EPA

State and Local Climate and Energy Program

State Energy and Environment Guide to Action:
Maximizing Grid Investments

2022

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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

> Many modern grid investments can support a state's environmental, clean energy, and climate goals. A range of emerging grid technologies, management strategies, and new and enhanced planning paradigms can support greater energy efficiency, renewable energy, and flexible resource integration.

Policies that modernize the electric distribution system[1] are critical to accelerate clean energy adoption and realize its benefits. State policymakers, electric utility regulators (often called public utility commissions or PUCs), and utilities are making progress toward goals for affordability, resilience, energy efficiency, and renewable energy through interrelated technology investments, grid management strategies, and planning approaches. This chapter provides state policymakers, regulators, and stakeholders with technical background and examples of established, near-term opportunities for grid investments that support a modern electric distribution system, such as the deployment of clean and distributed energy resources (DERs). DERs are customer-side electric generation, demand response, energy efficiency, or energy storage systems located on the distribution grid, typically close to load, used individually or aggregated to provide more value. This chapter highlights three strategies for states to maximize grid investments:

- Distribution system efficiency. Policies and technologies that reduce energy loss and increase efficiency in the electricity distribution system can meet demand increases and defer or negate larger capital investments. Electricity delivered over long distances is accompanied by energy losses due to factors such as infrastructure condition, ambient temperature, conductor temperature (influenced by load), and weather. These "line losses" can be mitigated by voltage management or asset management practices ranging from engineering adjustments (e.g., voltage optimization and conservation voltage reduction, or CVR) to accelerated replacements (e.g., efficient distribution transformers).
- Clean energy integration. Technologies, planning approaches, and grid management practices can increase grid flexibility and support grid integration of intermittent renewables and DERs. Strategies to integrate the growth of intermittent sources and DERs include the use of advanced metering infrastructure (AMI), inverter systems, demand response and storage deployment, and participation in energy supply markets or a larger regional transmission grid organization.
- Enhanced grid planning. Comprehensive electricity planning approaches and tools can inform strategic grid investment decisions, which may last for 15 to 50 years, so they align with state policy priorities around affordability, reliability, resilience, and clean energy. Examples of these approaches and tools include assessments of timing and locational value of energy efficiency savings, consideration of non-wires alternatives (NWAs, sometimes called non-wire solutions or NWS), hosting capacity analysis (HCA), and integrated distribution system planning (IDSP). These approaches can support investment decisions that improve equitable outcomes for customers and service reliability. For example, decisionmakers can weigh the locational value of a distribution system upgrade(s), which can change over time, with data on how the upgrade would improve resilience or affordability for the low-income households it would serve.

[1] This chapter is focused on the distribution system, which is directly affected by state actions and state utility regulators. The transmission system and some federal policies are discussed to provide context. Many of the engineering principles and technologies presented in the chapter are relevant and applicable to both the transmission and distribution systems.

This chapter reviews each of the above grid investment strategies, provides detailed examples, and identifies the benefits they provide.[2] This chapter also identifies the action steps states can take to achieve these benefits, and highlights complementary resources such as those available from the joint National Association of Regulatory Utility Commissioners (NARUC) and the National Association of State Energy Officials (NASEO) Task Force on Comprehensive Electricity Planning (NARUC & NASEO n.d.). Lastly, this chapter describes examples of how these strategies have been employed in Connecticut, New York, Michigan, and the Pacific Northwest.

The following are several examples of action steps states are using to inform grid modernization investments:

- *Investigate grid modernization needs and opportunities.* Understanding the perspectives of multiple stakeholders become increasingly important as grid modernization efforts mature and DERs become more widely adopted. States can convene a stakeholder process and consider the proceedings of leading states to understand emerging issues. States that have already gained operational knowledge with modern grid deployments can review the role of existing utility policies in either inhibiting or encouraging optimizing grid investments to achieve energy efficiency or enhance integration of distributed renewables (e.g., revenue decoupling and performance-based regulation).
- *Assess and pursue opportunities for distribution system efficiency and clean energy integration.* Distribution system efficiency has not always been included in energy efficiency potential studies. States can consider including it in efficiency potential studies and/or consider allowing distribution system efficiency to count toward mandatory or voluntary energy efficiency standards. Other ways states accommodate and leverage the value of DERs on the grid include using inverters to support voltage and reactive power management and complementary deployment of demand response[3] and storage assets when making grid modernization investments.
- *Adopt new or enhanced grid planning.* States can direct utilities to use several interrelated analyses and grid planning paradigms to help better inform the value of DERs to the distribution system.
- *Implement Expeditious Deployment Programs.* Pilot studies, and similar programs such as regulatory sandboxes, can help utilities gain operational knowledge and understand costs and benefits prior to broader implementation. For many technologies, the development of best management practices is needed to help unlock their full potential. These programs can provide utilities and their third party partners the opportunity to improve grid performance or solve problems with new solutions with fewer administrative restrictions.

Benefits

Maximizing modern grid investments to increase distribution system efficiency and support renewable generation integration and clean energy deployment can improve energy efficiency, reduce air pollution including greenhouse gas (GHG) emissions, improve system reliability, and provide economic and environmental benefits to communities including those with environmental justice concerns. This section summarizes many of the benefits and identifies tools to quantify and communicate the benefits. Subsequent

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[2] This chapter does not attempt to cover the wide range of state actions to promote customer DER adoption, such as policies and programs on electricity rate design, community solar and storage, electric vehicles, and energy efficiency. Many state policy best practices on these topics are discussed in other chapters of the *Guide*.

[3] Demand response is a program that uses time-varying rates, financial incentives, or other customer feedback or interactive technology to enable participating customers to reduce their electricity usage during peak periods to help utilities balance grid supply and demand during those times (LBNL n.d.).

sections in this chapter, including Technical Background on Key Opportunities, provide additional details about specific grid strategies.

Electricity System Benefits

Modern grid technology investments, grid management strategies, and planning and communications approaches can provide a range of electricity system benefits. These include reduced fuel inputs and related operating costs, reduced energy consumption on the customer-side of the meter, enhanced system reliability and flexibility, reduced outage response time, reduced renewable energy curtailments,[4] and greater system transparency for utility and customer decision-making. Modeling of distribution-level impacts has demonstrated that smart grid[5] technology deployments can provide both direct benefits, such as energy savings from distribution system efficiency opportunities, and indirect benefits by enabling clean energy integration (e.g., demand response or distributed wind and solar generation) (PNNL 2012a).

Grid investments in distribution system efficiency can result in energy savings for the utility and customers. Utilities participating in smart grid demonstration projects involving voltage and power optimization and CVR have saved energy and reduced peak power in the range of one to four percent of delivered energy (Short 2016; DOE 2015). For example, the utility AEP Ohio documented results of two to four percent reduction in both energy and demand, and three percent reduction in peak load (DOE 2015).

Grid investments that increase transmission and distribution system efficiency, support strategically located renewable resources, and enable demand response capabilities can help reduce peak load and alleviate grid congestion. This also benefits ratepayers by reducing a utility's capacity costs or need to upgrade distribution systems by, for example, delaying or negating the need for investment in new generation infrastructure (NARUC 2016). For example, grid investments can enable greater integration of renewable energy resources and deploy complementary resources such as storage or demand response during periods when renewable resources wane (e.g., when solar production is interrupted due to cloud cover). The flexibility of energy storage can reduce the need to dispatch more expensive and often higher polluting conventional generation resources that often need advanced notice to come online.

Environmental Benefits

Grid investments that produce electricity system benefits can, in turn, result in environmental benefits including reduced air emissions if less electricity is generated from fossil fuels. Through reduced electricity losses, increased system efficiencies, decreased use of fossil-fired peaking units, and increased renewable energy on the grid, states can decrease fossil fuel combustion for power generation. Renewable energy produces no GHG emissions from fossil fuels and reduces some types of air pollution (EPA n.d.). A national laboratory study estimated that grid investments to manage distribution system voltage could reduce carbon dioxide emissions by more than 63 million tons, based on annual energy savings of approximately three percent (PNNL 2012b).

Equity Benefits

Investments to modernize the grid can help advance equity by providing social, environmental, and economic benefits to historically marginalized communities. Minority, low-income, and indigenous populations

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[4] Curtailment is the intentional reduction of power generation or load. It is commonly associated with an oversupply attributable to intermittent wind and solar power, when more electricity is available to the grid from generators than needed to serve customer demand (NREL 2022). It can also be associated with demand-response. A utility can send a load curtailment request to customers to help maintain grid balance during peak periods (BPA 2018).

[5] A "smart" grid is capable of two-way communication between the utility and its customers and incorporates sensors and control systems to detect and respond to grid needs, including changing electricity demand, power quality, and equipment failures.

frequently bear a disproportionate burden of environmental harms and adverse health outcomes, including from power plants operating near their communities (EPA 2022b). Grid investments that reduce or shift peak demand can reduce the need for fossil-fired peaking plants near these communities (PEAK 2020). NWAs, for example, can improve equity in the power system by reducing environmental and health risks, decreasing the cost of the energy, or providing backup power during outages (Tarekegne et al. 2021). Community-owned storage in particular is promising for equitable distribution of benefits (PNNL 2021a). Some grid investments, such as voltage optimization and CVR, reduce the financial burden of electricity bills for low-income customers because most of the electricity savings from these strategies occur as end-use efficiency gains on the customer side. The resulting energy efficiency can help to reduce customer energy burdens and enhance household and community resilience. Energy efficiency is an important tool to support equity in electricity bill impacts (refer to the Energy Efficiency Programs and Resource Standards chapter of the *Guide*).

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 DERs, 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 benefit-cost 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 DERs.
- **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 benefits and comprehensively assess the value of energy policy and program choices.

Quantifying and Communicating the Benefits

Many of the grid investment strategies in this chapter are intended to increase the deployment of DERs and other clean energy resources. To help states and stakeholders analyze and quantify the impacts of clean energy resources, EPA has a range of tools highlighted in the text box. For example, EPA's AVoided Emissions and geneRation Tool (AVERT) allows users to quantify the emissions benefits and energy savings related to energy efficiency programs, such as grid improvements (EPA 2020). 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 and easily 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.

Understanding the benefits and how to quantify those benefits enables stakeholders to develop, implement, and justify programs and policies like modern grid management strategies and technologies, and investments that enable greater integration of energy efficiency, renewable energy, demand response, and storage. For jurisdictions that consider or account for health benefits 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 of demand reduction from increased clean DER deployment. 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). Also, EPA's ENERGY STAR program supports state and local governments in communicating the value streams of efficiency under three pillars: enabler of growth, mitigator of risk, and protector of the public good, and offers resources to harness the power of storytelling (EPA n.d.). The following sections, which describe in detail each of three key grid modernization opportunities, list additional benefits specific to each opportunity.

Technical Background on Key Opportunities

Modern grid investments can enable better visibility into grid conditions throughout the distribution system, allow two-way communication between the utility and customers or their devices, and permit automation to respond to grid conditions in real time. However, no single technology or combination of technologies delivers modern grid benefits automatically. How technologies and grid assets are managed is critical to achieving the promise of a modern grid. This section provides a technical overview and discusses three approaches to grid modernization that states are using to realize the benefits of clean energy, and highlights tools for a modern grid (refer to the text box).

Tools for a Modern Grid

No single technology or combination of technologies delivers modern grid benefits. How technologies and grid assets are managed is critical to achieving the promise of a modern grid. The following are some of the tools grid operators use to monitor, evaluate, and respond to grid connections in real time.

