).

[8] Shared renewable projects, community solar, or community shared solar (CSS) programs are large PV systems that provide power and/or financial benefit to multiple community members. These programs expand access to solar power to renters, those with shared roofs, and those who are unable to install solar systems for financial or other reasons. These programs are particularly beneficial to low- and moderate-income customers, who may face barriers to installing rooftop PV such as high upfront costs, low homeownership rates, and limited access to credit (NREL and CESA 2018; CESA 2019).

reach the maximum amount of solar energy they can accommodate, the program provides no compensation for distributed solar generation. The program compensates participants for power sent to the grid during the evening peak period or overnight when solar resources do not generate much energy and the utility would otherwise rely on fossil fuel generators. Rates vary by island where the DER operates (Hawaiian Electric n.d.).

Other examples of states that have replaced or updated their net metering policy with an alternate rate design include Utah and Nevada. In 2017, the Utah Public Service Commission (PSC) approved a stipulation between Rocky Mountain Power and others to replace net metering with an export credit, which paid a lower standard rate than the retail rate for each unit of energy exported to the grid for new systems brought online. In 2020, the Utah PSC determined the value of the export credit rate that is based on avoided cost principles and closer to wholesale electricity prices (UT PSC 2020). In Nevada, after the Public Utilities Commission eliminated net metering in 2015, the legislature passed Assembly Bill 405 in 2017 establishing a new net metering program with compensation levels that gradually step down as solar penetration increases (GTM 2017b). For more details on Utah and other states, refer to the State Examples section of this chapter.

Various stakeholders have sought changes to net metering policies not only at the state level, but also at the federal level. In 2020, FERC considered a stakeholder petition, filed by the New England Ratepayers Association, that sought to end state regulation of net metering rules by transferring jurisdiction to federal authority (FERC 2020b). There was broad opposition from state and DER stakeholders and FERC ultimately rejected the petition. The case provides another example of the uncertainty of the future policy landscape.

Updating and Streamlining Interconnection Processes for DERs

Some stakeholders are seeking changes to state interconnection standards. In some states, the changes would address interconnecting certain sizes or types of DER systems. The typical capacity size (in megawatts, MW) of a residential or small business-scale rooftop PV project is much smaller than that of a commercial, industrial, or utility scale PV system, and the interconnection standards can vary accordingly. The text box, *The Current Landscape of Interconnection Based on DER System Size*, summarizes general interconnection standards by project size. States may revise interconnection standards to address DER system safety or reliability, or to clarify processes around newer DER technologies.

The Current Landscape of Interconnection Based on DER System Size

- *10 MW or larger systems*. FERC has jurisdiction over developing standard interconnection requirements for larger systems that are connected directly to the transmission grid. Historically, electric utilities owned most grid-connected generation systems. As a result of restructuring and other legislation (e.g., the Public Utility Regulatory Policy Act or PURPA), utilities were required to interconnect non-utility owned generators to the electric grid. States and regulatory agencies such as FERC have begun to develop or have already implemented interconnection standards for non-utility generators.
- *0.1 MW (100 kW) to 10 MW systems*. This intermediate group represents systems that are interconnected to the distribution system but are larger than the systems typically covered by net metering rules. These systems are smaller than the large generating assets that interconnect directly to the transmission system and that are regulated by FERC. In response to the mounting demands by customers and DER developers to interconnect generation systems to the grid, utilities have increasingly established some form of interconnection process and requirements. In addition, to increase utility confidence around DER systems, industry organizations such as the IEEE and UL have begun to develop standards that enable safe and reliable interconnection of generators to the grid. However, states need to ensure that interconnection standards are established for generation systems of all sizes.
- *Less than 100 kW (0.1 MW) systems*. Some states have developed rules for the net metering of relatively small systems (i.e., less than 100 kW). These procedures are not typically as comprehensive as interconnection standards, but they can provide a solid starting point for industry, customers, and utilities with respect to the connection of relatively small DER systems to the electric grid.

Some state regulators are revising interconnection standards for energy storage, which is a growing market for residential customers. In the future, customers may increasingly consider installing energy storage systems, either with or without onsite generation, and states may need to update their standards to ensure these new systems are addressed. In California, the CPUC revised regulations on energy storage interconnection and rules surrounding energy storage systems exporting electricity to the grid, and clarified requirements for how bidirectional electric vehicle charging can be interconnected with utility permission (CPUC 2020). These revisions aim to clarify energy storage technology interconnection requirements (for more information on interconnection standards in California, refer to the State Examples section of this chapter).

Hosting Capacity Analysis

Hosting capacity analysis (HCA) is modern grid planning activity that can be used to expedite the interconnection process. HCA is used to help utilities and developers understand the threshold at which additional DERs will trigger an upgrade to the electrical system. It can be used as an analytical pre-screening process to determine whether a distribution system can accommodate new DERs (e.g., distributed PV, storage, and electric vehicles) at specific locations without upgrades. HCA increases transparency into current operational conditions and limits through maps and supporting datasets. The information can help state regulators and utilities identify where in the distribution system new DERs could provide beneficial services and support longer term strategic DER investment decisions, weighing the benefits against the costs to upgrade the local distribution system. The insight from HCA maps and data on current grid conditions and operational constraints allows a utility customer or DER developer to target specific grid locations for a cost- and time-efficient DER interconnection process (IREC 2018). HCA establishes the baseline of the maximum distributed generation the grid could accommodate safely, considering thermal, voltage, and protection limits (ICF 2016). After the initial process of identifying operating limits, HCA may consider the locational value of additional DERs on the grid (ICF 2016).

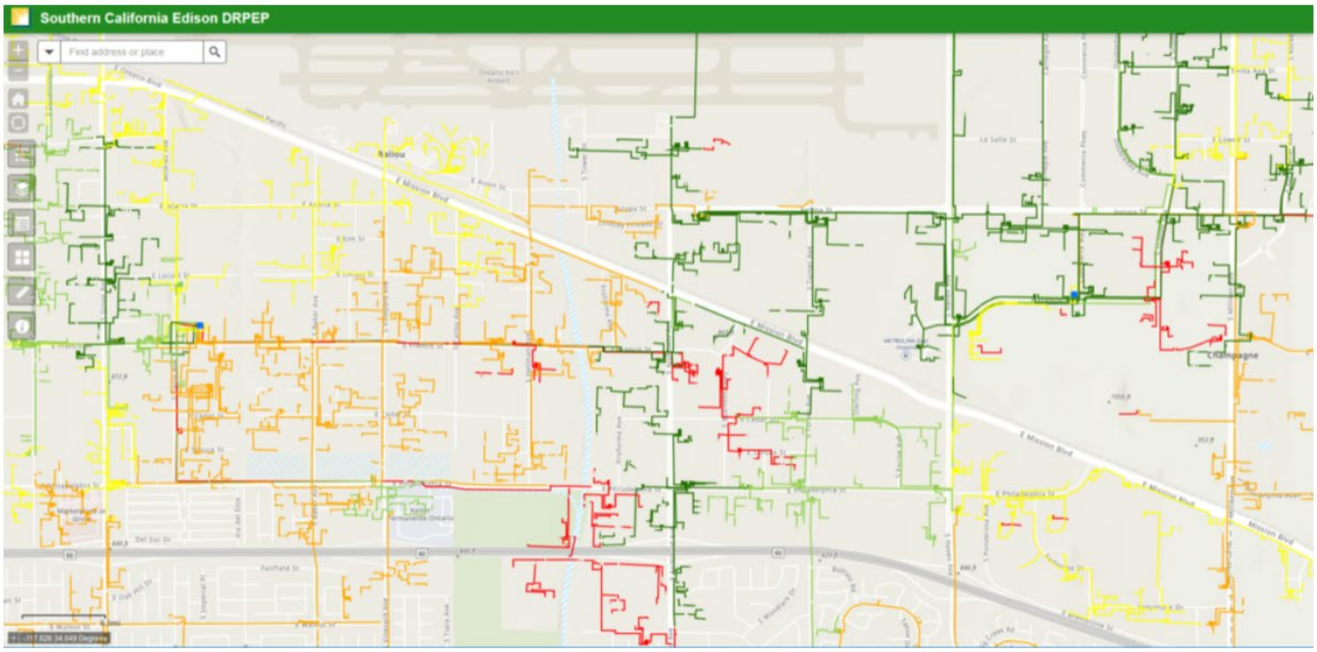
In some states, including California, Hawaii, Minnesota, and Nevada, utility regulators require utilities to produce HCAs to support distribution system planning and grid modernization (IREC 2018). Some utilities, like National Grid in Rhode Island, create interactive maps that incorporate HCAs and other information, such as sea level rise estimates and the utility's non-wires alterative program (National Grid n.d.). The Interstate Renewable Energy Council recommended to the Colorado Public Utilities Commission the following HCA process (IREC 2020):

1. Rulemaking sets general HCA requirements.
2. Utility regulator hosts workshops to identify criteria to guide HCA implementation and selects criteria via order.
3. Utility performs HCA, validates data, and publishes results.
4. Utility regulator tracks results, learns about latest improvements, and evolves requirements.

