7.5 Maximizing Grid Investments to Achieve Energy Efficiency and Improve Renewable Energy Integration

Policy Description and Objective

Summary

State have found that the U.S. electric grid has significant potential to deliver energy efficiency and support renewable energy integration if technology and infrastructure investments are made and managed with these goals in mind. As electricity is transmitted across long distances and then distributed by underground or overhead wires to our homes and businesses, it undergoes a number of conversions and during each conversion some energy is lost as heat.[107] The U.S. Energy Information Administration estimates that on average 7.5 percent[108] of the electricity produced to serve customers is lost in transmission and distribution, with losses ranging from 5 to 13 percent depending on location (Wagner et al. 1991, as cited in DOE 2012).[109] Modern grid investments can provide grid operators with tools to better visualize and control conditions across the electric system, enabling them to reduce system losses, better accommodate intermittent renewable resources, and help customers use less energy.

State-regulated transmission and distribution investments have traditionally been made with a goal of providing economic, reliable service that alleviates congestion, allows recovery from outages, and expands to meet new or growing loads. While these remain primary goals, states also are working to encourage investments that are planned and managed to increase system energy efficiency, anticipate growth in renewable resources, and deal with related issues of balancing utility revenue requirements with customer rates. This section focuses on what states and public utility commissions (PUCs) are doing—primarily at the distribution level (i.e., actions that do not involve interstate transmission planning)—to realize clean energy benefits from the electric grid.

Objective

Enabled by new and emerging technologies coupled with aging transmission and distribution systems, states are finding that if intentionally designed and managed, modern grid investments will not only provide necessary grid services but also deliver energy efficiency benefits and better accommodate renewable resources. Since many of these investments will last for 15 to 50 years, ensuring that modern grid investments are planned and managed with these objectives in mind is an important policy and planning goal.[110] While not captured neatly by any single mechanism, these objectives are nonetheless being advanced through interrelated policies and state and PUC decisions throughout the nation. This section provides state policymakers and interested stakeholders with background on emerging opportunities and steps that can be taken to lay groundwork for future grid investments to support greater energy efficiency and renewable energy penetration.

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[107] Weather and other physical factors also contribute to line losses.

[108] Line losses estimate is based on the historical difference between total net generation (minus direct use) and retail sales of electricity, as cited in the Clean Power Plan (EPA 2013) and derived from EIA (2012).

[109] Nearly all of these losses are physical in nature (as opposed to theft, for example).

[110] See, for example, BPA (2010).

Benefits

Maximizing modern grid investments to increase transmission and distribution system efficiency and support renewable generation integration has the potential to deliver significant environmental benefits:

- Pacific Northwest National Laboratory estimates that a comprehensive nationwide effort to better manage distribution system voltage could reduce annual energy consumption by 3.2 percent and reduce related carbon dioxide emissions by more than 63 million tons (PNNL 2012).[111]
- Grid investments could also 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).
- Strategically located renewable resources, energy efficiency investments, and demand response capabilities can be targeted to alleviate grid congestion and defer capital investments. The flexibility of these resources can reduce the need to dispatch economically inefficient generation resources. Conventional generation resources also often need advanced notice to come online and need to run longer once started, even if periods of peak electricity demand are short. Storage and demand response do not usually need the same advance notice.

In addition, the ability to deliver energy efficiency and improve the integration of distributed renewables provides additional benefits for making the business case for modernizing electricity distribution systems.

Technical Background on Key Opportunities

Modern grid investments can enable better visibility into grid conditions throughout the distribution system, can allow two-way communication between the utility and customers (or their devices), and can enable automation to respond to grid conditions in real time. However, no single technology or combination of technologies delivers modern grid benefits. The way technologies and grid assets are managed is critical to achieving the promise of a modern grid. This section provides a technical overview of some of the energy efficiency and renewable energy benefits that states can realize if modern grid investments are planned for and managed with these resources in mind.[112]

Energy Efficiency Opportunities

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. These interrelated opportunities are discussed below:

- *Improved voltage management.* Throughout the United States, electricity is required to be delivered to most customers within a narrow range of voltages. For example, residential customer voltage is typically between 114 and 126 volts (for normal 120-volt service).[113] Delivering electricity closer to the lower end of

[111] Technical potential based on feeder modeling of representative high-value circuits; does not address time horizon for achievability.