System controls include *load tap changers*, which are installed on transformers and raise or lower voltage at the beginning of the feeder; *voltage regulators*, which are installed on substations or feeders, and raise or lower downstream voltage; and *capacitor banks*, which are installed at the substation or feeder, and manage reactive power and voltage. *Control packages* are installed on capacitor banks and voltage regulators and programmed to turn on and off based on system conditions or via remote signal.

Monitoring devices include *voltage sensors* on distribution lines, *synchrophasers* on transmission systems for synchronized measurement of voltages, and (increasingly) *AMI meters* for voltage reaching consumer premises.

Communications and automation are enabled by *distribution management systems* that (1) receive information from multiple utility information systems (e.g., supervisory control and data acquisition (SCADA) systems that monitor and control distributions systems and information systems that collect and store AMI data) and (2) analyze the data (online or offline) to determine how to optimize the distribution system and send control signals. An *advanced distribution management system (ADMS)* is a software platform that facilitates communication and automation to integrate DERs, improve resilience and reliability, and optimize grid performance. A *distributed energy resource management system (DERMS)* is a complementary tool originally developed by the National Renewable Energy Laboratory (NREL) that can provide greater control in managing peak loads by forecasting, aggregating, and dispatching DERs. DERMS and ADMS are increasingly important as distribution systems become more sophisticated in operations and DER integration.

Sources:

- **DOE Smart Grid Investment Program, Application of Automated Controls for Voltage and Reactive Power Management – Initial Results**
- **NREL Advanced Power Electronics and Smart Inverters**
- **NREL Renewable Energy Integration**
- **NREL Advanced Distribution Management**
- **IEEE Smart Grid – Grid Management System**

Distribution System Efficiency Opportunities

The U.S. Energy Information Administration estimates that on average 5 percent of the electricity produced to serve customers is lost in transmission and distribution (EIA 2021). When accounting for both the electricity that did not need to be delivered and the resultant improved efficiency of delivering electricity, the total savings (i.e., reduction in total line losses) from high DER penetration during peak demand can be as high as 15 to 20 percent of the energy value (IREC 2013). Voltages in the transmission and distribution system can be adjusted to reduce system losses and/or to reduce customer load level to manage peak demand or to achieve broader energy efficiency benefits. Customer meter data also can be used strategically by grid operators, energy efficiency program managers, and customers to reduce consumption. This section describes energy efficiency opportunities in the distribution system.

Improved voltage management. Electricity must be delivered to most customers within a defined range of voltages. For example, residential customer voltage is typically between 114 and 126 volts (for normal 120-volt service).[6] Because some electrical equipment consumes less energy when operated at the lower end of the acceptable voltage range, delivering electricity closer to the lower end of this range can save energy in homes and buildings by increasing the efficiency of customer appliances and devices (IET Smart Grid 2020). Operating the distribution system at lower voltages to achieve energy efficiency benefits has historically been referred to as CVR. Factors such as equipment type and local distribution system conditions affect the actual energy-saving potential of CVR.

While CVR is a mature approach and can be deployed without advanced technology, modern grid technologies enable a better understanding of the exact voltage at different points in the transmission and distribution system and increases operational confidence among grid managers and regulators. Rapid communication with controls, as well as the ability to automatically respond to grid conditions, offers the potential for greater energy savings.

CVR reduces peak loads and total annual energy use. While performance can vary by distribution feeder, climate zone, load type and other factors, modeling results found that CVR reduces peak load and total annual energy use by one half to four percent. Extrapolation of those results in a simulation of nationwide deployment demonstrated that CVR could provide a three percent reduction in annual energy consumption for electric power generation (PNNL 2010). Research from utility pilot projects and modeling of voltage optimization and CVR found that 90 to 95 percent of the electricity savings come from end-use equipment efficiency improvements on the customer side.

The 2016 Illinois Future Energy Jobs Act (IL S.B. 2814 2016), required utilities to create a voltage optimization plan. The Illinois utility Ameren's 2018 plan includes implementation at feeders in ZIP Codes that include 20 communities where over 50 percent of households are low-income. Although details on low-income household energy savings were not reported, the cumulative persisting annual energy savings of Ameren's voltage optimization plan is projected to be 1.5 percent in 2025 (Ameren 2018).

Improved reactive power management. In alternating current (AC) systems—almost universally used in the United States to deliver electricity—current and voltage can get out of phase from equipment like motors and other devices that require magnetic fields to operate.[7] This is referred to as *reactive power*. Since motors are ubiquitous in equipment found in factories, businesses, and homes, transmission and distribution system

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[6] ANSI C84.1, "Electric Power Systems and Equipment—Voltage Ratings (60 Hertz)," specifies the nominal voltage ratings and operating tolerances for 60-hertz electric power systems above 100 volts.

[7] Most devices that need magnetic fields will cause current and voltage to be out of phase. Besides motors, this will include some of the equipment used in transmission and distribution systems, such as transformers.

operators need to provide reactive power to maintain electric power flow. Some of the same technologies and strategies used to adjust system voltage can be used to better manage reactive power. Like voltage management, reactive power can be managed without modern grid technologies; however, modern grid technologies allow utilities to better monitor voltage and reactive power in real time along the entire delivery path from generator through transmission and distribution to the ultimate customers. Better communications and control equipment allows operators to adjust settings to control both factors all along the delivery path. This is a big improvement over adjusting settings manually and at infrequent intervals. Better reactive power management can reduce the fuel needed to operate the grid and can improve power quality.

Volt/var optimization. When utilities manage and optimize both voltage and reactive power simultaneously, it is referred to as volt/var optimization.[8] Since the flow of reactive power affects power system voltages, management of costs and operational performance of a power system may improve if voltage control and reactive power are well integrated (PNNL n.d.).

More efficient distribution transformers. Distribution transformers transfer current from one circuit to another and change the value of the original voltage or current as needed. Distribution transformers are the source of a significant amount of all electricity network losses. More efficient medium voltage, liquid-immersed distribution transformers can provide large energy and cost savings over the infrastructure's lifetime (EPA 2017). Energy savings can be achieved by optimizing transformer design to in-field load, which is utility and/or location specific, and purchasing based on total ownership costs (TOC). EPA estimates that replacing 20 percent of U.S. transformer stock with transformers purchased based on TOC and designed for their intended load could save an estimated 1.4 TWh annually (EPA 2017).

Beneficial use of customer data. AMI[9] coupled with sensors along distribution circuits give utilities access to system and customer data that are critical for future grid design and smart grid functionality. AMI enables utilities to read meters without having to go to customer addresses and provides a range of other benefits. For example, AMI facilitates same-day stop/start service when tenants move, helps detect outages during storms to speed service restoration, and enables utilities to offer their customers information, monitoring tools, and programs to save energy and manage costs. AMI meters can deliver consumption data at various intervals (e.g., every 5, 15, or 60 minutes). AMI data access policies and issues are also discussed in the Customer Rates and Data Access chapter of the *Guide*. Utilities continue to explore how to capture, store, analyze, and take advantage of these data to inform many applications, including the following:

- *Customer-level voltage and reactive power monitoring.*[10] AMI can be used to record voltages and reactive power flow periodically or on demand. This information can provide assurance that voltage and reactive power optimization efforts are performing as planned. For example, voltage readings can confirm that customers are receiving power at the intended voltage for equipment operation and energy efficiency.

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8 Vars or var is the unit of measurement of reactive power in electric transmission and distribution systems. The term is derived from "volt-ampere reactive."

9 AMI is a system of utility-owned two-way communication devices, wireless electricity meters, and data management systems that connects customer-site meters to utility-side meter data management and billing software. The Energy Information Administration defines AMI as "electricity meters that measure and record usage data at a minimum, in hourly intervals, and provide usage data to both consumers and energy companies at least once daily" (EIA n.d.).

10 States can direct utilities to use advanced, behind-the-meter energy management systems such as distributed energy resource management systems (DERMS) and advanced distribution management systems (ADMS) to support distribution system operation and DER integration. Refer to the Tools for a Modern Grid text box for more on DERMS and ADMS and links to additional resources for energy management systems.

- *Utility asset management*. AMI data can inform transformer location-specific load factors and load trends. This information supports asset management planning, such as distribution transformer maintenance scheduling, or replacement timing and sizing (discussed previously in this section).
- *Customer data services.* Utilities offer their customers energy usage information in varying levels of detail and through a variety of channels, such as customer bills, utility customer dashboards online, and automated data transfer services. The AMI data allows customers to make informed decisions about how much and when they consume electricity to meet daily needs. The large-scale information technology projects that are often part of AMI and other grid modernization investments present an opportunity for utilities to incorporate the development of improved data access for customers.
- *Behavior-based energy efficiency programs.* Utilities are combining insights from behavioral science with detailed energy use information to inform energy efficiency programs that use economic and non-economic incentives, education, and feedback to change how people use energy. Utilities may combine multiple behavioral insights within an energy efficiency program offering such as peer comparisons, competitions, goal-setting, and rewards. Behavior-based energy efficiency programs, which are enabled by customer data, can reduce annual average residential energy use up to three percent (NREL 2020).
- *Facilitating change in energy use in response to price signals.* Though not yet common in all deployments, some AMI systems can facilitate demand response programs and dynamic pricing programs. When coupled with time-varying rates that better reflect the cost of generating and delivering electricity, which varies throughout the day, AMI meter information can encourage customers to shift consumption to lower-cost periods and support efforts to reduce peak demand. In 2019, over a million customers nationwide, representing a 12.1 percent annual increase, enrolled in a retail demand response program, resulting in total enrollment for all census divisions of 10.9 million customers. In the same year, 1.7 million customers nationwide, representing a 18.9 percent annual increase, enrolled in a retail dynamic pricing program, resulting in total enrollment of 11.0 million customers (FERC 2021c). Time-varying rates are discussed further in the Customer Rates and Data Access chapter of the *Guide*.
- *Energy efficiency program planning, implementation, and evaluation.* AMI data can be analyzed for usage patterns to inform energy efficiency opportunities. PG&E in California (PG&E n.d.) and ConEd in New York (ConEd n.d.) have used pilots to analyze data to provide virtual energy audits for interested customers. Programs that use more detailed energy usage data from AMI can be used to inform evaluation, measurement, and verification of energy efficiency programs (ACEEE 2017).

Clean Energy Integration Opportunities

Generally, transmission and distribution system losses increase as the distance between generation and customer load increases. Increasing DER penetration on the distribution system can reduce losses but also introduce other challenges. Planning tools like Hosting Capacity Analysis (HCA)[11] can be used to determine the amount of DER penetration that can be accommodated by a system before it experiences voltage and reliability issues from exceeding operational performance limits (Ismael et al. 2019). Because DERs can affect reliability, utilities have an interest in direct visibility, participation, ownership, or operation of DERs. To maximize the benefits of the increasing amount of distributed and renewable resources in the distribution system, state utility regulators are developing policies for utilities to better manage and integrate DERs in the system. Strategies that can help maximize the clean energy contribution of DER include improved voltage and

[11] Additional discussion of HCA is covered in the Interconnection and Net Metering chapter of the *Guide*.

reactive power management using inverters[12] and complementary deployment of demand response and storage technologies.