Different tools are available to conduct HCA, such as the Electric Power Research Institute's DRIVE software (EPRI n.d.). Figure 1 presents an example of a distribution system HCA map produced by Southern California Edison (IREC 2019). As methods and tools are refined, HCAs can produce increasingly accurate maps and datasets and become more useful for streamlining interconnections, reducing time and expense, and better supporting grid planning and optimization.

A policy that is closely linked to the interconnection process is cost allocation for distribution system upgrades. Generally, states operate on a first-come, first-served basis, which means that if you are the first to connect to a distribution system feeder line, you are free to do so. Once that line reaches its capacity, the next customer who wants to connect their DERs to the line must pay for the upgrade. These upgrades can make projects prohibitively expensive, preventing further integration of DERs in that area until the line is upgraded. HCA helps customers and developers understand where there is capacity to connect without incurring the large costs of upgrading the line (NREL 2018b). Some states, like New York, have changed these policies to allocate the costs of upgrades across the entire customer base who benefit from the additional DERs and availability of new line capacity. In January 2019, the New York PSC approved the Cost-Sharing 2.0 Proposal, which covers DERs of 5 MW or less and reduces the upfront costs to upgrade lines (HodgsonRuss 2021).

Figure 1. Hosting Capacity Analysis Map produced by Southern California Edison



Source: (IREC 2019). Color scale indicates the available capacity on the line, with red indicating the most limited, orange, yellow, and light green each indicating higher levels of capacity, and dark green indicating ample capacity.

Designing Effective Interconnection Standards and Net Metering Rules

States consider several key factors when designing interconnection standards and net metering rules to balance the needs of DER customers and owners, utilities, clean energy developers, and the public. To design effective polices, states can promote broad stakeholder participation during policy development, address a range of technology types and sizes for interconnection and net metering, and consider current barriers to customer participation. To maximize the benefits of DERs to the grid, to customers, and for the environment, states may also consider adopting modern grid planning and analysis approaches to strategically plan for and facilitate DER interconnections.

Participants

Key stakeholders who can contribute to the process of developing effective interconnection standards and net metering rules include the following:

- *Electric utilities.* Utilities are responsible for maintaining the reliability and integrity of the grid and ensuring the safety of the public and their employees. Investor-owned utilities (IOUs) are privately owned utilities that are directly overseen by the state utility regulators. Other utility stakeholders that may not be under the jurisdiction of the state utility regulators include:

- *Publicly Owned Utilities (POU).* POUs are normally non-profit utility companies organized by the community and run as a division of local government. This type of utility is governed by a local city council or an elected or appointed board and sells power directly to the community it represents.
- *Electric Cooperatives (Co-ops).* Electric cooperatives are private, independent electric utilities, owned by the customers in the service area. They operate on a non-profit, cost-of-service basis.

- *State Utility Regulators.* Regulators have jurisdiction over IOUs and, in some cases, cooperatively and municipally owned utilities. They are often instrumental in setting policy to integrate or encourage onsite generation, and are legally required to ensure the safety, accessibility, affordability, and reliability of the electricity grid.
- *Developers and owners/operators of DER systems and their respective trade organizations.* Developers and the customers that will rely on these systems can provide valuable technical information and real-world scenarios.
- *Technical allied organizations.* Organizations such as the Institute of Electric and Electronic Engineers (IEEE) and certifying organizations like the Underwriters Laboratories (UL) have been active in establishing interconnection protocols and equipment certification standards nationwide. In addition, organizations such as the Interstate Renewable Energy Council (IREC) help to develop national standards related to interconnection and net metering policy and to advance regulatory policy innovation.
- *Regional transmission organizations (RTOs).* These organizations may have already implemented interconnection standards using FERC's requirements for large non-utility generators, generally above 10 MW.
- *Other government agencies.* Federal (e.g., FERC) and state environmental and public policy agencies, including state consumer advocates, can play an important role in establishing and improving interconnection standards and net metering rules.
- *Public or utility customers.* Customers that purchase electricity from utility companies.
- *Utility Consumer Advocates.* These government or non-government organizations who represent ratepayers seek to promote and advocate for the interests of utility customers. Some states have a citizens' utility board (CUB) that actively participates in utility regulatory proceedings, advocates for ratepayers in rate cases, and promotes clean energy and consumer protections. The Illinois CUB, for example, joined rooftop solar supporters to advocate on behalf of net metering customers in a 2020 case before the Illinois Commerce Commission that would have otherwise allowed the utility (Ameren) to end net metering credits sooner based on how Ameren implemented the five percent net metering cap (IL CUB 2020).
- *Customers and community-based organizations.* Communities of color, low-income households, and residents of particular home types (for example, residents of manufactured homes or multifamily buildings) are participants whose insights are important for equitable policymaking, yet many of these customers experience barriers to participation (DOE 2016). States vary on how easy or difficult it is to engage on a utility regulator proceeding. Some states hold public workshops and create public comment processes to help build the capacity of community members and advocates to participate in regulatory proceedings and policymaking (Synapse, RAP, and Community Action 2020). Six states have active intervenor compensation programs out of 16 that have authorized reimbursement for involvement in

proceedings (NARUC 2021). In some states, community-led organizations that represent historically underrepresented communities are active participants in policymaking. For example, in 2021 the California Low-Income Consumer Coalition advocated for the interests of low-income ratepayers by joining the CPUC proceeding on a successor to the net energy metering tariff and submitting comments regarding enhanced consumer protection measures for customer-generators, tariff transparency and customer understanding, and equity among customers (CLICC 2021). The text box has more information on inclusive practices to encourage underrepresented stakeholders in the development of net metering rules and interconnection standards.

- *Environmental Organizations.* These non-government, non-profit organizations advocate for the conservation, protection, and/or optimal management of environmental resources against their misuse or degradation caused by human misuse. The organizations may advocate for the fair treatment and meaningful involvement of all people with respect to the development, implementation, and enforcement of environmental laws and energy regulations.

Practices for Inclusive Engagement when Developing Net Metering Rules and Interconnection Standards

- Offer evening and weekend options for stakeholders to participate in hearings, workshops, public meetings. Provide intervenor training, translation services, and other informational community outreach activities to better include groups historically underrepresented in the standards-setting process, such as communities of color and low-income communities (Synapse, RAP, and Community Action 2020).
- Address historic and systematic barriers to participation by underrepresented groups and communities with environmental justice concerns and engage with community-based organizations and Tribes (DOE 2016).
- Require environmental and social justice evaluations during the policymaking process (Washington and California incorporate this practice into their state process).
- Financially compensate residential or small commercial customers who experience financial hardship as a result of participation as intervenors in a commission proceeding (e.g., presenting evidence or arguments that factor into the final decision), even if the commission does not ultimately align with the intervenor's position. California offers an example of this approach to intervenor compensation (NARUC 2021).

Typical Specifications for Interconnection and Net Metering

The specifications described in this section reflect typical elements found in existing state policies. The text boxes describe best practices derived from current literature or from existing state policy examples.

Specifications for Interconnection

States can promote clean DERs with comprehensive interconnection standards that address the following elements:

- *System size requirements.* State policies may establish individual system capacity limits and ensure that the policy applies to all state jurisdictional interconnections.
- *Technology and technical standards.* State requirements may specify or prioritize certain technologies that may be interconnected (e.g., inverter-based systems, induction generators, synchronous generators). In addition, states can keep metering requirements to a minimum and allow customers to opt-out of an external disconnect switch for smaller, inverter-based systems. A disconnect switch would add to start-up costs but would provide electricity resiliency benefits, for example during a power outage. It would enable a DER host customer to safely consume directly the electricity generated by its onsite renewable DER system after disconnecting from the grid.

- *Components.* States often list required components of the electric grid where the system will be interconnected (i.e., radial or network distribution, distribution or transmission level, maximum aggregate DER capacity on a circuit).
- *Application fees and timelines.* States can establish reasonable limits on interconnection application fees and timelines for system interconnections. Effective policies keep application costs to a minimum, especially for smaller systems, which promotes equitable access to DERs for residential and small business customers and ensure that timelines are imposed and enforced.
- *Limitations on liability insurance requirements.* States may prevent utility requirements for customers to purchase liability insurance (in addition to the coverage provided by a typical insurance policy) or add the utility as an additional insured.
- *Battery storage.* States may consider net metering policies that include regulations on behind-the-meter battery interconnection and rules surrounding exporting stored electricity to the grid.
- *Review process.* Best-practice policies generally allow for different tiers with different levels of review to accommodate systems based on system capacity, complexity, and level of certification.
- *Project technical screens.* Clean and transparent technical criteria for screening projects facilitates evaluation and supports effective policy implementation.
- *Customer redress*. These provisions specify the option to hold utilities and owners accountable for following the standards.