[112] A fully integrated modern grid is likely to enable greater potential for cost-effective energy efficiency and renewable energy opportunities from smart grid and advanced microgrid technologies. The *Guide to Action* focuses on some of the better-established, nearer=term opportunities that states can realize if grid investments are planned for and managed with energy efficiency and renewable energy goals in mind.

[113] 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.

this voltage range can save customers energy, because some equipment operates more efficiently at lower voltage (e.g., closer to 120 volts). For example, voltage reduction of incandescent lighting will generally reduce waste heat and therefore save energy. Not all customer devices will save energy by reducing voltage. For many water heaters, operating at the lower end the voltage range reduces immediate demand, but ends up using the same amount of energy to reach a target water temperature setting. Other loads, like today's fluorescent lamp ballasts, are likely to draw about the same amount of power regardless of voltage.[114]

Since the equipment used within homes, buildings, and industry varies, the potential for energy efficiency benefits also varies. In addition, some distribution circuits already operate in the lower band of voltage (i.e., 114–117 volts), further adding to the geographic variability of energy efficiency potential. Operating the transmission and distribution system at lower voltages to achieve energy efficiency benefits has historically been referred to as conservation voltage reduction (CVR). While CVR is a fairly 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. Rapid communication with controls, as well as the ability to automatically respond to grid conditions, offers the potential for greater energy savings. The improved information also increases operational confidence among grid managers and regulators. While performance can vary by circuit, many utilities find 1 to 4 percent savings on initial deployment (PNNL 2010).

- *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.[115] (This is referred to as reactive power and is measured in vars).[116] Since motors are ubiquitous in equipment found in factories, businesses, and homes, transmission and distribution system 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. 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 (NEMA n.d.).
- *More efficient distribution transformers.* Distribution transformers are devices that are used to transfer current from one circuit to another and change the value of the original voltage or current as needed. A significant amount of all electricity network losses are due to distribution transformers. The use of more efficient medium voltage, liquid-immersed distribution transformers has the potential to yield large energy and monetary savings when projected over the products' lifetime. Despite substantial improvements made

[114] More information on power consumption responses to voltage is available in PNNL (2010) or Bokhari et al. (2014).

[115] 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.

[116] Vars or var is the measure or reactive power in electric transmission and distribution systems. The term is derived from "volt-ampere reactive."

to distribution transformer efficiencies over recent years and new Federal efficiency standards set to take effect in 2016, EPA estimates that additional savings of up to 4 to 5 terawatt-hours per year can be achieved through identification and further deployment of the most efficient transformers available on the market today (EPA 2014).[117]

- *Strategic use of customer data/big data.* To customers, changes in utility meters may be the most noticeable new technology investment. These new meters, which are also referred to as smart meters or advanced metering infrastructure (AMI) meters, have sometimes caused controversy related to privacy concerns and billing accuracy among customers. Nonetheless, they have several operational advantages over conventional meters: they enable utilities to read meters without having to go to customer addresses, can facilitate same-day stop/start service when tenants move, and can help in detecting outages during storms to speed service restoration. AMI meters, along with sensors along distribution circuits, are giving utilities access to an unprecedented amount of data about their system and the customers they serve. For example, AMI meters can deliver consumption data at various intervals (e.g., hourly, 15-minute or 5-minute interval consumption data). Utilities are beginning to explore how to capture, store, analyze, and take advantage of "big data" to inform the following applications:
  - *Customer-level voltage and reactive power monitoring.* Modern AMI meters can be programmed 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.
  - *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, the Web, and automated data transfer services. 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 (SEE Action 2013).
  - *Behavior-based energy efficiency programs.* Utilities are combining insights from behavioral science with energy use information to inform new energy efficiency program offerings. These behavior-based programs 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 (CEE 2014).
  - *Facilitating change in energy use in response to price signals.* Though not yet common in all deployments, some AMI meters can facilitate a two-way flow of information between the utility and the customer. When coupled with time-varying rates (see Section 7.4) that better reflect the price of electricity (which varies throughout the day), this information can encourage customers to shift consumption to lower-cost periods and support efforts to reduce peak demand (SEE Action 2014).
  - *Energy efficiency program planning, implementation, and evaluation.* AMI data can be analyzed for usage patterns to inform energy efficiency opportunities (for example, fluctuating usage may indicate that equipment is cycling on and off often, indicating that an appliance is improperly sized or ready for replacement). These data can inform program planning and targeting efforts. Some programs have begun pilot efforts to analyze data to provide virtual energy audits for interested customers.[118] Research is also underway to better understand how the more detailed energy usage data from AMI