Improved voltage and reactive power management with inverters. Some utilities, potentially as a requirement from state utility regulators, develop strategies to manage voltage and reactive power to regulate power quality at the distribution feeder level with the goal of integrating increased levels of distributed renewables on their distribution grids (APS 2020). Distribution feeders are the final stage in the delivery of electric power to individual consumers. These feeders were originally designed for one-way power flow—from substation to customer. Like the branches of a tree, feeders have their heaviest loading near the substation with decreased loading as the various branches reach their end-use customers. Generally, the voltage on distribution feeders also falls at points farther from the substation. Adding distributed generation with modern inverters can provide locational benefits by boosting voltage on longer circuits. This strategy can keep all points on the distribution systems within acceptable levels, as today's inverters can set the power output voltage when converting from DC to AC.

Use of smart inverter systems. In addition to use of inverters to set DER output voltage, states can accelerate the use of inverters with smart functionality that provides real-time voltage and reactive power management. Combined with other modern grid technologies, inverter systems used with solar and wind generation have the potential to further benefit the system by real-time control of feeder voltages. As noted, voltage tends to be higher closer to substations, and under some grid conditions, conventional inverters disconnect solar resources to avoid overvoltage to the system. Advanced inverter systems have the potential to tailor the output of solar and wind resources to meet system needs and provide grid services such as voltage or reactive power support and can respond very quickly when needed. As of 2021, much of the installed base of inverters in the United States has smart capabilities that are not yet in use. The IEEE Standard for *Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*, which includes requirements for smart inverter functionality, will lead to greater uniformity in performance and functionality. Because IEEE standards are voluntary, state regulators and utilities decide if and when to test and deploy that functionality in the distribution system (IEEE 2018; NERC 2020).

Complementary deployment of demand response and storage. Since customer demand for electricity is variable, grid system operators have historically balanced generation and demand by relying on fossil fuel fired power plants that can ramp up or down relatively quickly. This balancing happens on time scales from seconds to hours. As the amount of intermittent renewable generation increases, balancing becomes more challenging. Adding demand response and storage provides flexibility with the potential to help system operators balance supply and demand without the need to start up peaking power plants for short periods solely to provide additional balancing capability.

When DERs can be aggregated and connected to form a virtual power plant (VPP), they offer an alternative to fossil fuel peaking plants, which can be more expensive and higher polluting. In a VPP, the DERs can be controlled as a demand flexibility[13] resource to create more value for the grid than the sum of independent DERs. In Massachusetts, the Mass Save ConnectedSolutions VPP program lets customers with battery storage devices to earn incentives for allowing the utility Eversource to use their battery's energy during peak periods

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[12] An inverter is a devise that converts direct current (DC) to alternating current (AC). Transmission and distribution lines use AC. Because some DERs including solar photovoltaic panels produce DC power, inverters are used to convert the DC output to AC for use in homes and businesses.

[13] Demand flexibility is the ability of electricity loads on the distribution system to change their usage patterns by the hour or other time increment in response to price signals or utility controls to take advantage of available renewable energy resources (LBNL n.d.).

(Mass Save n.d.). In 2022, the first residential VPP completed a summer season of operation in ISO-NE, successfully transferring 1.8 gigawatt-hours of energy to the grid across New England (Sunrun 2022).

Traditional demand response programs, which are offered by many utilities nationwide, provide financial incentives in return for customers reducing consumption during certain conditions, e.g., periods of peak load. Historically, most utilities call on these customers to respond to peak events for a limited number of hours per year. Refer to the Customer Rates and Data Access chapter of the *Guide* for more information.

Automation of demand response offers great promise for customer participation, not only in peak load reduction events but also in serving as a flexible resource to provide other grid services for shorter periods of time (NREL 2018). Utilities have used pilots to automate demand response by communicating with the building energy management systems of participating commercial customers. A case study with a commercial real estate company using PG&E's Automated Demand Response Program demonstrated bill savings from energy efficiency and time savings for facility engineers (PG&E 2017). The emergence of ENERGY STAR products with connected functionality (refer to the ENERGY STAR Products with Connected Functionality text box) may increase the availability of products with connected features and the willingness and ability of residential customers to participate in automated demand response initiatives.

Energy storage is increasingly being used to support renewable energy integration. For example, storage can store excess renewable energy for later use; it can be installed close to where energy will be consumed, potentially alleviating congestion and line losses on transmission and distribution systems during peak periods; and certain storage technologies with rapid response capabilities can help manage fluctuations on the electricity grid caused by the intermittency of some renewable energy resources. Due to their flexibility and ability for rapid response, automated demand response and storage are being explored by system operators for better integrating distributed renewable energy resources.

ENERGY STAR Products with Connected Functionality

As of May 2022, ENERGY STAR Connected Criteria are optionally available for 14 product categories, with more on the way. Products recognized as ENERGY STAR Connected provide a mix of user convenience, tools for saving energy, and grid services. Connected criteria are required for certain controls products (e.g., thermostats, smart home energy management systems) where data from the field is needed to verify energy savings.

In particular, ENERGY STAR Connected Criteria for large loads (water heaters, central air conditioning and heat pumps, pool pumps, electric vehicle charging equipment, ice makers, and smart thermostats) require open communication standards and functionality to receive and respond utility curtailment signals issued to the aggregators and service providers they work with to manage demand response programs. Connected criteria for large loads are designed to advance interoperability and increase user awareness of consumption, maintenance, and operation.

Utility participation in ISO/RTO. State public utility commissions and electric cooperative and municipal boards sometimes have a role in approving utility participation in independent system operators (ISOs), regional transmission organizations (RTOs), or voluntary energy imbalance markets (EIMs), such as those operated by the California Independent System Operator (CAISO) and Southwest Power Pool (SPP). Similarly, state legislatures have introduced bills to require utilities to join or explore joining an ISO/RTO to advance clean energy objectives (NV S.B. 448 2021; CO S.B. 72 2021; OR S.B. 589 2021).

When utilities participate in an ISO or RTO, they are better able to accommodate and integrate higher levels of intermittent renewable energy deployment like wind and solar. This is because an ISO/RTO represents a larger "balancing area" (i.e., the area within which energy demand and generation must be balanced at all times) than the territory of any one utility. Being in a larger balancing area reduces the aggregate variability in renewable energy generation, while increasing the portfolio of dispatchable generation resources that are available to adjust their output in response to fluctuating renewable generation (Utility Dive 2021; NV S.B. 448 2021).[14]

Participation in an Energy Imbalance Market. An EIM is a real-time energy supply market that offers electricity generation and transmission service to balance demand and dispatch power based on lowest cost. Market participants include multiple balancing authorities and utility territories (PSE n.d.). An EIM can support greater deployment and integration of renewable energy resources because those resources often have near-zero marginal operating costs. Unlike a typical wholesale electricity market run by an ISO/RTO, an EIM makes participation available to entities outside of its ISO territory without the same requirements and financial obligations required to be part of the ISO. Having a larger balancing area provides economic efficiency and can help reduce renewable curtailments by the access to more resources for supply and demand balancing across a larger area.

New or Enhanced Planning

The growth of DER comes with many benefits but also challenges for management and integration. States are using new planning systems and approaches to address some of the issues such as lack of visibility into customer DER (discussed further in this section) and need for better understanding of the value of DER on the grid in place and time. NARUC and NASEO have developed a joint Task Force on Comprehensive Electricity Planning, which helps states develop policies to improve grid resilience and reliability by addressing the growth of DERs, storage, energy efficiency, demand management, and the implementation of new technology solutions (NARUC & NASEO n.d.).

Many DERs have been adopted by customers over time without explicit coordination with the utility operator, who may lack visibility into where these resources are deployed, what capabilities they have, and in some cases (e.g., storage resources) how they are operated by customers at different times. Furthermore, utilities often lack the ability to dispatch or control these resources. Due to utilities' responsibility to ensure that service is delivered to customers in a safe and reliable manner, utilities may seek to have a role or to stay informed of planning, siting, and controlling DERs that are integrated into the distribution system. Not all DER are equally valuable in all locations or in all hours of the day. For example, a DER located at the end of a distribution feeder providing electricity in the middle of the day to an unoccupied home would be less valuable to the grid if there is not a plan in place to productively store and/or use that electricity (LBNL 2021). Conversely, a DER that is strategically located with known performance attributes can be extremely valuable to the distribution system, particularly when bundled together to provide complementary services that meet an identified need.

States and utilities are taking several interrelated approaches to help better inform the value of DER to the distribution system:

- *Assessing timing and locational value* of energy efficiency and demand flexibility can provide additional value particularly if those savings address air quality concerns or electrical grid needs at necessary times and locations. The timing of energy savings and demand flexibility is determined by collecting and analyzing data on how the operating characteristics of the efficient equipment reduce or shift energy consumption predictably during certain periods of time. For example, efficient air conditioners can reduce energy consumption during peak summer use. The location of energy savings is determined by collecting

[14] For more details, refer to the National Renewable Energy Laboratory's 2015 resource, Balancing Area Coordination: Efficiently Integrating Renewable Energy Into the Grid.

and analyzing data on the geographic distribution of energy efficiency projects and measures. Locations of interest may vary from the regional level to neighborhood-level grid distribution points (EPA 2019).

- *Hosting capacity analysis (HCA)* is an analytical "pre-screening" process used to determine the distribution system's ability to accommodate new distributed generation at specific grid locations without exceeding operational performance limits or requiring feeder upgrades. HCA increases transparency into the distribution grid's current operational conditions and limits through maps and supporting datasets. The information can help commissions, utilities, or developers identify where new DER could provide beneficial services and support longer term strategic DER investment decisions. The insight from HCA maps and data on current grid conditions and operational constraints allows a utility customer or DER developer to more efficiently target specific grid locations (IREC 2018). A hosting capacity analysis considers thermal, voltage, and protection limits and establishes the baseline for the maximum distributed generation the grid could accommodate safely (ICF 2016). After the initial process of identifying operating limits, a hosting capacity analysis may also consider the locational value in additional DER on the grid (ICF 2016). Several states now require utilities to conduct HCA, as summarized in Table 1. Additional discussion of HCA is covered in the Interconnection and Net Metering chapter of the *Guide*.
- *Assessing non-wires alternatives (NWAs)* involves strategically evaluating and planning for options other than traditional capital investments in distribution system infrastructure. Some utilities assess the physical and operational needs of a project and determine whether DERs with different attributes can be bundled to avoid or defer the infrastructure investment at a cost savings. For example, a DER bundle to relieve a congestion bottleneck might include CVR or volt/var optimization under the direct control of the utility, automated demand response through smart thermostats in the congestion area provided by a third-party service provider (also referred to as an aggregator), and strategic use of battery storage owned either by a customer or the utility. Research by a national laboratory has found that with thoughtful siting and energy storage, NWAs have the potential to improve energy equity, reduce environmental and health hazards, or provide backup power during outages (refer to the Equity Benefits section in this chapter). In Maine, a 2019 law requires the state's public advocate office, which represents the interests of utility ratepayers, to analyze NWA options as alternative to transmission and distribution system investments (LBNL 2021; ME L.D. 1181 2019).
- *Integrated Distribution System Planning (IDSP)* is a more comprehensive approach that expands on analyses described above. IDSP, which can include scenario analysis, locational benefit analysis, and hosting capacity analysis, can help utilities develop a distribution investment roadmap to prioritize grid improvements (ICF 2016). IDSP "assesses the physical and operational changes to the electric grid necessary to enable safe, reliable, and affordable services that satisfies changing customer expectations and use of DERS" (ICF 2016). Due to utilities' responsibility and accountability for the distribution system's safety and reliability, utilities have an interest in maintaining final decision-making authority that is informed by this framework. IDSP "includes stakeholder-informed scenarios on expectations on growth of DERS over time, and is coordinated with other planning scenarios to identify:
  - Necessary investments to enhance safety, reliability, and security, including replacement of aging infrastructure and grid modernization
  - Changes to interconnection processes and integration investments to support DER adoption
  - The value of DER and opportunities to realize net benefits for all customers through use of DER-provided services" (DOE 2018).