Some states are developing application processes and technical requirements for differently sized or certified systems. Since a DER system's size can range from a renewable system of only a few kilowatts (kW) to a CHP system of tens of MW, standards can be designed accordingly. Several states have developed a multi-tiered process for systems that range in size from less than 10 kW to more than 2 MW. Similar to the FERC guidelines, some states (Colorado, Florida, and North Carolina) have divided DER systems into three categories based on generator size. Other states use fewer categories (such as New York, Georgia, and West Virginia) or more categories (such as Delaware, Illinois, and Maine, which each have four). States define fees, insurance requirements, and processing times based on the DER category. The level of technical review and interconnection requirements usually increases with generation capacity, although the requirements are ultimately prompted by the applicant's impact on the grid as determined through the study process and the criteria identified in the application process. Simplified interconnection processes for the smallest projects helps offset the absence of financial or technical resources available to customers likely to pursue a smaller system. The simplified processes can enable a wider range of residential or small business customers to install DER projects (NCCETC 2021).

In states with a multi-tiered interconnection process or preliminary technical screen, smaller systems that meet IEEE and UL standards or certification generally pass through the interconnection process faster, pay less in fees, and require less protection equipment because there are fewer technical concerns. States that require faster application processing for smaller systems (up to 30 kW) include California, Connecticut, Massachusetts, Michigan, Minnesota, New York, and Utah. For relatively large DER systems, processes and requirements may be similar or identical to those used for large central power generators. For mid-size systems, states may need to develop several levels of procedural and technical protocols to meet the range of needs for onsite generators, utilities, and regulators.

Best Practices for Interconnection Standard Policy Design

States seeking to support clean DER through interconnection standards may consider taking the following actions:

- Work collaboratively with interested parties to develop interconnection standards that are clear, concise, and applicable to potential DER technologies. Proactively seek participation of social or environmental justice groups and community groups, offering intervenor training and meetings outside typical workday hours. Collaborate with technical experts and customer advocates to streamline the process and avoid untimely and costly rework.
- Develop standards that cover the scope of the desired DER technologies, generator types, sizes, and distribution system types.
- Avoid restrictive requirements that place unnecessary mandates on customers to buy liability insurance or require customers to make the utility an additional insured party.
- Consider adopting portions of national models (such as those developed by the National Association of Regulatory Utility Commissioners, IREC, and FERC) and successful programs in other states, or consider using these models as a template in developing a state-based standard. Consider that consistency within a region increases the effectiveness of these standards.
- Apply common state practices that reduce industry compliance costs. The NREL SolarAPP+ is a free online tool designed to create a standardized process.
- Maximize consistency between the RTO and the state standards for large generators.
- Broaden DER access to residential or small business customers by making the interconnection process less complex, less time-intensive, and more affordable for projects below a determined size threshold.
- For small DER systems, omit unnecessary hardware requirements, offer expedited applications and approvals, combine applications for multiple aspects of a project, offer pre-filled online forms that are easy to modify and submit, provide grid infrastructure information accessible online, publish clear and predictable timelines for each step in the process, and maintain a transparent online queue of applicants.

IREC provides more information in its Model Interconnection Procedures. (2019).

Specifications for Net Metering

States can promote clean DERs with comprehensive net metering rules that address the following elements:

- *REC Ownership.* States may allow the DER host or owner of a net metered system to retain ownership of Renewable Energy Certificates (RECs) produced by the system, unless transferred to the utility or another party in exchange for acceptable compensation. A REC is a market-based instrument that represents the rights to the environmental, social, and other non-power attributes of renewable generation. Only the owner of the REC can "retire" the REC, which means the REC can no longer be traded and the owner can then claim the use of renewable energy.
- *Rollover policy.* States may provide flexible options for retail rates and credits to enable customers to roll unused credits into a defined number of billing cycles. States can specify that customers are to be paid for annual net excess generation or at a different set time interval, such as monthly or the number of billing cycles.
- *Rates*. States may specify the exact rate or delegate the rate to be determined in proceedings before utility regulators. Customers are usually compensated at or near the retail rate with net metering programs, but some states are updating their programs with generally lower compensation rates. Rates are rarely below the average daytime wholesale price at which the utility would otherwise have to purchase the electricity. Arizona uses an innovative approach involving a resource comparison proxy to determine the amount of compensation per kWh a customer receives for solar generation. The resource comparison proxy is updated annually and based on avoided cost principles, tying the rate to the utility-scale price of similar solar resources (APS 2017). The rate takes avoided transmission and distribution losses into account, and it limits how much the rate can drop in a single year. This approach, which replaced the state's original net metering program, was approved by Arizona Corporation Commission in 2017 (AZCC 2017). After this

approach was implemented, there was a drop in residential solar PV installations, but in 2021 there were more residential installations than in 2017 (SEIA 2021).

- *New metering equipment.* States can avoid requiring retail electric customers to purchase new metering equipment. States can require utilities to make smart metering and other digital technology for energy management available to solar and other customers on a non-discriminatory and open-access basis. Integrating smart meters or other advanced metering technologies can lead to more detailed and reliable meter data, which in turn can lead to more efficient planning and energy use.
- *Shared renewables, community renewables, and virtual net metering.* States may provide an option for shared renewables (e.g., community solar), which is a billing approach often appealing to utility customers whose onsite solar resource potential is limited, those who rent, and those who cannot afford the upfront cost or are otherwise unable or unwilling to install a clean DER system on their residence or commercial building. States have taken one of three legislative paths to authorize shared renewables: virtual net metering, community renewables programs, or a hybrid of these (NCSL and NASEO 2017). As of 2020, 39 states and Washington, DC, have community solar projects, and 20 states and Washington, DC, have policies that support community solar (NREL 2021b). Net metering or alternative arrangements, such as group billing or joint ownership, can credit shared renewables participants; however, eligibility depends on utility and state-level requirements. Colorado, for example, has legislation on community solar that allows systems to qualify if they are (1) in the same county as its subscribers, and (2) between 10 kW and 2 MW. In Colorado's framework, participants receive a credit on their bill after transmission costs are subtracted (Low-Income Solar 2018). In Florida, the PSC recently approved Duke Energy Florida's Clean Energy Connect Program, which enables all customers, whether or not they have physical access to a PV system, to subscribe to kilowatt blocks of solar from a portfolio that provides a monthly bill credit based on their subscription (FL PSC 2021).
- *Meter aggregation.* States may allow for a utility customer's DER project to offset their electricity use from multiple meters on their own or another adjacent property. Examples include a solar PV system on a farm where multiple loads are metered, or a government owned DER system that offsets the electrical use of adjacent, separately metered government buildings.
- *Fixed costs and externalities.* States may enact policies that require customers to pay for the fixed costs and externalities that result from net metering systems to mitigate cost-shifting to other ratepayers. This can be done through minimum bill requirements or grid access charges. Such policies may include time varying rate structures for net metering customers, or program monitoring or review requirements to determine the net metering program's impact on low-income customers.

Best Practices for Net Metering Standard Policy Design

States seeking to support clean energy through net metering may consider the following actions:

- Ensure that the value of DER electricity is quantified fairly and that DER customers are adequately compensated.
- Ensure the customer's right to generate electricity and connect to the grid without discrimination or undue process.
- Evaluate the costs and benefits of net metering on participants and non-participants. If the utility implements charges to recover embedded net fixed costs, ensure that these charges are applied only after accounting for all utility benefits and offsetting all cost reductions from DER.
- Consider time varying rates for net metering customers.
- Establish measures to monitor the program's impact on the energy burden of low-income customers.
- Ensure that net metering rules, regulations, and practices are applied consistently statewide.
- Ensure that the policy provides transparent access to data, such as load data (including hourly profiles), so customers can understand the economic implications of adopting onsite clean energy technologies.
- Avoid restrictive total program or state (aggregate) capacity limits or individual system capacity limits beyond that of the host customer's load or electricity consumption.
- Ensure transparency in who retains renewable energy certificate (REC) ownership and their associated environmental and social attributes.
- Make DERs affordable for and accessible to more customers. Allow collective ownership and/or net metering policies that enable a group of customers to share the costs and benefits of a DER system (e.g., community solar).
- Incentivize utilities to include small businesses, low-income communities, and communities with environmental justice concerns in clean distributed energy projects by implementing targets for DER for these communities.
- If creating or increasing incentives, ensure the interconnection process can handle the increased application load before the incentives are enacted.

IREC provides information on best practices for net metering policy design in its publications Model Net Metering Rules (2009) and Model Interconnection Procedures (2019).