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[117] Given the aggregate energy losses of millions of medium voltage distribution transformers, EPA recently launched a stakeholder process to develop criteria for ENERGY STAR designation.

[118] Pacific Gas and Electric in California and Con Edison in New York are two such examples.

can be used to inform evaluation, measurement, and verification of energy efficiency programs (PEEC n.d.).

Renewable Energy Integration Opportunities

Generally, transmission and distribution system losses increase as the distance between generation and customer load increases. When renewable energy is located in the distribution system close to customers, it can reduce losses.[119] To take full advantage of increasing renewable resources in the distribution system, state PUCs are working with utilities to better understand how distributed renewables can be managed and integrated into the system. Improved voltage and reactive power management, together with the aid of modern inverters and complementary deployment of demand response and storage assets, show promise for helping maximize the clean energy contribution of renewable resources.

- *Improved voltage and reactive power management with modern inverters.* Utilities and state PUCs are increasingly looking to strategies like improved voltage monitoring and management in anticipation of more distributed renewables coming online. The greatest effects will likely be felt in distribution feeders—the final stage in the delivery of electric power to individual consumers. Traditionally, these feeders were designed for one-way power flow—from substation to customer. Similar to the branches of a tree, feeders have their heaviest loading near the substation with decreased loading as the various branches reach their ends. Generally, the voltage on distribution feeders also falls at points farther from the substation. Utilities have traditionally managed these voltage drops using conventional technology. Adding distributed generation on longer circuits can boost voltage to help reach end-of-line customers, but the distribution system must still stay within acceptable voltage levels.

  Combined with other modern grid technologies, advanced inverter systems used with solar and wind generation have the potential to further benefit the system by improving control of feeder voltages. In general, it is advantageous to locate solar generation near substations because electricity generally flows from generation to load. However, voltage also 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. Many of the inverters being installed in the United States today have smart capabilities that are not yet in use. Government and industry are working to develop standards for how advanced inverters will work in the U.S. market (Solar Oregon 2014).

- *Complementary deployment of demand response and storage.* Since demand is variable and not completely predictable or controllable, grid system operators typically rely on conventional fossil-fuel-fired peaking power plants to balance generation and demand. This balancing happens on time scales from seconds to hours. Since some renewable generation is intermittent, as the amount of renewable generation is increased, balancing becomes more challenging. Adding flexible loads through demand response and storage has the potential to help system operators balance supply and demand without the need to start up economically inefficient power plants for short periods solely to provide additional balancing capability.

[119] This advantage applies to all distributed generation, not just renewable energy generation.

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. 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. Utilities have begun conducting pilot programs to automate demand response by communicating with the building energy management systems of participating commercial customers. The emergence of ENERGY STAR products with connected functionality (see text box), combined with automation, may increase the willingness and ability of residential customers to participate in demand response initiatives.

ENERGY STAR® Products with Connected Functionality

To help advance the market for products with connected functionality that can offer immediate consumer convenience and control as well as energy and demand savings, EPA has developed connected criteria for several appliance categories as well as pool pumps. ENERGY STAR products with connected functionality offer:

- Convenience: communicate with other devices and services, provide alerts and maintenance information.
- Personalized insights: provide energy usage feedback.
- Energy and cost savings: provide a means of optimizing energy use to enable savings.
- Control: remotely control energy settings either through a consumer or utility device.