While states have not adopted integrated distribution planning uniformly, some states have developed plans, such as California; Delaware; Indiana; Hawaii; Maryland; Michigan; Minnesota; Nevada; New York; Rhode Island; and Virginia (LBNL 2020).

There is increasing attention on the benefits and need to better coordinate distribution system planning with bulk power system planning processes, such as utility integrated resource planning (IRP)[15] or the resource adequacy planning done by some ISO/RTOs[16] (for more on planning processes, refer to the Electricity Resource Planning and Procurement chapter of the *Guide*). This attention is driven in part by Federal Energy Regulatory Commission (FERC) Orders that have enabled the participation of DER in wholesale electricity markets (refer to the Interaction with Federal Programs and Regulations section in this chapter for discussion of FERC orders). Although DER can potentially provide energy, capacity, or ancillary services, a DER providing a distribution system service to the local utility may preclude the resource from providing the same or a different service at the same time to the ISO/RTO. For example, if an energy storage device is discharging energy to relieve local congestion on the distribution system, it is likely unavailable at that time to provide frequency regulation for the bulk power system. Those who plan and operate the grid at either level need to see when resources are available to meet system needs and to know their location and capabilities. Enhanced visibility and planning also helps regulators protect ratepayers by taking steps to ensure that DER owners are not paid twice (by their utility and by the ISO/RTO) for the same service.

Current Landscape

State governments and utility regulators use planning to deploy additional DERs, make the grid more resilient and reliable, and increase energy efficiency. A combination of interrelated planning, management, technologies, and engineering decisions ensure that modern grid investments complement energy efficiency and support the growth in renewable resources. These decisions are not captured by any single policy and comprehensive data on the extent of these efforts are not widely available. Notable efforts in California, Hawaii, Oregon, Massachusetts, and Minnesota have convened multiple stakeholders to address diverse perspectives including environmental considerations in planning grid modernization efforts (LBNL 2020). Table 1 highlights states with policies to promote energy efficiency, renewable energy integration, and enhanced planning in grid investments, and the State Examples section presents a selection of case studies.

Some states' grid modernization planning efforts use principles of inclusive stakeholder engagement (Racial Equity Tools n.d.). One objective is to ensure that grid modernization plans lead to benefits for and address concerns of communities that are the most vulnerable to bill increases or electricity outages. For example, the Massachusetts Energy Efficiency Advisory Council has an Equity Working Group that provides guidance to utilities on behalf of moderate-income customers, renters, small businesses, and customers with limited English proficiency. Examples of emerging efforts of the working group include outreach by National Grid to multilingual-focused community based organizations to develop relationships that will help increase participation among limited English proficiency customers (MA EEAC 2020). New York has a Climate Justice

[15] Integrated resource planning includes the review of current and future resource options for meeting customer demand for electricity services under a range of scenarios. In addition to supply-side, demand-side, and transmission and distribution system resources, states can require utilities to consider environmental and social factors, incorporate input from communities and stakeholders, and align planning and procurement processes with state policy priorities. Some states require utilities to develop an integrated resource plan. IRP can be used to refer to the planning or the plan.

[16] The National Association of Regulatory Utility Commissioners and the National Association of State Energy Officials Task Force on Comprehensive Electricity Planning develops and curates resource lists for members to learn more about the evolving planning process. Resources are available across 15 topic areas, including Distribution System Planning (DSP), Emerging Practices in DSP, and Utility Best Practices for Integrated Planning (NARUC n.d.).

Working group with local and regional advocates advising the state's Department of Environmental Conservation priorities (NY State n.d.). The state previously convened a Storm Hardening and Resiliency Collaborative focused on resiliency to extreme weather, with members including community and consumer groups (Georgetown Climate Center n.d.). The resulting order from New York's Public Service Commission adopted stakeholder strategies to keep costs low and improve resilience for vulnerable communities (NY PSC 2014a). The utility ConEd indicates efforts have avoided almost 700,000 customer outages from 2014 through 2020 (ConEd 2021a). California offers funding for low-income customers and those with medical needs to install solar plus battery storage as a way to maintain electricity service during wildfire events (CPUC 2020).

Table 1: States with Policies to Advance Energy Efficiency, Renewable Integration, and Enhanced Planning in Grid Investments

Policy	Description	State Examples
Energy Efficiency Opportunities		
Provide incentives/remove disincentives to grid-side energy efficiency investment in the distribution system	Enable grid-side energy efficiency to be credited toward energy efficiency goals or resource standards. Alternatively, provide performance incentives to utilities for grid-side efficiency and reduced line losses.	Includes CVR as energy efficiency portfolio option: MD, NC, OH, OR, PA, WA (Willoughby 2015)
		Has policies providing energy efficiency credit for efficient distribution transformers: MD, WA, OR, MN BPA, (EPA 2017)
Time and locational value of energy efficiency savings	Assess time and/or locational value of energy savings from energy efficiency measures.	CA, NY (Synapse 2018)
	Incorporate time and/or locational value of DERs in benefit-cost framework.	Refer to (NESP 2022) for a description of these states calculating locational distribution capacity impacts: MN, NH, NY, RI
Automated demand response for efficient connected products to support renewables integration	Pilot or implement a program to use efficient, connected products, which may be controlled by the utility.	CT (ACEEE 2019), OR (PGE n.d.)
Renewable Energy Integration Opportunities		
Updated interconnection standards and processes	Update standards and processes to conform with IEEE 1547-2018 and activate full capability of DER inverters.	MN (MN PUC n.d.) Refer to the Interconnection and Net Metering chapter of the Guide for additional information.
DER potential studies	Investigate the potential of individual and DER bundles to meet system needs while reducing renewable curtailments.	CA, Tennessee Valley Authority (TVA 2020), Bonneville Power Authority (BPA 2019)
Expanded balancing area	Study the benefits and costs of participating in a larger market such as an EIM or RTO/ISO to better accommodate and or increase renewable energy.	Western EIM (Western EIM n.d.)
New and Enhanced Planning		
Grid modernization proceeding	Convene or initiate a proceeding to plan for and implement grid modernization.	CA, HI, OR, MA, OH, (LBNL 2020) MD (MD PSC n.d.), DC (DCPSC n.d.)
Hosting capacity analysis	Require utilities to analyze and communicate distribution system's ability to accommodate new DER at specific locations without upgrades.	DC (Pepco n.d.), CA, HI, MN, NV, NY (IREC 2018), CT (PURA 2020) Refer to the Interconnection and Net Metering chapter of the Guide for additional information on HCA.
Non-wires alternatives	Evaluate combinations of DER as a potential cost-saving alternative to grid infrastructure investments on a pilot or routine basis.	AZ, ME, NY (LBNL 2021), RI (RI H. 8025 2006)

Policy	Description	State Examples
Integrated Distribution System Planning	Institute a transparent process requiring utilities to periodically file long-term distribution system plans.	CA, MI, MN, NV, NY (LBNL 2020)

Note: State examples provide a sample, not an exhaustive list.

Designing Effective Policy to Maximize Grid Investments

Efforts to advance grid modernization involve many participants and depend on highly technical design issues. Some states and utilities are reconsidering who participates and expanding communication about different aspects of grid modernization.

Participants

Many participants are involved in policy design associated with grid investments. Key players include:

- *State executive and legislative bodies.* At the state level, the governor's office, state legislature, and state energy offices are often involved in policy- and goal-setting that includes or is facilitated by modern grid investments. Depending on how utilities are regulated by their state and the issue at hand, state legislatures may become involved in modifying existing legislation to accommodate modern grid investments. For example, state energy efficiency resource standard legislation may be created or revised to include grid-side efficiency investments.
- *State electric utility regulators/utility boards.* Utility regulators and boards of municipal or cooperative utilities oversee goals, investments, planning processes, and ratemaking for electric utilities. Most of this oversight is found in regulatory proceedings, including those for modern grid investments. These proceedings may approve pilots, define which resources count toward energy efficiency resource standards, determine AMI investment, or modify rate structures. For investor-owned utilities, regulators also deliberate on a range of topics—such as transmission and distribution capital plans and planning standards—through periodic general rate case proceedings. Utility regulators and oversight boards are faced with new challenges as the volume and complexity of proceedings increase.
- *Electric utilities.* Electric utilities are the primary purchaser of modern grid technologies and need to make the internal and external business case for modern grid investments while also responding to regulatory mandates or board directives. In the changing landscape of modern grid technologies and operations, utilities are often concerned about investing in technologies that may become obsolete before their costs can be fully recovered. Utilities may also seek compensation between rate cases for lost revenues associated with reduced electricity use due to grid-side energy efficiency or increased customer reliance on distributed generation (including renewables). While utilities have the expertise to execute grid modernization initiatives, absent permission or guidance from their regulators, their tendency may be to avoid risk or delay deployment. Some states have used a test bed approach to allow some managed risk in the interest of innovation (refer to the Regulatory Sandbox text box). Because of their ability to reach every customer, utilities are well suited to ensure equal customer opportunity and access to technology programs and equal realization of the benefits. Utilities also have an interest in the size, location, and operation of DERs on the distribution grid due to their responsibility and accountability for the system's safety and reliability.
- *Regional transmission organizations (RTOs)/independent system operators (ISOs).* Regional balancing authorities coordinate the transmission of electricity across states. In some areas of the country, where

wholesale markets are restructured, this coordination takes place through organizations known as ISOs or RTOs. Approximately two-thirds of U.S. electricity demand is served in RTO regions[17] (FERC 2021a). RTOs/ISOs use long-term planning to identify effective and cost-efficient ways to ensure grid reliability and system-wide benefits. Coordination and cooperation between utilities, utility regulators, and RTOs/ISOs is often required to advance energy efficiency and renewable energy integration goals in grid modernization.

- *Consumer advocates, community-based organizations, and environmental advocates.* Groups representing consumers, environmental interests, and other public interests are often involved in offering technical expertise as well as public perspectives. Equitable outreach strategies for groups that have not historically participated in proceedings include holding proceedings at times outside of traditional working hours, at locations that are transit-accessible, with translation services, and with the option to receive financial compensation for time invested providing input for the policy. Some consumer advocates may support policies that help to maintain low rates and ensure equitable treatment of all customer classes. Environmental advocates may promote topics such as pursuit of all cost-effective energy efficiency, robust funding for traditional energy efficiency programming, or transmission and distribution investments to support renewable energy integration. Some organizations may have an interest in privacy and data access issues associated with AMI, as well as alignment of utility business models are with public interest goals. Customer engagement will vary by customer size and class and/or interest in key issues such as rate impacts and pricing structures, power quality, ability to participate in providing demand response and other grid services, renewable energy, and data access and privacy. In general, it is advisable to

Regulatory Sandboxes: Expeditious Pilots

A regulatory sandbox is a program or regulatory structure that offers regulated utilities and potentially unregulated entities to try innovative solutions to challenges with fewer administrative requirements than pilots, enabling faster innovation and results. Sandboxes can enable innovative ways to increase DER integration, such as using electric vehicles as storage assets or improving distribution system efficiency. The sandbox approach can involve new technologies or dynamic programs. Participants may test streamlined or expected approval processes, removing contacting or procurement requirements, or providing assurances for cost recovery. Below we highlight two examples:

Hawaii Pilot Process. In 2018, Hawaii Public Utility Commission implemented a new process to “foster innovation with an expedited implementation process” to test new technologies, programs, and business models for larger scale implementation. The approach exempted companies from the traditional restrictive contract bidding and selection processes and relieved them of some administrative reporting burdens. The program caps costs at $10 million and incorporates them into a revenue requirement of an annual review process, rather than addressing them in separate mechanism that would need to be justified and litigated.