Interaction with Federal Policies

States have found that several federal initiatives, particularly FERC standards, can be used when designing their own interconnection standards. Relevant and recent FERC orders are summarized as follows:

- FERC, in 2006, set standard terms and conditions for interconnections under FERC jurisdiction at the transmission level for public utilities to interconnect new DER sources by issuing Small Generator Interconnection Procedures (SGIP) and Small Generator Interconnection Agreement (SGIA). The SGIP contain technical procedures as well as standard contractual provisions. They provide three ways to evaluate an interconnection request. The SGIP require interconnection equipment to be certified according to IEEE Standards 1547 and UL 1741. The SGIA was updated with specific technical requirements intended to improve grid resilience and reliability in 2016 and again in 2018 with FERC Order No. 842 (FERC 842 2018).

Under the Public Utility Regulatory Policy Act (PURPA), utilities are required to allow interconnection by qualifying facilities. States have significant flexibility in administering PURPA, although amendments made in 2005 and FERC decisions have limited the applicability of PURPA in some regions, particularly for facilities larger than 20 MW. In 2010, FERC ruled that California's "multi-tiered" avoided-cost-rate structure for a feed-in tariff for CHP systems of up to 20 MW is consistent with PURPA. FERC affirmed that state procurement obligations can be considered when calculating avoided cost, for example, when states require utilities buy particular sources of energy with certain characteristics (e.g., renewable energy) to meet procurement obligations (FERC 132 2010). In 2020, FERC amended PURPA through Orders 872 and 872-A in response to the many changes in the energy landscape in recent decades. Some of the changes gave state regulators more flexibility, for example, by allowing states to incorporate market forces in establishing avoided cost rates for qualifying facilities (FERC 2020f; 2020d). The changes may prompt states to revisit their interconnection standards and net metering rules as regulators and utilities implement the PURPA amendments (APPA, EEI, NARUC, and NRECA 2021).

- Energy storage became an eligible resource type to interconnect under FERC SGIP procedures in 2013 through FERC Order 792. States may want to consider how state interconnection standards accommodate storage assets and how they interact with existing FERC orders (FERC 2020c). While FERC's updates are not binding for states, they can provide useful models for establishing provisions that anticipate and enable higher DER penetration.
- In 2020, FERC dismissed a New England Ratepayers Association petition, which was filed to request (1) that FERC declare exclusive federal jurisdiction over wholesale energy sales from generation sources located on the customer side of the retail meter, and (2) that rates for such sales be priced in accordance with the Federal Power Act (FPA) or PURPA (FERC 2020a; DOE n.d.). Those in favor of the petition argued that by compensating customers or companies who operate these systems for their excess electricity at retail rates, ratepayers end up paying more for electricity that could be purchased at the lower wholesale rates, resulting in a regressive cost-shifting from rooftop solar owners, who generally have higher incomes, to low-income ratepayers. Those against the petition argued that net metering is an integral element of retail billing, which is strictly a state jurisdictional issue and that net metering transactions are local by their nature because net metering concerns the relationship between the retail customer and the local utility. The petition was rejected on procedural grounds, and Commissioners' notes in their concurrences indicated that the jurisdictional merits of the case were still unanswered by FERC (FERC 2020a).

Interaction with State Policies

Interconnection standards and net metering rules complement other clean energy policies and programs such as state renewable portfolio standards, clean energy standards, utility incentive mechanisms, and utility planning practices, which are covered in other chapters of the *Guide*. For example, the utility incentive mechanism of performance-based regulation (PBR), which can be implemented by utility regulators, could tie a small part of utility revenue to interconnections. Specifically, regulators can use performance incentive metrics (PIMs) for interconnection request timelines or incentivize PV adoption by applying PIMs to the number of new residential PV customers added in a service territory. PBR equity and affordability metrics could also accompany interconnection standards and net metering rules to better align overall utility financial interests with goals to reduce customer bills for low-income customers. Interconnection and net metering policies can also help states achieve other related environmental, energy, and economic goals. For example, by providing incentives to site renewable energy on brownfields (formerly contaminated lands), landfills, or mine sites, the state can help protect open space and transform blighted properties into community assets.

Implementation and Evaluation

This section describes the implementation and evaluation of interconnection standards and net metering rules.

Implementation

State legislatures and utility regulators may develop interconnection standards and net metering rules, and utilities are ultimately responsible for their implementation. Facilitating the interconnection process is a primary implementation activity. By establishing clearly defined categories of technologies and generation systems, utilities can streamline the interconnection process for customers and lessen the administrative time related to reviewing applications. In some states, utilities create multiple categories and tiers for reviewing applications with established maximum review periods, in accordance with state policy. Across these technology categories, the maximum processing time allowed can vary by more than a factor of five depending on the technical complexity and size of the interconnection. Several states (including California, Connecticut, Massachusetts, Michigan, Minnesota, New York, and Wisconsin) have created tiered application processes based on system size and other factors. This tiered approach streamlines the process for smaller systems while maintaining a standard process for larger systems.

- A streamlined process that applies to smaller or simpler (e.g., inverter-based) systems could have lower fees, shorter timelines, and fewer requirements for system impact studies. In some cases, states (i.e., California and New York) have pre-certified certain devices. Other states (i.e., Connecticut, Massachusetts, Minnesota, New Jersey, and Texas) require compliance with UL 1741 or IEEE 1547 and other applicable standards to expedite approval. In addition to streamlining processes, Minnesota's 2018 update of statewide interconnection standards allows customers to request relevant grid information before they start their interconnection application and requires utilities to maintain a publicly available transparent application queue that tracks timeline compliance (MN PUC 2018).
- Systems in a standard process are subject to a comprehensive evaluation. Applicants for these systems are typically required to pay additional fees for impact studies to determine how the DERs may affect the performance and reliability of the electrical grid. Because of the higher degree of technical complexity, fees are higher and processing times are longer.

There is tremendous diversity among the key elements of interconnection standards recently established at the state level. The detailed state examples at the end of this chapter illustrate different approaches to application process elements like fees, timelines, and eligibility criteria. Greater similarities are emerging among states' technical requirements, and this consistency makes it easier to increase the amount of clean DERs in the states.

Evaluation

Utilities and state regulators may conduct evaluation of interconnection application process timelines to ensure an efficient process for customers. As noted previously, some states monitor the timing of interconnection applications from receipt to final interconnection agreement. This enables the states to determine how standards affect the process for applicants by types and sizes of interconnected systems. States can monitor utility compliance with the new standards and timelines. States can also consider approaches to accountability.

As previously noted, many states are evaluating reimbursement rates and considering or adopting changes to their original net metering policies. For example, some states are evaluating their policy approach to improve equitable distribution of cost burdens among DER stakeholders.

Action Steps for States

Some states have adopted successful interconnection standards and net metering rules that expedite the implementation of clean energy technologies while accounting for the reliability and safety needs of utility companies. This section provides examples of action steps for states establishing interconnection and net metering policies and procedures, and for ensuring ongoing success after the policies are adopted. Importantly, the success of effective interconnection standards is enhanced by effective net metering rules. States that have recognized the need for concurrent net metering policy have either incorporated net metering rules into the interconnection standards or established separate net metering rules.

States with Existing Interconnection and Net Metering Policies

A priority after establishing interconnection standards and net metering rules is to evaluate the policy implementation and mitigate issues that might adversely affect success. In addition, being able to demonstrate and communicate the benefits of the policies is critical to their acceptance and use by stakeholders. States that have existing interconnection and net metering policies may consider taking the following steps to optimize policy effectiveness:

- Compare existing state interconnection and net metering policies to established model rules and best practices.
- Monitor interconnection applications from the time of receipt to the time of final interconnection agreement. Determine how the standards affect the application process and how they impact different types of interconnected systems. Consider monitoring utility compliance with the new standards and timelines, and creating a point-of-contact to resolve disputes or noncompliance.
- Consider updating interconnection standards or net metering rules as needed in response to the results of monitoring and evaluation activities. For smaller DER systems, if there are disproportionally high costs or long durations to interconnect to the grid, consider streamlining the policy for small DER systems to limit the length of the application review periods or technical requirements.
- Identify an appropriate organization to maintain a database on interconnection applications and new DER systems, evaluate the data, and convene key interconnection stakeholders when necessary.
- Consider whether interconnection standards and net metering rules can indirectly support utility initiatives designed (1) to advance equity by increasing access and reducing barriers to DER adoption for targeted communities, and (2) to increase electricity affordability for low-income customers. This can be done by providing access to community-based DER systems such as shared solar projects.

States without Existing Interconnection and Net Metering Policies

Stakeholder support can help facilitate and accelerate the development of new policies. Gaining stakeholder support is a first step for a state that seeks to establish interconnection and net metering policies. The following strategies foster support from public officials and other stakeholders:

- Determine the level of demand and support for interconnection and net metering policies from public office holders and key industry members (e.g., utilities, equipment manufacturers, project developers, potential system owners).
- Conduct an analysis of proposed policy costs and benefits to stakeholders in the state, perhaps accompanied with a pilot program.
- Implement an educational effort targeted at key stakeholders to raise awareness of potential benefits of net metering policies.
- Establish a collaborative working group of key stakeholders to develop recommendations for a standard interconnection process and technical requirements if the state has DER regulations. One approach is for the state utility regulator to open a docket with the goal of receiving stakeholder comments and developing a draft regulation. Another option is to work with members of the legislature and the utility regulator to develop support for the new interconnection and net metering policies.
- Consider implications of DER incentives (e.g., new net metering program) on the volume of interconnection applications. Expect that implementing interconnection standards may take some years.