By recognizing ENERGY STAR-certified products with connected functionality, EPA hopes to encourage manufacturers to design products that offer consumer convenience and control and ultimately help customers manage their energy usage directly or enable their participation in utility demand response programs.

In addition, storage is being used to support renewable energy integration. For example, storage can be used to store excess renewable energy for later use; it can be installed close to where energy will be consumed, potentially alleviating congestion on transmission and distribution systems during peak periods; and certain storage technologies with rapid response capabilities can be used to 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.

States with Policies to Encourage Energy Efficiency and Renewables Integration in Grid Investments

As noted in previous sections, efforts to ensure that modern grid investments include energy efficiency and support the growth in renewable resources are not captured neatly by any single policy mechanism. Therefore comprehensive data on the extent of these efforts are not widely available. Nonetheless, there have been a few notable efforts in California, Massachusetts, and Hawaii to convene multiple stakeholders to address diverse perspectives including environmental considerations in planning grid modernization efforts (see *State/Regional Examples* for additional information).

A growing number of states have gained experience with modern grid deployments in part due to the American Recovery and Reinvestment Act of 2009, Smart Grid Investment Grants. Overseen by the U.S. Department of Energy (DOE), Smart Grid Investment Grant matching funds totaling $3.4 billion were awarded to nearly 100 recipients to accelerate the modernization of the nation’s electricity infrastructure. As a result, a growing number of states, PUCs, and utilities have gained operational experience with enabling technologies and related enhanced operations. In addition, since award recipients were required to co-fund projects, many states and utilities have gained experience with funding grid modernization efforts (See Table 7.5.1). States are also gaining knowledge and operational experience by supporting microgrid projects at state universities or critical facilities. (See text box, “Campus Microgrids Serve as Laboratories of Learning.”)

Table 7.5.1: States with Policies to Advance Energy Efficiency and Renewable Integration in Grid Investments

Policy	Description	States
Stakeholder process for grid modernization	Has convened or initiated a stakeholder process to determine how to plan for and implement modern grid investments.	CA, HI, IL, MA, NY, VT
Pilot for voltage management to improve energy efficiency	At least one utility in the state has implemented pilot effort testing the ability of modern grid investments to better manage voltage with the explicit goal of achieving energy efficiency benefits.	AZ, CA, CO, IL, NV, OH, RI, WA
Credit for voltage management for energy efficiency as a resource	Has policies or plans to enable utilities to count energy efficiency from improved voltage management toward energy efficiency goals or resource standards	Pacific NW (ID, parts of MT, OR, UT, WA, WY), AZ, IN, MD, NC, PA
Decision about cost recovery for grid investments that deliver end-use energy efficiency benefits	Has made an initial decision on cost-recovery for grid-side investments that deliver end-use energy efficiency benefits. This does not include compensating for lost revenue associated with reduced sales. Maryland however does have revenue decoupling (see Section 7.2 for more on this topic).	Recovery through rates: MD Recovery through other mechanism: IN, Pacific NW (WA, OR, ID, parts of MT, WY, UT)
Policy on customer access to energy usage data	Has policies supporting customer access to their own energy usage data.	CA, CO, IL, OK, PA, TX, WA

A few states are planning for and crediting grid-side efficiency in their energy efficiency goals. The Northwest Power and Conservation Council—which coordinates supply planning for the Columbia River basin and serves Washington, Oregon, Idaho, and parts of Montana, Wyoming, and Utah—targets distribution energy efficiency in its most recent power plan. Arizona, Maryland, North Carolina, and Pennsylvania have also approved voltage management for energy efficiency and will allow it to count toward their energy efficiency goals.