Portland General Electric (PGE) Smart Grid Test Bed. The Oregon Public Utility Commission authorized PGE’s Test Bed project in the utility’s 2016 Integrated Resource Plan. The project was designed to test and learn from innovative demand response resources that could be developed to eventually replace generation resources. The Commision authorized the use of technology and customer incentives to achieve their goals. PGE’s efforts evolved into the Smart Grid Test Bed, and in 2021, the Department of Energy selected PGE for a $6 million grant to renovate 500 buildings in historically underserved neighborhoods with the goal of reducing energy burdens through energy efficiency and connected devices. As part of the program, PGE offers customers a a rebate and montly credits for connecting their battery to the grid as part of the Smart Battery Pilot.

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[17] In the rest of the country, which operates in the traditional vertically integrated utility model, the same entity (a utility) is responsible for electricity generation, transmission, and distribution to retail customers within the utility’s defined geographic service area and with oversight by utility regulators at the state level. For more background, refer to the Overview of Electric Utility Policies chapter of the *Guide*.

provide customers with proactive education and outreach on the installation of AMI meters and any changes to billing or rate structures.

- *Vendors and service providers.* Vendors of smart grid technologies and software may be called on to provide expertise during public proceedings, to respond to formal requests for information or proposals from utilities or states, or to participate directly in public dialogue to advance the interests of their organization. Service providers that acquire and aggregate demand response and distributed solar resources may be interested in regulatory proceedings that will affect how distributed resources will be valued and compensated by regulators, utilities, and capacity markets. Other service providers, such as those wishing to offer integrated home energy management services, may be interested in data access and privacy issues.

Key Design Issues and Constraints

Many existing policies affecting electricity generation, transmission and distribution, renewable energy, and demand-side management (e.g., energy efficiency and demand response) have been designed independently from one another. As a result, programs are often planned and managed by different departments within a utility—each with unique expertise and regulatory drivers. Successful planning and management of modern grid investments to achieve broader energy efficiency and renewable energy benefits requires some integration of utility functions and policy goals to achieve the multiple objectives of grid modernization. Key considerations during the design of state policies for modern grid investments include:

- The prudent level of investment considering the state of the market, local conditions and system needs, existing investments, the availability of funding (e.g., federal grants), and experience with key technologies.
- How the need to engage multiple functional departments within a utility will affect timing and success.
- The best way to gain operational experience using modern grid technology to maximize energy efficiency benefits and distributed resource integration.
- When, where, and how to take proven pilot initiatives to scale.
- How to apportion costs given the multiple benefits of technologies and practices.
- How to balance customer rates and utility revenue requirements.

The following section provides more information on these key policy design considerations and constraints that states and utility regulators can consider when providing oversight for grid investment processes and strategies.

Evaluating Current Systems and Future Needs

Before making investment decisions, representatives from multiple departments within a utility meet to discuss existing system assets and operations, anticipated future system needs, the purpose of pilots, and key design considerations (refer to the Implementation, Oversight, and Evaluation section in this chapter). During this phase, participants review technical data about the system such as the configuration of the distribution system and substations; equipment ratings; historical data on usage, voltage, costs, reliability, and risk; and current operating criteria and practices such as how temperature is monitored and controlled at the transformer to avoid overheating and to extend equipment life. State and federal regulatory requirements also are discussed to ensure a clear understanding of what various parties are legally required to do and to identify any regulatory issues, such as how property rights for new assets will be assigned, that will require further legal review or action. Utility regulators are not normally involved at this stage but can influence whether such evaluation occurs. For example, regulators can require an assessment of grid-side energy efficiency potential or request utilities to consider pilots to deliver grid-side efficiency or to improve the integration of distributed renewables.

Gaining Operational Experience

Most utilities conduct pilots or use a regulatory sandbox (refer to the Regulatory Sandbox text box) to gain experience with new technologies and operational practices before making larger-scale investment. Many utilities have gained operational experience with one or more modern grid investments through participation in Federal Smart Grid Investment Grants and Demonstration Programs, as well as through demonstration projects in partnership with the Electric Power Research Institute (refer to the Interaction with Federal Programs and Regulations section and the Information Resources section, respectively). Pilots and demonstration projects may be subject to regulatory or board approval. During pilots, it is helpful to establish clear objectives, milestones, and a process for reviewing progress and tracking actual costs and benefits. With proven costs and benefits from a real-world pilot, the business case for full deployment gains credibility for approvals within utilities and with regulatory bodies.

Making the Business Case

When evaluating the benefits of investing in modern grid technologies and related changes to operations and management, state policymakers, utility regulators, and utilities have found it helpful to apply a comprehensive benefit-cost analysis that accounts for the benefits, costs, and risks associated with some of these investments.

Note that costs and benefits will vary by location and specific operating situations. The same technology can have a different implementation cost and benefit in a rural area with low customer density than in an urban area with high customer density and significant commercial loads. Service territories need to be examined by similar groupings of circuits, which can then be separately analyzed for costs and benefits, and the analysis should account for how modern grid investments are managed as well as how they interact with one another. For example, investment in one technology can help avoid costs in the implementation or operation of another technology. In addition, investment in technology may provide a limited benefit unless it's managed to specific objectives such as energy efficiency or increased DER integration. Some states are using system controls, monitoring devices, and communications and automation tools (refer to the Tools for a Modern Grid text box), which enable increases in distribution grid efficiency, and reduce the cost to integrate clean energy. The National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources (NSPM for DERs) provides methodologies and principles for jurisdictions to assess and compare the cost-effectiveness of energy efficiency – including distribution system efficiency – and other DERs. NSPM for DERs was designed to help make the business case for clean energy integration (NESP 2020).

The Bonneville Power Administration (BPA), which operates the federal power and transmission grid in pacific northwest states, summarized its business case for each of the 35 strategic grid modernization projects in 2022. The project summaries explain how the investments reduce future costs, create new market opportunities, and support increases in system efficiency and reliability. One anticipated benefit of the load and renewable forecasting project is more accurate, consistent forecasts, which could reduce the cost of water management within the federal hydropower system (BPA 2022b).

Funding and Cost Recovery

Electric utility regulatory frameworks and financial incentives have a strong influence on utility investment in modernizing the electric grid. The traditional utility cost of service regulation model creates financial incentives for regulated utilities to maximize the volume of electricity sales (throughput incentive) and use capital-intensive solutions to meet grid needs (capital bias). Some state regulators have established or reinforced policies to help curb the throughput incentive and capital bias, ensure clean energy program cost recovery, and define shareholder performance incentives (refer to the Electric Utility Regulatory Frameworks and Financial Incentives chapter of the *Guide*). In many parts of the country, utilities are years away from experiencing significant revenue impacts from the high penetration of distributed renewables or grid-controlled energy efficiency, but some states with higher renewables penetration and/or a strong interest in improving grid resiliency to respond to increasing severe weather events have begun to discuss an evolving utility business model in the context of grid modernization (refer to the State Examples section in this chapter).

Utilities and their regulators are evaluating how to fund modern grid investments, absent a full rate case, since transmission and distribution planning investments are typically recovered through rates. Additional or unforeseen investments in grid technology require utilities to risk that these investments will not be recovered through future rate cases. Other issues include ensuring that benefits are widely distributed among customers and whether regulators will compensate utilities for lost revenues when the modern grid investment delivers end-use energy efficiency benefits to customers.

Interaction with Federal Programs and Regulations

A range of federal initiatives and regulations, including FERC orders, are relevant to state grid modernization planning and investments. State utility regulators oversee local electricity distribution and in-state transmission while FERC has authority over interstate electricity transmission. In addition to FERC activities, federal agencies and national laboratories conduct research and support the development of grid technologies and implementation of state planning efforts. Relevant and recent FERC orders are summarized as follows:

- Public Utility Regulatory Policy Act (PURPA) requires that utilities allow interconnection by qualifying facilities. States have significant flexibility in administering PURPA, although amendments made in 2005 and several subsequent FERC decisions have affected the applicability of PURPA in some regions (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 2020d; 2020c). Refer to the Interconnection and Net Metering chapter of the *Guide* for a more detailed discussion of PURPA.
- FERC Order 792 addresses storage interconnections. In 2013, FERC updated the Small Generators Interconnection Procedures (SGIP) through Order 792. Among other changes, these updates added energy storage to the list of resources eligible to interconnect under FERC procedures. States may want to consider how state interconnection standards accommodate storage assets and how they interact with existing FERC orders (FERC 2020a). While FERC's updates are not binding for states, they can provide useful models for establishing provisions that anticipate and enable higher DER penetration.
- FERC Order 841 advances energy storage. In 2020, the U.S. Court of Appeals for the D.C. Circuit upheld FERC Order 841 and in doing so removed market barriers to energy storage. Order 841 permits energy storage to compete with traditional fossil fuel generators in wholesale power markets.
- FERC Order 2222 enables DER aggregation. In 2020, FERC Order 2222 enabled DER aggregators to compete in each of the regional organized wholesale electric markets. This action further authorizes DER resources to participate in the regional markets for capacity, energy, and ancillary services, alongside traditional resources. Multiple distributed resources that are bundled together, such as in a VPP, can satisfy minimum size and performance requirements that they might not meet individually (FERC 2020b). In a 2021

rehearing of Order 2222, FERC ruled that demand response can combine with other aggregated DERs, and that grid operators may not forbid the participation of demand response (FERC 2021b).

- FERC Order 745 requires wholesale market operators to compensate energy efficiency and demand response providers at the same rate as electricity generation (FERC 745 2011). In 2016, the U.S. Supreme Court ruled that FERC acted within its authority to regulate interstate wholesale markets, allowing Order 745 to take effect and for demand response to compete with all electricity resources in the wholesale market (RMI 2016).

The federal government also provides funding for projects that catalyze grid modernization. Examples include:

- The U.S. Department of Energy (DOE) Connected Communities program provides funding to projects for "grid-interactive efficient buildings" that deploy DERs and serve as assets to the grid (DOE n.d.). DOE and its national laboratories also produce research, policy evaluation, technology development, and innovation in grid modernization, in areas such as inverters for the future electric grid, and sensors and controls for grid-interactive loads. In addition, the Energy Act of 2020 advances grid modernization goals by establishing an energy storage and microgrid grant and technical assistance program at the DOE. This program aims to help rural electric cooperatives and public utilities design storage and microgrid projects that incorporate renewable energy, improve system reliability, and support resilience (US H.R. 133 2020)
- The Infrastructure Investment and Jobs Act, known as the Bipartisan Infrastructure Law (BIL), provides $62 billion to be administered by DOE "for investment in energy infrastructure that can support a pathway to a clean, yet resilient and equitable energy future." This includes enhancing the reliability, resilience, and efficiency of the electric grid (NETL n.d.).
- The Inflation Reduction Act (IRA) provides significant incentives to encourage clean energy development as well as transportation electrification and efficient electrification of homes and buildings, both of which will impact electricity demand and related utility planning efforts. The IRA provides tax credits for net-zero emission generation and energy efficiency improvements, funds states' greenhouse gas reduction planning and implementation, creates a $27 billion Greenhouse Gas Reduction Fund, and funds programs and groups advancing environmental justice (EPA 2022a).