- Consider developing the state interconnection standards before increasing incentives to DER adoption, for example to avoid a backlog of interconnection applications.
- Consider existing federal and state standards while developing new interconnection procedures. Rely on accepted IEEE and UL standards to develop interconnection technical requirements.

State Examples

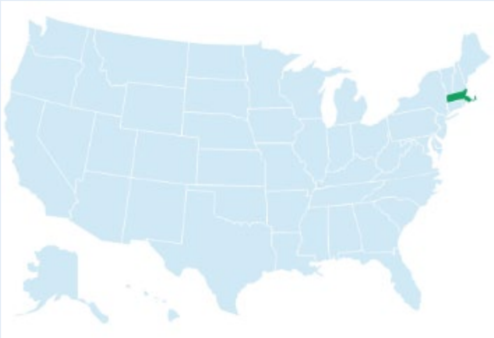
Massachusetts

Massachusetts is a national leader in net metering policy and in the amount of total net metered energy sold back to the utility, which in 2020 was 717 GWh, approximately 28 percent of all net metered energy sold back in the United States (EIA 2020). The state's successful efforts to encourage clean DER development can be attributed to the state's net metering policy design. In 2009, the Massachusetts Department of Public Utilities (DPU) issued its model net metering tariff. DPU required all IOUs in the state to offer net metering and to ensure that the net metering tariffs are consistent across all participating utilities (MA DPU 2009).

In April 2016, state legislation increased the net metering aggregate capacity limits of a utility's peak load from four percent to seven percent for private facilities and from five percent to eight percent for government facilities (MA S.1979 2016). Massachusetts has a shared renewables billing policy, called neighborhood net metering, that allows customers to share the utility bill credits from renewable DER installations among multiple customers that share in the ownership interest in the facility (NREL 2016). Massachusetts adopted a new clean energy and climate policy in 2021 that requires the state to reach net-zero greenhouse gas emissions by 2050. It addresses several aspects of net metering, and provides new exemptions for net-metering caps for qualifying facilities (MA S.9 2021).

Massachusetts' interconnection standards apply to all forms of DERs, including renewables, and to all customers of the state's three IOUs: Unitil, Eversource, and National Grid. Both fossil-fuel and renewable-fuel CHP systems are eligible for standardized interconnection. However, only renewable-fuel CHP systems are eligible for net metering (NREL 2016).

Massachusetts Policies Encouraged High Levels of Net Metered Distributed Generation



- The state's net metering policy is open to a variety of renewable and other DER technologies.
- Massachusetts allows neighborhood net metering, a type of shared renewables policy that expands participation to those who may have been unable to afford the total upfront cost of a DER project.
- The state has a simplified, an expedited, or a standard interconnection process depending on the project size and technical complexity.
- State policies encourage renewable energy on brownfields and landfills, making Massachusetts a leader in renewable energy redeveloping these lands with over 125 sites with an estimated 330 MW of completed in Massachusetts.

Resources for more information:

- Massachusetts Net Metering Guide
- The Guide to Developing Solar

The state's complementary policies have encouraged clean energy expansion. For example, policies on redevelopment of brownfields and closed landfills support DER development. As a result of its robust programs and policies, Massachusetts leads the nation in siting solar projects on landfills and similar sites. The state accounts for roughly 30 percent of all such installations across the country (EPA 2020). In 2018, the

Massachusetts Department of Energy Resources established the Solar Massachusetts Renewable Target (SMART) incentive program under authority granted by the state legislature. The program began with an initial 1,600 MW competitive procurement of solar projects developed by residential, commercial, governmental, and industrial electricity customers throughout the state and expanded in 2020 with an additional 1,600 MW procurement (MA DOER n.d.). The SMART program is a tariff-based incentive paid by the utility company directly to the solar system owner connected to one of the three IOUs (MA DOER 2020).

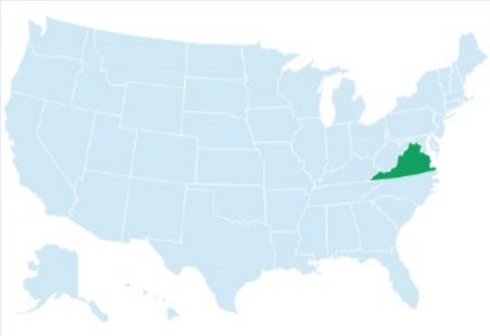
Virginia

The Virginia Clean Economy Act, adopted in 2020, expanded the state's net metering policy to further promote renewable DERs and advance energy equity (VA H.B. 1526 2020). This legislation increased the cap on facility-specific net metering and the total amount of renewable energy that can be net metered across a utility's service territory. The law also designates a portion of the allowed net metering quantity for low-income customers. The legislation specifies that the net metering rate is to be established in a standard contract or tariff and approved by the State Corporation Commission (SCC) (VA H.B. 1526 2020). Specifically, the new law amends the net energy metering program in the following ways:

- increasing the maximum capacity of renewable generation facilities of participating nonresidential eligible customer-generators from one to three MW
- increasing the cap on the capacity of generation from facilities from the customer's expected annual energy consumption to 150 percent of such amount
- increasing each utility's systemwide cap from one percent of its adjusted Virginia peak-load forecast for the previous year to six percent of such amount, five percent of which is available to all customers and one percent of which is available only to low-income utility customers

The Virginia legislature adopted complementary legislation in 2020 directing the SCC to establish a shared community solar program (VA H.B. 1634 2020). The shared solar programs bill required shared solar facility developers to designate at least 30 percent of capacity to serve low-income customers, and utilities to monitor and report the amount of capacity that has been allocated to low-income customers. The bill directed the SCC to establish a monthly minimum bill that would be applied to shared solar subscribers, and to exempt low-income customer participants from the minimum bill. To facilitate low-income customer and low-income service organization participation in the program, H.B. 1634 directed the SCC to initiate a stakeholder process that engages low-income community representatives and community solar providers (VA H.B. 1634 2020).

Virginia Clean Economy Act supports Equity in Net Metering



Virginia's Net Metering Program is an example of a state's legislature expanding net metering in a way that considers low-income utility customers. The expansion promotes equity by specifically designating one-sixth of net-metered projects to be available only to low-income utility customers.

For more information, refer to the following:

- Virginia Clean Economy Act
- Virginia Code §56-594 on net metering provisions
- SCC net metering information
- SCC shared solar programs and applicable rules, including multi-family shared solar program

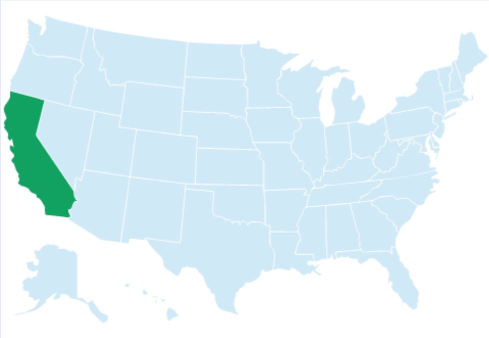
California

In 2020, California updated its long-established Electric Rule 21 that governs interconnection and operating requirements for generation facilities connected to the electricity grid, which had dated back to 1996. Rule 21 provides customers wanting to install generating or storage facilities on their premises with access to the electric grid while protecting the safety and reliability of the distribution and transmission systems at the local and system levels. Rule 21 governs Commission jurisdictional interconnections, which include the interconnection of all net energy metering facilities, non-export facilities, and qualifying facilities intending to sell power at avoided cost to the host utility. As a result of a 2012 settlement agreement, CPUC directed utilities to implement a Fast Track process in which all interconnection requests are screened by size and complexity, allowing smaller less complicated projects to continue through a streamlined review (CPUC n.d.).

The 2020 amendments to Electric Rule 21 updated the state interconnection and net metering policies as part of an ongoing rulemaking that began in 2017 (CPUC 2021c). The changes add grid flexibility to accommodate new technologies and allow for more data-driven decisions. Overall, the updates are designed to improve the efficiency, transparency, certainty, and clarity of the interconnection process (CPUC 2021c). Specific changes include the following:

- Study requirements for interconnections are more streamlined and efficient
- Battery storage interconnection is addressed, including standards for exporting stored electricity to the grid
- Bidirectional electric vehicle charging requirements are clarified (CPUC 2020).