EPA also provides multiple resources that identify federal funding opportunities for green infrastructure investments, many of which support energy sector projects.

Interaction with State and Local Programs

States and municipalities can use policy levers and establish programs to advance and support modern grid investments, which frequently interact with and advance other priorities such as reducing costs, improving the environment, promoting innovation, and enhancing reliability. One step that states and municipalities can take is to determine whether existing energy efficiency resource standards and savings targets allow investments in modern grid technologies to count towards compliance (refer to the Energy Efficiency Programs and Resource Standards chapter of the *Guide*). Jurisdictions can similarly examine renewable portfolio standards and other renewables policies to identify opportunities to simultaneously advance demand response and flexible loads (refer to Electricity Resource Planning and Procurement and other chapters of the *Guide*). Another step that states and municipalities can take is to assess and expand the deployment of customer information programs that use AMI data to improve energy efficiency deployment and encourage energy-saving behaviors. For more on states that are using and protecting customer data and deploying AMI to realize the benefits of energy efficiency, refer to other chapters of the *Guide* such as Interconnection and Net Metering, Customer Rates and Data Access.

Implementation, Oversight, and Evaluation

Implementation

Engaging senior leadership and multiple operating units within a utility is often critical to the success of efforts to deploy, manage, monitor, and evaluate programs or initiatives that leverage grid modernization investments for load reduction, energy efficiency, and other DER integration. Utilities have cited the importance of deepening coordination across departments as a key step for success. It is helpful for states and their utility regulators to understand these operational complexities in setting realistic timeframes for pilots or larger-scale deployment. The following are examples of how different operating departments within a utility may be engaged in modern grid deployments or pilot initiatives:

- Electric distribution operations staff are directly engaged in planning and operations. They know critical system data; understand the mix of residential, commercial, and industrial customers along various feeders; and are responsible for ensuring that grid operations deliver expected services within allowable voltage levels.
- Electric forecasting departments are instrumental in understanding and planning future load requirements, including seasonal, peak, time-of-day, or customer class impacts.
- Energy efficiency and demand-side management program staff are interested in the implications of grid-side efficiency programs and the potential to count customer impacts toward program goals. As such, they provide valuable insights on how to track and monitor costs and benefits.
- Key account managers are usually engaged in any demonstration that could potentially affect service to large customers or customer groups.
- Customer call centers and billing departments manage customer contact, usage history, and other information necessary for pilot design and measurement, depending on the project being implemented. They are often a first point of contact for any service or billing accuracy complaints, such as those associated with new AMI meter deployments.
- Regulatory and public affairs staff become involved in developing the strategy for raising customer awareness of new technologies, making the business case for implementing modern grid investments, and engaging in related regulatory proceedings.

Oversight

The oversight of utility distribution system modernization efforts is primarily through the state utility regulator or board, depending on utility type (RAP 2016). The regulator or board generally approves capital investments, establishes the policies that govern investment and operation of the electric grid, and ensures fair treatment and equity between the ratepayer and the utility and among ratepayers.

Decisionmakers generally have both formal and informal options available for oversight. For example, formal utility regulatory processes are often handled through dockets with evidence-based hearings and opportunities for public comment. These formal processes are generally used to approve or disapprove a specific grid investment proposal. For a deeper exploration of the pros and cons of a range of grid modernization options, oversight organizations—on their own or at the request of interested parties—may opt to initiate an informal process, such as workshop or stakeholder collaboration. Informal proceedings may be an alternative option but they are authorized or limited based on state statute. Informal processes may lead to formal processes, but in the meantime, they allow decisionmakers to engage and learn without the limitations associated with rules of evidence, enabling a deeper exploration of the advantages and disadvantages of the full range of opportunities.

Evaluation

Utility regulators in some states are requiring evaluation of modern grid investments. This includes estimating the potential for grid investments to achieve energy savings and other benefits, as well as conducting evaluation, measurement, and verification (EM&V). These evaluation approaches are already in place for most demand-side energy efficiency investments. The goals of evaluation for modern grid technologies are the same as for existing efficiency programs: understanding the magnitude of savings and other benefits under different scenarios, while ensuring that publicly funded technologies are operating properly and achieving critical electricity reliability, cost savings, and other policy goals. While the specifics of how evaluation is applied may differ slightly for each grid technology, establishing such approaches ensures that key processes and impacts are assessed in a manner that is robust, transparent, and well documented. A CVR example is provided in this section, along with key EM&V resources.

Conservation Voltage Reduction (CVR) Evaluation Example

- *Estimating potential.* The potential of CVR to deliver energy efficiency to customers will vary by circuit. It is typically estimated by examining groups of circuits in a service territory that are similar in length, voltage levels, customer class, and other technical characteristics. Utilities typically conduct modeling to inform which circuits are best suited to voltage management. Once operational experience is gained on a range of circuits, utilities can understand and target high-value circuits for future deployments.
- *Developing tracking metrics and systems*. Evaluations of modern grid technologies can be complemented by developing tracking metrics and systems in advance of deployment. In the case of CVR, such metrics and systems are critical to managing the data generated at each phase of deployment, from assessing the impacts of pilot projects, to oversight of established programs, to retrospective evaluation and EM&V. The most effective CVR tracking metrics and systems are typically informed by a clear understanding of the multiple objectives of a CVR project or program. Data tracked may include technical performance, such as customer counts by circuit or transformer, historical load or energy usage, as well as interval energy and voltage data. Equity metrics are another way to measure success in terms of the distribution of benefits of grid investments. These metrics are useful for identifying target populations (such as a measure of program accessibility), making decisions about investments (such as a measure of workforce impact), and assessing program impact (such as a measure of energy burden change) (PNNL 2021b). Within its new performance-based regulation (PBR) framework, the Minnesota Public Utilities Commission (PUC) identified metrics for the utility Xcel Energy to track reliability and customer service by geography, income, and other key equity benchmarks. In their 2019 order, the MN PUC directed the application of equity metrics to modern grid technologies, which could apply to the state's CVR investments (MN PUC 2019). For more information on performance metrics, refer to the Electric Utility Regulatory Frameworks and Financial Incentives chapter of the *Guide*.
- *Establishing baselines*. As with other customer-side energy efficiency investments, establishing credible energy-usage baselines is critical to estimating program impacts. Since weather and season affect customer energy use, CVR baselines are typically established by cycling voltage control on and off for a sufficient duration at different times throughout the year. Depending on system type, utilities usually follow either a day on/day off or week on/week off protocol. Because data gained from these operations are often used as proxy data for other system-wide planning efforts, it is important that they be regularly refreshed. For example, if a particular circuit experiences rapid load growth, the usefulness of its data for broader estimation purposes will quickly be reduced.

- *Assessing benefits and costs.* As discussed previously, it can be beneficial to understand the additional costs, savings impacts, and other benefits that can be realized from modern grid technology versus traditional approaches. For example, CVR can be implemented in tandem with conventional grid technology, however, additional energy savings that is realized when implemented with modern grid technologies. It is also important to include difficult-to-quantify benefits such as increased operational confidence that come from modern grid investments.
- *Understanding how benefits are allocated.* With modern grid technology, customers can increasingly consume and generate electricity, benefit from and provide grid services, and participate actively or passively in energy efficiency and demand response programs. As a result, utilities and regulators are examining opportunities to track costs and benefits at a more granular level. Depending on the policy and regulatory environment, the distribution of impacts can vary—either between ratepayers and the utility, or among different ratepayer groups. The use of multiple methods can help establish these distributional impacts. For example, comparing CVR impacts at the substation to CVR impacts at the customer meter, in combination with engineering simulations, is a useful approach for estimating the proportion of energy savings realized by the customer (compared to the energy savings the utility will realize from operational improvements).

Evaluation Resources

For additional information, EPA offers resources for state and local government staff on EM&V for energy efficiency policies and initiatives. Also, the State and Local Energy Efficiency (SEE) Action Network maintains an EM&V Resource Portal that identifies and describes the key EM&V techniques for DERs, including energy efficiency and demand flexibility. The SEE Action Network also describes five important considerations when assessing the performance of buildings that participate in demand flexibility programs: assessment objectives, defining boundaries of an assessment, performance metrics, how the metrics will be calculated, and reporting requirements (SEE Action 2020).

For utilities interested in gaining energy efficiency credit for grid-side efficiency programming, use of a third-party evaluator will be beneficial for making the case to their oversight authority. Many states require use of third-party evaluators for energy efficiency program impact evaluations.

Action Steps for States

State policymakers and utility regulators seeking to advance grid modernization to achieve affordability, resilience, and clean energy benefits and to better accommodate growing renewable resources may consider the following actions:

- *Convene a stakeholder process.* Understanding the perspectives of multiple stakeholders will become increasingly important as grid modernization efforts mature and distributed resources become more prevalent. Stakeholders may benefit from tracking the proceedings of leading states from their region and around country to gain insights on emerging issues.
- *Assess the potential for additional grid-side efficiency.* Grid-side energy efficiency has not historically been included in the energy efficiency potential studies that quantify the magnitude of efficiency that is achievable, cost-effective, and/or technically feasible. States can include grid-side efficiency deployments such as CVR in existing potential studies, or in a standalone analysis.

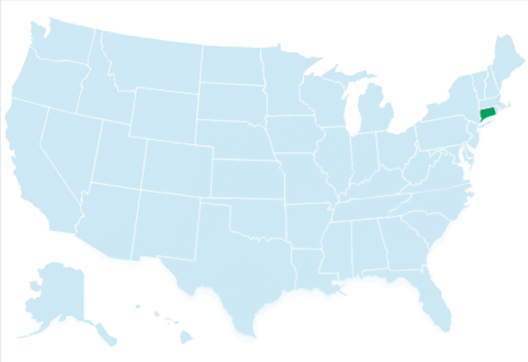
- *Assess and pursue additional opportunities for clean energy integration.* States can facilitate DER integration by using inverters to support voltage and reactive power management, accelerating the use of smart inverter functionality to support real-time grid management, and complementary deployment of demand response and storage assets.
- *Integrate grid investments in new or enhanced resource/procurement planning.* Including modern grid investments in routine utility planning efforts, such as integrated resource plans and integrated distribution plans, can increase operational confidence in grid-side energy efficiency, demand-responsive resources, and the ability of the distribution system to integrate and benefit from distributed generation and storage. As such, these resources deserve increased attention in long-term integrated resource and procurement planning efforts. For more information, refer to the Electricity Resource Planning and Procurement chapter of the *Guide*.
- *Review and modify existing policies to encourage investment.* Stakeholders interested in expanding the role for modern grid investments can review existing utility policies to determine whether they inadvertently inhibit modern grid technologies, and whether modifications or amendments are needed to facilitate additional investment. For example, utilities have found that crediting customer-side savings from CVR as part of their energy efficiency resource standards can incentivize additional deployment. Similarly, utilities in territories with "decoupling" policies in effect are neutral to the revenue losses from reduced sales associated with both CVR and customer-sided renewables. In addition, newer performance-based regulations can incentivize (and remove disincentives for) utilities to employ customer and third-party owned distributed resources (refer to the Electric Utility Regulatory Frameworks and Financial Incentives chapter of the *Guide*).
- *Conduct pilots*. Pilots can help utilities gain operational knowledge and an understanding of costs and benefits prior to broader implementation.