California Improves Efficiency, Transparency, Certainty, and Clarity of the Interconnection Process



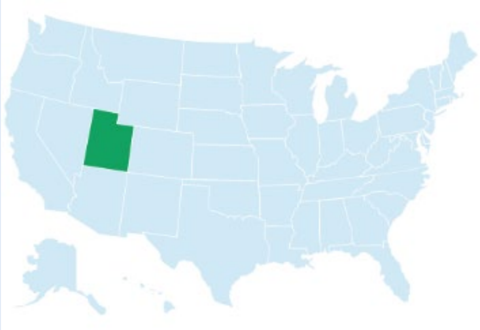
- Electric Rule 21 allows streamlined interconnection processes for small or simple electricity generation or storage projects.
- Although in existence for a few decades, Rule 21 is continuously undergoing updates to accommodate new technologies and policy goals.

For more information, refer to the California Public Utilities Commission Electric Rule 21 webpage.

Utah

Utah provides an example of a state that has replaced its net metering policy with an alternate rate design, an Export Credit Rate, which resulted in reduced compensation for exported power from rooftop solar systems. Through the 2010s, Utah Public Service Commission (PSC) required the state's IOU, Rocky Mountain Power, and cooperatively owned utilities serving more than 10,000 customers, to offer net metering to customers who generate electricity. The state required electric utilities to credit rooftop solar customers for excess power at full retail rates. In March of each year, excess kWh credits were applied to a utility low-income program at the avoided cost value (UT 2015). Utah saw rapid growth in solar penetration as a result of their net metering policy, falling costs for solar installations, and state and federal incentives. Utah statute authorized the Utah PSC to set a cap for the program, after which, the PSC could transition to an alternative compensation structure for new applications (UT PSC 2020).

Rate Revision in Utah



Utah restructured rooftop solar customer compensation by revising the rate paid to rooftop solar customers to a lower rate that is closer to wholesale prices. The lower rate resulted in fewer rooftop solar PV installations.

For more information, refer to the Application of Rocky Mountain Power to Establish Export Credits for Customer Generated Electricity.

In 2017, the Utah PSC approved a settlement stipulation between Rocky Mountain Power (RMP) and numerous other parties. The settlement ended net metering at retail rates, created a transitional program, and required the establishment of an export code, which paid a lower standard rate for each unit of energy exported to the grid. The PSC found the proposed approach to phasing out net metering for DER customers and replacing it with export credits "offers a compromise that all stakeholder groups generally believe to be acceptable, just, reasonable, and in the public interest" (UT PSC 2017). Following this decision, the PSC implemented a transitional value for the export credit rate and began an investigation into the costs and benefits of distributed solar. In 2020, the Utah PSC reviewed several proposals to determine the value of the export credit rate. The final rate approved by the PSC for excess power is an even lower, seasonal rate based on avoided cost principles that is closer to the wholesale electricity price (UT PSC 2020).[9]

[9] Utah's new export credit rate, which replaces net metering for customer generation, is 5.969 cents/kWh in summer rates and 5.639 cents/kWh in winter rates. These rates represent an avoided energy component of 2.439 cents/kWh in summer rates (June through September); 2.109 cents/kWh in winter rates (October through May); plus total avoided generation, transmission, and distribution capacity costs of 3.53 cents/kWh (UT PSC 2020). The framework that enables the PSC to determine how customers receive credits for DER is established in the Utah Code § 54-15-101 et seq. Title 54 (Public Utilities), Chapter 15 (Net Metering of Electricity), established in 2002 and last updated in 2016.

Information Resources

Research Reports and Other Net Metering Resources

Title/Description
National Academies of Sciences, Engineering, and Medicine, The Role of Net Metering in the Evolving Electricity System (forthcoming). This forthcoming study, which is mandated by Congress to be prepared for the Department of Energy, will examine net metering and alternative mechanisms, impacts on the electricity grid and consumers, and potential contributions of net metering to decarbonization, equity, and resiliency.
The National Conference of State Legislatures. State Net Metering Policies (2017). This report provides summary and detailed information about state net metering policies and programs.
National Regulatory Research Institute. Review of State Net Energy Metering and Successor Rate Designs (2019). This NRRI resource includes reviews of the regulatory status and changes to net metering, or DER program rate designs, from 2014 through mid-2018.
National Regulatory Research Institute. Review of State Net Energy Metering (2019). The appendix from this report, Summaries of Recent State Actions on Net Energy Metering Policies in Five Vertically Integrated and Five Restructured States, summarizes actions on net metering states across the United States such as rate design.
North Carolina's Clean Energy Technology Center. Database of State Incentives for Renewables and Efficiency (DSIRE). This database provides information on the state's regulatory policies and financial incentives that support clean energy, including net metering.
Regulatory Assistance Project. Designing Distributed Generation Tariffs Well: Fair Compensation in a Time of Transition. (2016). This paper outlines current tariffs, including net metering, and considerations for regulators as they weigh the benefits and costs of DERs for all stakeholders.

Federal Resources

Title/Description
Department of Energy. Solar Power in Your Community (2022). This guide provides case studies and approaches for local governments and stakeholders to increase access to and development of solar PV.
Environmental Protection Agency and National Renewable Energy Laboratory. Best Practices for Siting Solar Photovoltaics on Municipal Solid Waste Landfills (2013). This report addresses common technical challenges for siting solar PV on municipal solid waste (MSW) landfills, including considerations around interconnection and net metering.
Environmental Protection Agency. dCHPP (CHP Policies and Incentives Database). This database allows users to search for state-level or federal-level policies and incentives for combined heat and power, including interconnection standards and net metering policies.
Environmental Protection Agency. RE-Powering America's Land: Mapping and Screening Tools. This website provides tools for evaluating the renewable energy potential of current and formerly contaminated lands, landfills, and mine sites. It includes information about incentives, case studies of successful projects, and a Decision Tree tool for determining site suitability for solar or wind.
Environmental Protection Agency. The Combined Heat and Power Partnership (CHPP). This website provides information about a voluntary program that seeks to reduce the environmental impact of energy generation by promoting the use of CHP. The CHPP helps states identify opportunities for policy development to encourage efficiency through CHP and can provide additional assistance to help states implement standard interconnection.
National Renewable Energy Laboratory. An Overview of Distributed Energy Resource (DER) Interconnection: Current Practices and Emerging Solutions (2019). This report gives high-level and strategic-planning guidance on DER interconnection topics such as standards, processes, and technologies.
National Renewable Energy Laboratory. The Effect of State Policy Suites on the Development of Solar Markets (2014). This report examines the effectiveness of state policies in fostering successful solar PV markets and highlights the benefits of net metering and interconnection policies for achieving market growth.

National Standards Organizations

Title/Description
Institute of Electric and Electronic Engineers Standards Association. IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power (2018). The IEEE Standards Association has developed standards relevant to many of the technical aspects of interconnection. In particular, Standard 1547 provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of interconnection.
Underwriters Laboratories Standards. UL 1741: Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources (2010). UL develops standards for interconnecting DERs. UL 1741 combines product safety requirements with the utility interconnection requirements developed in the IEEE 1547 standard to provide a testing standard to evaluate and certify DER products.

Examples of Interconnection Standards

Title/Description
Department of Energy, State and Local Energy Efficiency Action Network. The Guide to the Successful Implementation of State Combined Heat and Power Policies (2013). This guide provides actionable information to assist state utility regulators and policymakers in implementing key state policies that impact CHP. It discusses five policy categories, including state approaches to interconnection standards for CHP.
Department of Energy. Connecting to the Grid: A Guide to Distributed Generation Interconnection Issues (2009). This guide provides a model stakeholders can use to develop state-level interconnection standards.
Interstate Renewable Energy Council. Regulatory Engagement. IREC has prepared Model Interconnection Procedures (2019) and various DER guidelines for policymakers.

References

AEE. 2018. "Distribution System Planning: Proactively Planning for More Distributed Assets at the Grid Edge." Advanced Energy Economy. https://info.aee.net/hubfs/Distribution%20System%20Planning%20FINAL%20-%2007-03-2018.pdf.

APPA, EEI, NARUC, and NRECA. 2021. "PURPA Title II Compliance Manual 2.0." American Public Power Association, Edison Electric Institute, National Association of Regulatory Utility Commissioners, and National Rural Electric Cooperative Association. https://pubs.naruc.org/pub/47AD30DC-1866-DAAC-99FB-975A60906D6B.

APS. 2017. "Resource Comparison Proxy Plan of Administration, Arizona Corporation Commission Dockets No. E-01345A-16-0036 and E-01345A-16-0123." Arizona Public Service Commission. https://images.edocket.azcc.gov/docketpdf/0000182181.pdf.