State Examples

Connecticut

Connecticut has taken several steps to modernize its electricity grid. In 2019, the Connecticut Public Utilities Regulatory Authority (PURA) established the Equitable Modern Grid Framework to foster innovation in solving grid challenges including hosting capacity, and exploring new opportunities like electric storage deployment, while also promoting equitable outcomes. The Framework is a four-phased process that includes deep dive investigations into eleven near-term topics with the objective of collectively and comprehensively growing Connecticut's green economy, cost-effective decarbonization across all sectors, improving grid reliability and resilience, along with cybersecurity, and enhancing affordable service for underserved communities. PURA initiated formal investigations into all eleven topics between the fourth quarter of 2019 and the fourth quarter of 2022, as has completed nine of those investigations as of November 2022 (PURA 2021b).

Connecticut Highlights Efforts to Develop an Equitable Phased Grid Modernization



For more information, refer to the following:

- PURA Framework for an Equitable Modern Grid
- Energy Storage Solutions Program
- PURA-Approved Clean Energy Programs
- Low-Income Heat Pump Water Heater Pilot

The Framework process addresses many topics, from interconnection transparency and best uses of hosting capacity maps to electric storage and light-duty electric vehicle program design. Within both the electric storage program (or Energy Storage Solutions Program) and the light-duty electric vehicle charging program (or EV Charging Program), PURA has incorporated equity into its objectives by prioritizing increased resilience and/or financial benefits for low- and moderate-income customers in environmental justice or economically distressed communities (PURA 2021a). Specifically, both programs include incentive adders above the typical program compensation for low- and moderate-income customers, with additional measures to encourage deployment of energy storage resources on distribution circuits impacted most by extreme weather. PURA has updated the interconnection standards (PURA 2020) and the regulatory guidance to incentivize electric energy storage (PURA 2021a). One initiative–the Innovative Energy Solutions (IES) program–will test technologies, products, and services to help achieve the state's clean energy and climate goals (PURA 2022).

Relatedly, in 2020 PURA established new programs specifically for behind-the-meter applications of renewable energy projects located on residential and commercial and industrial customers' premises. Both programs, the Residential Renewable Energy Solutions (RRES) and Non-Residential Renewable Energy Solutions (NRES) Programs, include provisions to promote the flow of benefits to low- and moderate-income customers consistent with the Biden Administration's Justice40 initiative. Specifically, the RRES Program includes financial adders for both low-income customers and customers located in distressed municipalities. The RRES Program also allows for direct payments between the electric utilities to project developers for the production from the renewable energy project, eliminating the perceived issue for solar developers of low-income customer credit worthiness. Similarly, under the NRES Program, which is conducted as a twice-annual reverse auction, includes bid preferences for project that provide financial benefits to customers environmental justice communities

Connecticut's grid modernization planning and investments began prior to PURA's Framework. For example, in 2017, PURA approved the utility Eversource's spending proposal for HCA and mapping tools that facilitate DER interconnections. The funding also supported an online portal to improve transparency and streamline the utility's application and tracking process for customers and developers seeking to interconnect DERs to the grid (Eversource 2017).

In 2018, the state's Department of Energy and Environmental Protection established a pilot program to provide connected ENERGY STAR electric heat pump water heaters (HPWHs) to low-income households at no cost (ACEEE 2019). At the time of the pilot, water heaters were the second highest source of home energy use and ENERGY STAR HPWHs had potential to reduce energy costs associated with water heating by up to 50 percent (ACEEE 2019). The pilot evaluated 108 homes, installed 65 HPWHs, and generated over $91,000 in yearly savings for the installed HPWHs (ACEEE 2019).

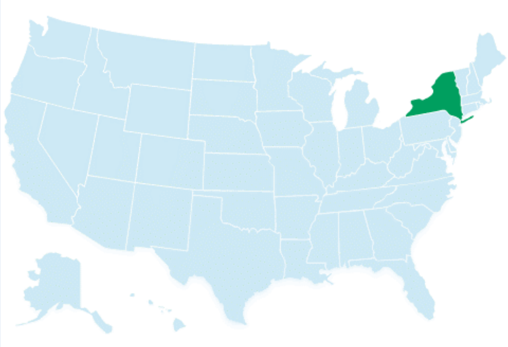
New York

New York has taken a series of planning and investment steps to establish policies and frameworks to ensure that its transmission and distribution infrastructure can reliably and cost-effectively support clean energy resources. The state has adopted policy to ensure grid modernization activities are aligned with its state clean energy and climate goals established in its Climate Leadership and Community Protection Act (CLCPA) (NY S.B. 6599 2020). Recent state actions require utilities to consider NWAs before developing traditional grid solutions, including policies to support locational value for DERs and the development of an Integrated Energy Data Resource (IEDR) (NY PSC 2021; 2019; NYSERDA 2021).

In 2020, New York passed the Accelerated Renewable Energy Growth and Community Benefit Act, which creates a State Power Grid Study and Investment Program (NYSERDA 2020). This Act requires the New York Public Services Commission (PSC) to use the findings of the Power Grid Study to support the identified needs for transmission and distribution system upgrades and planning necessary for, and aligned to, the goals established in the CLCPA. The Accelerated Renewable Energy Growth and Community Benefit Act creates an approach to accelerate grid infrastructure planning and construction to ensure renewable energy integration, while using input from, and providing benefits to, local communities (NYSERDA 2020).

New York's NWA policy has roots in the PSC's foundational "Reforming the Energy Vision" (REV) initiative, introduced in 2014, which proposed transformative changes to the state's energy industry and regulatory practices (NY PSC 2014b). The REV framework helped advance the role of the utility as a distribution platform company and encouraged customers and third parties to partner with utilities in modernizing the distribution grid and integrating clean energy (NYSERDA n.d.). REV required utilities to identify at least one NWA project and allowed utilities to propose NWA investments in lieu of traditional system upgrades. For this REV NWA program, the PSC adopted a regulatory framework and implementation plan (NY PSC 2015).

New York Has Developed Programs to Encourage Non-Wires Alternatives, Policies to Support Locational Value for DERs, and a Framework to implement an Integrated Energy Data Resource



For more information, refer to the following:

- New York Power Grid Study – Initial Report
- New York – Non-Wires Alternatives
- NY-SUN – Value of Distributed Energy Resources (Value Stack)
- NYSERDA – Integrated Energy Data Resource (IEDR)

The REV initiative built upon a 2013 rate case settlement in which the PSC required a utility to achieve demand reduction goals through investment in NWAs. The PSC directed the utility ConEd to develop the Brooklyn Queens Demand Management (BQDM) program to mitigate the projected increases in electricity demand in Brooklyn and Queens (NY PSC 2014c). The program required a reduction of 69 megawatts (MW) of peak demand through 41 MW of customer-side energy reduction, 11 MW of utility-side reductions, and 17 MW of traditional solutions (NY PSC 2014c). By 2021, the BQDM program had saved over 59 MW of peak of generation (ConEd 2021b). Through the success of the BQDM program, the PSC approved an extension in 2017, which allowed ConEd to continue the program but not exceed the initial $200 million cap on program expenditures (NY PSC 2017). Since the development of the BQDM program, other utilities in the state have made investments in NWAs (Joint Utilities n.d.).

The New York PSC also developed the Value of Distributed Energy Resources (or "Value Stack") methodology, which compensates DER customers based on several characteristics, including the demand reduction value and locational benefit of the energy resource (NY-SUN n.d.). The NY PSC issued an order in 2017 that provides a framework for establishing the value of a particular DER using the Value Stack (NYPSC 2017). Projects are also eligible for credits that recognize other benefits, such as avoided emissions (NYPSC 2017; NY-SUN n.d.). The PSC restricted the eligibility of the credits based on regional capacity limits with defined tranches (NYPSC 2017). The NY PSC updated the Value Stack order in 2019 to incorporate other compensation mechanisms, including a Community Adder to incentivize projects in certain regions (NY PSC 2019). New York State has been reviewing its compensation framework for the value of DERs and has been considering modifications in response to critiques regarding how the regional capacity tranches affected project finance for DER projects (NY-SUN 2021).

In addition to state policy developments and PSC actions that help maximize grid investments, the New York State Energy Research and Development Authority (NYSERDA) funds smart grid opportunities to support DER integration and other grid technologies and has been involved in scoping and developing an IEDR. IEDR is a new framework for data access that streamlines third-party access to customer usage and system data, which is critical to many energy efficiency and demand response programs, including building energy benchmarking (discussed elsewhere in the *Guide*). The IEDR is part of the New York State PSC Proceeding on Motion of the Commission Regarding Strategic Use of Energy Related Data (NYPSC 2021).

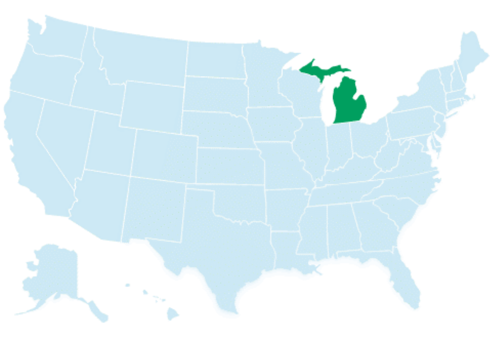
Michigan

Michigan has pursued multiple policies to drive greater grid integration of energy efficiency and renewable energy, including a grid modernization initiative launched by its Public Service Commission (PSC) and a climate executive order.

In 2019, the Michigan PSC launched MI Power Grid initiative, a three-phased approach to distribution and transmission planning, to provide a transition to a cleaner energy grid (MI PSC 2021). Phase I focused on electric distribution planning and included engagement of key stakeholders—utilities, customers, and state agencies—to consider issues such as NWAs and hosting capacity analysis for DERs (MI PSC 2021).

In 2020, Governor Whitmer issued an executive directive that ordered the Department of Environment, Great Lakes, and Energy to require IRPs filed with the state's PSC to include an analysis of their consistency with state emission targets and adding the requirement to consider environmental justice and health impacts (MI ED 2020-10 2020). The PSC accepted recommendations from a PSC staff report based on stakeholder collaboration for the MI Power Grid initiative to ensure compliance with the executive directive and to include more in-depth analysis of NWAs with IRPs (MI PSC 2020).