AZCC. 2017. "Opinion and Order: Decision No. 26295 (Docket No. E-01345A-16-0036 In the Matter of The Application of Arizona Public Service Company for a Hearing to Determine the Fair Value of the Utility Property of the Company for Ratemaking Purposes, to Fix a Just and Reasonable Rate of Return Thereon, to Approve Rate Schedules Designed to Develop Such Return, and Docket No. E-01345A-16-0123 In the Matter of Fuel and Purchased Power Procurement Audits for Arizona Public Service Company)." Arizona Corporation Commission. https://docket.images.azcc.gov/0000182160.pdf?i=1642797977461.

CAISO. 2016. "What the Duck Curve Tells Us about Managing a Green Grid." California Independent System Operator. https://www.caiso.com/documents/flexibleresourceshelprenewables_fastfacts.pdf.

CLICC. 2021. "Reply Brief of the California Low-Income Consumer Coalition, CPUC Order Instituting Rulemaking to Revisit Net Energy Metering Tariffs Pursuant to Decision 16-01-044, and to Address Other Issues Related to Net Energy Metering." California Low-Income Consumer Coalition. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M407/K765/407765393.PDF.

CPUC. 2020. "Resolution E-5165. Approval, with Modifications, of Vehicle-to-Grid Implementation Plans and Technical Requirements in Compliance with Decision 20-09-035." California Public Utilities Commission. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M411/K454/411454854.PDF#:~:text=In%20Decision%2020-09-035%2Cathe%20California%20Public%20Utilitiespathway.Commission%20%28CPUC%29%20adopted,pilots%2C%20temporarily%2C%20from%20Rule%2021%20smart%20inverter%20requirements.

———. 2021a. "Utility Costs and Affordability of the Grid of the Future an Evaluation Of Electric Costs, Rates and Equity Issues Pursuant To P.U. Code Section 913.1." California Public Utilities Commission. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2021/senate-bill-695-report-2021-and-en-banc-whitepaper_final_04302021.pdf.

———. 2021b. "Draft Distributed Energy Resources Action Plan, Aligning Vision and Action." California Public Utilities Commission. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/distributed-energy-resources-action-plan/draft-der-action-plan-20-public.pdf.

———. 2021c. "Order Instituting Rulemaking to Consider Streamlining Interconnection of Distributed Energy Resources and Improvements to Rule 21 (Proceeding R1707007)." California Public Utilities Commission. December 15, 2021. https://apps.cpuc.ca.gov/apex/f?p=401:56:0::NO:RP,57,RIR:P5_PROCEEDING_SELECT:R1707007.

———. n.d. "Rule 21 Interconnection." California Public Utilities Commission. Accessed January 21, 2022. https://www.cpuc.ca.gov/Rule21/.

DOE. 2016. "Advanced Metering Infrastructure and Customer Systems." U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/12/f34/AMI%20Summary%20Report_09-26-16.pdf.

———. n.d. "Public Utility Regulatory Policies Act of 1978 (PURPA)." U.S. Department of Energy, Office of Electricity. Accessed January 24, 2022. https://www.energy.gov/oe/services/electricity-policy-coordination-and-implementation/other-regulatory-efforts/public.

EIA. 2020. "Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files." U.S. Energy Information Administration. https://www.eia.gov/electricity/data/eia861/.

———. 2021a. "Electric Power Monthly, Table 6.2.B. Net Summer Capacity Using Primarily Renewable Energy Sources and by State, June 2021 and 2020 (Megawatts)." U.S. Energy Information Administration. https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_02_b.

———. 2021b. "Electric Power Annual 2020: Table 4.3. Existing Capacity by Energy Source, 2020 (Megawatts)." U.S. Energy Information Administration. https://www.eia.gov/electricity/annual/html/epa_04_03.html.

EPA. 2018. "Quantifying the Multiple Benefits of Energy Efficiency and Renewable Energy: A Guide for State and Local Governments." U.S. Environmental Protection Agency. https://www.epa.gov/statelocalenergy/quantifying-multiple-benefits-energy-efficiency-and-renewable-energy-guide-state.

———. 2020. "RE-Powering America's Land Initiative: Project Tracking Matrix." U.S. Environmental Protection Agency. https://www.epa.gov/sites/default/files/2020-10/documents/repowering_tracking_matrix_october_2020_508.pdf.

EPRI. n.d. "Distribution Resource Integration and Value Estimation (DRIVE)." Electric Power Research Institute. Accessed January 24, 2021. https://www.epri.com/pages/sa/drive.

FERC. 2018. "An Overview of the Federal Energy Regulatory Commission and Federal Regulation of Public Utilities." Federal Energy Regulatory Commission. https://ferc.gov/sites/default/files/2020-07/ferc101.pdf.

———. 2020a. "Order Dismissing Petition for Declaratory Order Re New England Ratepayers Association under EL20-42. Commissioner McNamee Is Concurring with a Separate Statement Attached."

https://www.ferc.gov/sites/default/files/2020-07/07-2020-E-2.pdf.

———. 2020b. "Petition for Declaratory Order of New England Ratepayers Association under EL20-42." Federal Energy Regulatory Commission. https://elibrary.ferc.gov/eLibrary/docinfo?document_id=14851599.

———. 2020c. "Standard Interconnection Agreements and Procedures for Small Generators." Federal Energy Regulatory Commission. August 20, 2020. https://www.ferc.gov/industries-data/electric/electric-transmission/generator-interconnection/standard-interconnection.

———. 2020d. "FERC Affirms, Clarifies PURPA Final Rule." Federal Energy Regulatory Commission. November 19, 2020. https://www.ferc.gov/news-events/news/ferc-affirms-clarifies-purpa-final-rule.

———. 2020e. "Item E-2: Commissioner Richard Glick Dissent in Part Regarding Qualifying Facility Rates and Requirements (Order No 872-A)." Federal Energy Regulatory Commission. https://www.ferc.gov/news-events/news/item-e-2-commissioner-richard-glick-dissent-part-regarding-qualifying-facility.

———. 2020f. "Order No 872-A, Final Rule; Order Addressing Arguments Raised on Rehearing and Clarifying Prior Order in Part." Federal Energy Regulatory Commission. https://www.ferc.gov/media/order-no-872.

FERC 132. 2010. "Order on Petitions for Declaratory Order, Docket Nos. EL10-64-000 and EL10-66-000." Federal Energy Regulatory Commission. https://www.dwt.com/files/Uploads/Documents/Advisories/10-10_CAISO_0715.pdf.

FERC 842. 2018. "FERC Order No. 842, Essential Reliability Services and the Evolving Bulk-Power System-Primary Frequency Response." Federal Energy Regulatory Commission. https://www.ferc.gov/sites/default/files/2020-06/Order-842.pdf.

FL PSC. 2021. "Florida PSC Approves Duke's Clean Energy Connection Program." State of Florida Public Service Commission. January 5, 2021. http://www.psc.state.fl.us/Home/NewsLink?id=11905.

GTM. 2017a. "Rooftop Solar in Oahu Crashes With Loss of Net Metering, Lack of Self-Supply Installs." *Greentech Media*, February 7, 2017. https://www.greentechmedia.com/articles/read/rooftop-solar-in-hawaii-crashes-with-loss-of-net-metering-lack-self-supply.

———. 2017b. "Nevada's New Solar Law Is About Much More Than Net Metering." *Greentech Media*, June 16, 2017. https://www.greentechmedia.com/articles/read/nevadas-new-solar-law-is-about-much-more-than-net-metering.

———. 2019. "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.

Hawaiian Electric. n.d. "Customer Renewable Programs: Smart Export." Hawaiian Electric Company. Accessed January 20, 2022. https://www.hawaiianelectric.com/products-and-services/customer-renewable-programs/private-rooftop-solar/smart-export.

HodgsonRuss. 2021. "Aimed at Improving Fairness in Cost Allocation and Reducing Barriers to New Renewable Generation, the Public Service Commission Approves a New Interconnection Cost-Sharing Mechanism." HodgsonRuss Attorneys. August 2, 2021. https://www.hodgsonruss.com/newsroom-publications-13422.html.

ICF. 2016. "Integrated Distribution Planning." ICF International. https://www.energy.gov/sites/prod/files/2016/09/f33/DOE%20MPUC%20Integrated%20Distribution%20Planning%208312016.pdf.

———. 2018. "Review of Recent Cost-Benefit Studies Related to Net Metering and Distributed Solar." ICF International. https://www.energy.gov/sites/prod/files/2020/06/f75/ICF%20NEM%20Meta%20Analysis_Formatted%20FINAL_Revised%208-27-18.pdf.

IL CUB. 2020. "ICC Sides with CUB, Ameren's Net Metering Credits Continue." Citizens Utility Board of Illinois. December 18, 2020. https://www.citizensutilityboard.org/blog/2020/12/18/icc-sides-with-cubamerens-net-metering-credits-continue/.

IREC. 2018. "The Evolution of Hosting Capacity Analysis as a Grid Modernization Tool." Interstate Renewable Energy Council. https://irecusa.org/blog/regulatory-engagement/the-evolution-of-hosting-capacity-analysis-as-a-grid-modernization-tool/.