Michigan Launched a Multi-year Stakeholder Initiative, Power Grid, to Integrate Higher Levels of Renewable Energy and Energy Efficiency and Maximize the Benefits of the State's Clean Energy Transition



For more information, refer to:

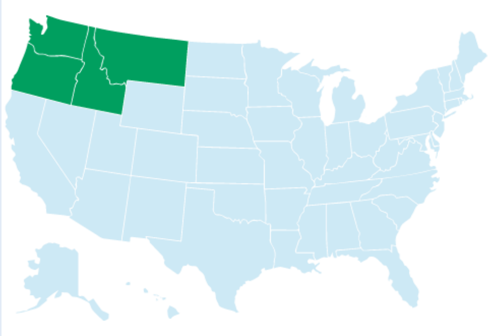
- MI Power Grid Initiative
- Phase I – Electric Distribution Planning
- Phase II – Integration of Resource/ Distribution/Transmission Planning
- Phase III – IRP filing requirements, demand response study, and energy waste reduction study

Phase II of the MI Power Grid initiative addressed the integration of the IRP process with distribution and transmission planning that is critical for utilities to meet the state's GHG and energy goals. In December 2020, the PSC filed a report recommending two options for near-term filings for utilities in addition to what is required for IRPs (MI PSC 2020). The first option requires utilities to conduct modeling to show a path toward achieving 28 percent carbon reduction by 2025 relative to 2005 with a 2 percent annual load growth rate (MI PSC 2020). The second option, which responded to stakeholder feedback for more aggressive decarbonization, requires utilities to model a 32 percent carbon reduction by 2025 relative to 2005 levels, assuming a 2 percent annual load growth rate (MI PSC 2020). Phase III of the MI Power Grid initiative focused on IRP parameters and filing requirements, and included energy waste reduction and demand response potential studies and ongoing IRP cases (MI PSC 2022).

Pacific Northwest

States in the pacific northwest coordinate their electricity system planning and contribute to grid investments in multiple ways. State utility regulators oversee the electric utility companies' planning for the operation and maintenance of distribution systems and authorize programs such as utility pilots that involve the regional transmission service provider, Bonneville Power Authority (BPA). BPA invests in transmission grid projects including those that support system energy efficiency and demonstrate grid integration of new technologies

Under the Pacific Northwest Electric Power Planning and Conservation Act (Act), Idaho, Montana, Oregon, and Washington formed a council – the Northwest Power and Conservation Council – for the purpose of developing the Northwest Power Plan (Plan), a 20-year electric plan that is revised and updated with public input every 5 years. The plan promotes collaboration with the regional Western electric grid to amplify cost savings and system efficiency (NWPCC 2021a). Congress passed the Act in 1980 and revised it in 2011 (16 U.S.C 839-839h 2011). In addition to grid efficiency, the Act promotes power reliability, public participation, and regional management of the hydropower dams and their impacts on the environment and wildlife (NWPCC 2021b). The Council's 2021 Northwest Power Plan is the eighth update to the Plan, and it prioritizes acquisition of cost-effective energy efficiency and cost-effective renewable energy. The Act requires BPA, a self-funding federal power marketer and transmission service provider in four northwest states, to acquire all necessary energy resources, ensure energy efficiency, and deploy renewable energy (NWPCC 2021b). BPA makes grid investments in a variety of categories—including voltage optimization and distribution transformer replacements, NWA, and demand response through connected products, summarized as follows:



Pacific Northwest states of Washington, Oregon, Idaho, and Montana are coordinated in their investments in grid modernization, voltage optimization, distribution transformer replacements, NWA, and demand response.

For more information, refer to:

- Northwest Power Conservation Council's "Council Brief 2021"
- Bonneville Power Administration's Grid Modernization information resources

Grid modernization. BPA invests in a range of grid projects to improve reliability and modernize assets and operations (BPA n.d.). In 2022, BPA had a modernization project portfolio of at least 12 completed projects and another 20 grid upgrades in progress (BPA 2022a). Certain grid modernization projects were prerequisites for BPA's participation in the Western Energy Imbalance Market (EIM), which BPA joined in May 2022 (BPA 2020; 2022c). The EIM is a centralized, real-time energy market that helps address and balance energy fluctuations across the power system systems of participating entities. Participation in the Western EIM, which is operated by the California Independent System Operator, provides BPA with additional grid management tools such as Bid and Base Scheduling (BPA 2022c; n.d.).

Distribution system efficiency. BPA acquires energy savings from the distribution utilities that it serves through a portfolio of energy efficiency programs, which include improvements to the electric grid. Voltage Optimization and replacement of distribution transformers with high efficiency transformers are two included measures (BPA 2021).

Non-wires alternatives. An early pioneer of the concept, BPA investigates NWA and other tools that can help to defer or avoid a major transmission infrastructure investment (ACEEE 2018). After substantial research and analysis of the construction of a 79-mile, $700 million high-voltage transmission line in Washington and Oregon, BPA canceled the project, based in part on NWA and grid congestion management tools (PNNL 2018; LBNL 2021; BPA 2017).

Connected products. BPA participates in pilot projects on emerging technologies to mitigate peak loads and inform future investments. For instance, BPA teamed with DOE's Pacific Northwest National Laboratory (PNNL), the Northwest Energy Efficiency Alliance (NEEA), Portland General Electric, and other northwest utilities to study CTA-2045, the demand-response control technology,[18] and demonstrate and evaluate the load-shifting and energy storage potential of heat pump water heaters. The study involved recruiting customers to test their electric resistance or heat pump water heaters, installing communications on the CTA 2045-equipped water heaters, and running demand response events – over 600 events including multiple demand response events every day for 220 days (BPA 2018). The results demonstrated that connected heat pump water heaters can shift load and reduce peak demand at various times of day and seasons. For example, controlled electric resistance water heaters compared to connected heat pump water heaters reduced evening peak load by 90 percent. Reduced loads in turn reduce capacity risk for utilities and energy costs for customers. The BPA team's research contributed to the Northwest Power and Conservation Council approval of a load-shifting analysis methodology[19] for water heaters in 2019 (DOE 2019).

Information Resources

Understanding the Modern Grid and Its Benefits

Title/Description
National Association of State Energy Officials (NASEO) and National Association of Utility Regulatory Commissioners (NARUC). Grid-Interactive Buildings Working Group. Grid-interactive Efficient Buildings: State Briefing Paper. (2019). This report provides a summary of how grid-interactive efficient buildings can help states manage load on the grid and ensure greater reliability.
National Association of Utility Regulatory Commissioners (NARUC) and the National Association of State Energy Officials (NASEO). The Task Force on Comprehensive Electricity Planning. (n.d.). This site offers extensive resources and provides states with a forum to discuss pathways to a more resilient grid, including optimizing DERs, storage, and grid reliability.
National Association of Utility Regulatory Commissioners (NARUC). Energy Infrastructure Modernization. Smart Grid. Center for Partnerships and Innovation (n.d.). This website contains resources about smart grid deployment, benefits, learning modules, and links to other resource.
National Governors Association. Grid Smarts: State Considerations for Adopting Grid Modernization Technologies. (2017). This paper looks at considerations in developing a modern grid, including technologies and policies that can advance this objective.
National Renewable Energy Laboratory (NREL). Advanced Distribution Management Systems. (n.d.). The website provides NREL's research regarding how advanced distribution management systems can improve reliability and resilience. The site contains a description of a partnership with the Pacific Northwest National Laboratory to develop open-source software which can help utilities test ADMS applications cheaply.
National Renewable Energy Laboratory (NREL). Advanced Power Electronics and Smart Inverters. (n.d.). NREL's research addresses how the use of advanced technologies can help provide stability to the grid by managing voltage and frequency, which can help with the integration of DERs, such as solar and storage.
National Renewable Energy Laboratory (NREL). Renewable Energy Integration. (n.d.). The website provides links to resources and tools developed by NREL for integrating DERs into the grid.
National Renewable Energy Laboratory (NREL). Smart Grid-Enabled CVR: Advanced Application for Distribution Management Systems. (2018). Provides an overview of the research and methodologies used to conduct an analysis of the energy savings obtained through CVR.
U.S. Department of Energy. What Is the Smart Grid? (n.d.). This is a resource for information about the smart grid concepts and government-sponsored smart grid projects.

[18] ANSI/CTA-2045 is a standardized grid-customer communication interface designed for appliances that have flexibility in when they use electricity (BPA 2018).

[19] To quantify the demand response impacts of residential water heaters during a demand response event, the Regional Technical Forum (RTF) of the Council developed maximum obtainable per-household technical potential estimates (NWPCC 2019).

Resources from Government Agencies, Institutes, and Networks

Title/Description
Federal Energy Regulatory Commission (FERC). Federal Energy Regulatory Commission (n.d.). FERC's website provides information on smart grid advancements, including annual assessments of demand response and advanced metering potential.
National Energy Screening Project. National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources (2020). The NSPM for DERs provides methodologies and principles for jurisdictions to assess and compare the cost-effectiveness of energy efficiency and other DERs.
National Institute of Standards and Technology (NIST). Smart Grid Group. (n.d.). This website provides an overview of smart grid technology and the development of interoperability standards to make it possible.
State and Local Energy Efficiency Action Network (SEE Action). Determining Utility System Value of Demand Flexibility from Grid-Interactive Efficient Buildings. (2020). The report discusses methods and practices to determine the economic value of grid-interactive efficient buildings to the utility system. The document includes enhancements to current evaluation practices that policymakers can use, along with ways to prioritize implementation of these suggested improvements.
U.S. Department of Energy. Advanced Metering Infrastructure and Customer Systems: Results from the Smart Grid Investment Grant Program. (2016). This DOE report provides the results of projects implementing AMI to help decisionmakers weigh the costs and benefits associated with AMI for the grid.
U.S. Department of Energy. SmartGrid.gov. (n.d.). This website is the gateway to information on federal initiatives that support the development of technologies, policies, and projects to transform the electric power industry.
U.S. Department of Energy. Voluntary Code of Conduct (VCC) Final Concepts and Principles (2015). Utilities and third parties can adopt these concepts and principles voluntarily in order to address privacy related to customer data.
U.S. Environmental Protection Agency. Conservation Voltage Reduction/Volt VAR Optimization EM&V Practices. (2017). This EPA technical resource provides background on methods for assessing energy savings potential, data tracking considerations, and current impact evaluation processes associated with the energy efficiency impact of CVR and VVO.

Resources from Energy Industry Associations

Title/Description
Advanced Energy Management Alliance (AEMA). AEMA. (n.d.). AEMA is a demand response advocacy group that maintains a directory of industry demand response resources.
Association for Demand Response & Smart Grid (ADS). Reports and Research. (n.d.). The ADS website provides links to ADS-generated reports and case studies, as well as major reports issued by government and others.
Green Building Elements, LLC. Smart Grid Interoperability Panel (SGIP). (2022). SGIP is a public-private partnership with a mission to accelerate the implementation of interoperable smart grid devices and systems. Members develop standards to help educate key stakeholders on best practices, lessons learned, and vectors of influence affecting successful integration of next-generation smart grid technologies.
Institute of Electrical and Electronics Engineers. Grid Management System – A Key Enabler of Grid Modernization. (2019). The resource provides an overview of the components of a grid management system, which replaces an Outage Management System, and is composed of an advanced distribution management system and distributed energy resource management system. The resource also shows how Southern California Edison, one of the nation's larger utilities, implemented a grid management system in its territory.
National Electrical Manufacturers Association (NEMA). NEMA maintains information on smart grid solutions, which include smart meters and high-tech sensors. In addition, the NEMA Utility Products and Systems Division provides information on standards, products, and resources to support DERs and grid modernization.
American Clean Power (formerly the Energy Storage Association). State Energy Storage Filings. (n.d.). ESA maintains a list of state legislative and regulatory proceedings that relate to energy storage.
The Gridwise Alliance. Gridwise Alliance. (n.d.). Gridwise is a coalition of stakeholders that works to transform the electric grid by creating a venue for collaboration across the electricity industry. Gridwise provides a broad range of online resources about smart grid technologies and policies.

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