———. 2019. "What Grid Transparency Looks Like." Interstate Renewable Energy Council. August 20, 2019. https://irecusa.org/blog/regulatory-engagement/what-grid-transparency-looks-like/.

———. 2020. "Steps to Success: A Decision Making Framework for Implementing Hosting Capacity Analyses (HCA), Interstate Renewable Energy Council. Filed with the Colorado Public Utilities Commission under Proceeding Number 19M-0670E Distribution System Planning." Presented at the Colorado Public Utilities Commission, May 22. https://www.dora.state.co.us/pls/efi/efi.show_document?p_dms_document_id=926851&p_session_id=.

Kavlak, G., J. McNerneya, and J. Trancik. 2018. "Evaluating the Causes of Cost Reduction in Photovoltaic Modules." *Energy Policy* 123 (December): 700–710. https://doi.org/10.1016/j.enpol.2018.08.015

LBNL. 2017. "Putting the Potential Rate Impacts of Distributed Solar into Context." LBNL-1007060. Lawrence Berkeley National Laboratory. https://emp.lbl.gov/publications/putting-potential-rate-impacts/.

Low-Income Solar. 2018. "Community Solar: Colorado." Low-Income Solar Policy Guide. May 2018. https://www.lowincomesolar.org/best-practices/community-solar-colorado/.

MA DOER. 2020. "Solar Massachusetts Renewable Target (SMART) Program." Massachusetts Department of Energy Resources, 225 CMR 20.20. 2020. https://www.mass.gov/regulations/225-CMR-2000-solar-massachusetts-renewable-target-smart-program.

———. n.d. "Solar Massachusetts Renewable Target (SMART)." Massachusetts Department of Energy Resources. Accessed April 2, 2022. https://www.mass.gov/solar-massachusetts-renewable-target-smart.

MA DPU. 2009. "Order Adopting Model Net Metering Tariff, DPU 09-03-A (8/20/2009)." Massachusetts Department of Public Utilities. https://fileservice.eea.comacloud.net/FileService.Api/file/FileRoom/9289179.

MA S.9. 2021. *Bill S.9, An Act Creating a next-Generation Roadmap for Massachusetts Climate Policy*. https://malegislature.gov/Bills/192/S9.

MA S.1979. 2016. *An Act Providing for the Establishment of a Comprehensive Adaptation Management Plan in Response to Climate Change*. https://malegislature.gov/Bills/189/S1979.pdf.

Maninder, P.S., C. Tessum, I. Azevido, and J. Marshall. 2019. "Fine Particulate Air Pollution from Electricity Generation in the US: Health Impacts by Race, Income, and Geography." *Environmental Science & Technology* 53 (23): 14010–19. https://doi.org/10.1021/acs.est.9b02527.

ME PUC. 2015. "Maine Distributed Solar Valuation Study." Maine Public Utilities Commission. https://www.nrcm.org/wp-content/uploads/2015/03/MPUCValueofSolarReport.pdf.

MN PUC. 2018. "Order Establishing Updated Interconnection Process and Standard Interconnection Agreement. In the Matter of Updating the Generic Standards for the Interconnection and Operation of Distributed Generation Facilities Established Under Minn. Stat. § 216B.1611. Docket No. E-999/CI-01-1023 and Docket No. E-999/CI-16-521." Minnesota Public Utilities Commission. https://mn.gov/puc/edockets/

NARUC. 2021. "State Approaches to Intervenor Compensation." National Association of Regulatory Utility Commissioners. https://pubs.naruc.org/pub/B0D6B1D8-1866-DAAC-99FB-0923FA35ED1E.

National Academies of Sciences, Engineering, and Medicine. 2022. "The Role of Net Metering in the Evolving Electricity System." National Academies of Science, Engineering, and Medicine. 2022. https://www.nationalacademies.org/our-work/the-role-of-net-metering-in-the-evolving-electricity-system#sectionWebFriendly.

National Grid. n.d. "Rhode Island System Data Portal." National Grid. Accessed January 19, 2022. https://www.nationalgridus.com/Business-Partners/RI-System-Portal.

NCCETC. 2021. "The 50 States of Solar: Net Metering Reforms Lead Solar Policy Activity in 2020." NC Clean Energy Technology Center. January 27, 2021. https://nccleantech.ncsu.edu/2021/01/27/the-50-states-of-solar-net-metering-reforms-lead-solar-policy-activity-in-2020/.

NCSL. 2017. "State Net Metering Policies." National Conference of State Legislatures. https://www.ncsl.org/research/energy/net-metering-policy-overview-and-state-legislative-updates.aspx.

NCSL and NASEO. 2017. "Here Comes the Sun: A State Policy Handbook for Distributed Solar Energy." National Conference of State Legislatures and National Association of State Energy Officials. https://naseo.org/data/sites/1/documents/publications/Here%20Comes%20the%20Sun%20Handbook%20July%202017.pdf.

NESP. 2020. "National Standard Practice Manual For Benefit-Cost Analysis of Distributed Energy Resources." National Energy Screening Project. https://www.nationalenergyscreeningproject.org/wp-content/uploads/2020/08/NSPM-DERs_08-24-2020.pdf.

NREL. 2016. "Midmarket Solar Policies in the United States: A Guide for Midsized Solar Customers." NREL/TP-6A20-66905. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy16osti/66905.pdf.

———. 2018a. "Ten Years of Analyzing the Duck Chart: How an NREL Discovery in 2008 Is Helping Enable More Solar on the Grid Today." National Renewable Energy Laboratory. February 26, 2018. https://www.nrel.gov/news/program/2018/10-years-duck-curve.html.

———. 2018b. "The Cost of Distribution System Upgrades to Accommodate Increasing Penetrations of Distributed Photovoltaic Systems on Real Feeders in the United States." NREL/TP-6A20-70710. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy18osti/70710.pdf.

———. 2021a. "U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1 2020." NREL/TP-6A20-77324. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy21osti/77324.pdf.

———. 2021b. "Sharing the Sun: Community Solar Deployment, Subscription Savings, and Energy Burden Reduction." NREL/PR-6A20-80246. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy21osti/80246.pdf.

———. 2021c. "Fall 2021 Solar Industry Update NREL/PR-7A40-81325." National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy22osti/81325.pdf.

NRRI. 2019. "Review of State Net Energy Metering and Successor Rate Designs." National Regulatory Research Institute. https://pubs.naruc.org/pub/A107102C-92E5-776D-4114-9148841DE66B.

RAP. 2021. "Health Benefits by the Kilowatt-Hour: Using EPA Data to Analyze the Cost-Effectiveness of Efficiency and Renewables." Regulatory Assistance Project. https://www.raponline.org/wp-content/uploads/2021/09/rap-seidman-shenot-lazar-health-benefits-by-kilowatt-hour-2021-september.pdf.

SEIA. 2021. "Arizona Solar, Data Current Through: Q4 2021." 2021. https://www.seia.org/state-solar-policy/arizona-solar.

Synapse, RAP, and Community Action. 2020. "Energy Infrastructure: Sources of Inequities and Policy Solutions for Improving Community Health and Wellbeing." Synapse Energy Economics, Regulatory Assistance Project, and Community Action Partnership. https://www.synapse-energy.com/sites/default/files/Equity-in-Energy-Report-19-037-0.pdf.

UT. 2015. *Utah Code §54-15-104(4)*. https://le.utah.gov/xcode/Title54/Chapter15/54-15-S104.html.

UT PSC. 2017. "Order Approving Settlement Stipulation, Docket No. 14-035-114 (Investigation of the Costs and Benefits of PacifiCorp's Net Metering Program)." Public Service Commission of Utah. https://pscdocs.utah.gov/electric/14docs/14035114/29703614035114oass9-29-2017.pdf.

———. 2020. "Order, Docket No. 17-035-61, Application of Rocky Mountain Power to Establish Export Credits for Customer Generated Electricity." Public Service Commission of Utah. https://pscdocs.utah.gov/electric/17docs/1703561/3161911703561o10-30-2020.pdf.

Utility Dive. 2018. "How Two Value-of-Solar Studies Add up to No Clear Value of Solar." Utility Dive. May 10, 2018. https://www.utilitydive.com/news/how-two-value-of-solar-studies-add-up-to-no-clear-value-of-solar/522892/#:~:text=An%20April%2010%20draft%20study,kWh%20and%20about%20%240.41%2FkWh.

VA H.B. 1526. 2020. *Virginia Clean Economy Act*. https://lis.virginia.gov/cgi-bin/legp604.exe?201+sum+HB1526.

VA H.B. 1634. 2020. *Shared Solar Programs*. https://lis.virginia.gov/cgi-bin/legp604.exe?201+sum+HB1634.

Verdant. 2021. "Net-Energy Metering 2.0 Lookback Study." Verdant Associates. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/net-energy-metering-nem/nemrevisit/nem-2_lookback_study.pdf.

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