Big data is also presenting opportunities for utilities to enable greater energy efficiency. As utilities explore how to capture, store, analyze and take advantage of big data, state regulators are grappling with issues of data access and privacy. Several states including California, Colorado, Illinois, Oklahoma, Pennsylvania, Texas, and Washington have policies giving customers access to their own data, though application of this principle to support greater energy efficiency varies (SEE Action 2012). In addition, utilities and third parties can voluntarily adopt DOE's Voluntary Code of Conduct, which includes concepts and principles regarding customer data privacy.[120]

States also are encouraging utilities to increase customer access to energy usage data through mechanisms such as Green Button and Web services to exchange data with Portfolio Manager, EPA's ENERGY STAR building benchmarking tool. Regardless of the mechanism used, states must also balance customer privacy with ease of data access (SEE Action 2013). States are beginning to explore use of demand response to assist with grid operation and the integration of renewables. Currently, at least one utility in every state offers some form of

[120] DOE's Office of Electricity Delivery and Energy Reliability and the Federal Smart Grid Task Force facilitated a multi-stakeholder process to develop the Code. The Final Concepts and Principles, as released on January 12, 2015, are available at http://www.energy.gov/sites/prod/files/2015/01/f19/VCC%20Concepts%20and%20Principles%202015_01_08%20FINAL.pdf.

demand response through load management programs and/or pricing programs. Even though demand response is being offered across the country, automation of demand response to provide additional grid services and support the integration of renewable energy is not yet widespread. For example, the California Energy Commission is exploring policies to expand the amount of automated demand response resources for renewable energy integration (CEC 2013).

Similarly, states are enacting policies and regulations to encourage the demonstration and deployment of storage to complement the integration of greater renewable energy in a modern grid. For example, California has mandated 1.3 gigawatts of storage statewide by 2024 and requires future renewable portfolio standards plans in the state to comply with the storage decision (CPUC 2014a). Washington State enacted two laws related to energy storage: the first enables qualifying utilities to credit energy storage output of renewable sourced energy at 2.5 times the normal value in meeting the state's renewable energy targets, and the second requires electric utilities to include energy storage in all integrated resource plans (Washington House of Representatives 2013a, 2013b). Lastly, the New York Battery and Energy Storage Technology Consortium is an example of leveraging a public-private partnership to research storage technology and manufacturing and aid energy storage organizations and other stakeholders on policies and programs that could improve energy storage.

Campus Microgrids Serve as Laboratories of Learning

"Microgrid" refers to a group of interconnected distributed generators (such as solar panels and diesel generators), storage, combined heat and power (CHP) systems, distribution lines, controllable loads, and associated communication and control systems. A microgrid can be designed to meet some or all of the power needs of a facility or campus and may or may not be connected to the larger electric grid. When connected to the grid, a microgrid can be designed to island itself during a power outage to serve all or part of the load of the facility or campus. A grid-connected microgrid can also be designed and managed to serve as a multi-function grid resource, providing reliable and resilient electricity supply, load shedding, and other important grid services. To date, most microgrids have been developed for critical applications, such as military installations, and for university campuses, where they also serve as laboratories of learning. For example,

- The University of California, San Diego (UCSD) operates a microgrid that generates roughly 95 percent of its own energy and saves more than $8 million annually compared to importing the same amount of energy. UCSD leveraged various state energy efficiency and clean energy programs, federal grants, the university's capital investment budget and other sources to fund their microgrid build out. UCSD's microgrid consists of a CHP system; solar power; a fuel cell; battery energy storage systems; and flexible loads including a thermal energy storage tank, electric and steam driven chillers, and building level demand response. The performance of all of the systems is recorded using a centralized monitoring system, giving UCSD access to key data points that can help to continually improve the operation of the microgrid. The UCSD microgrid serves as a testbed for campus research including research on how to utilize its microgrid to provide renewable integration services. (See http://calsolarresearch.ca.gov/funded-projects/73-innovative-business-models-rates-and-incentives-that-promote-integration-of-high-penetration-pv-with-real-time-management-of-customer-sited-distribut and http://sustainability.ucsd.edu/highlights/microgrids.html).
- In addition to providing economic benefits and the potential to supporting clean energy integration, microgrids are getting increased attention for their ability to island from the grid during severe weather events or other electricity service disruptions. Princeton University gained national recognition for the successful performance of its microgrid in the wake of Hurricane Sandy. The campus has a gas turbine generator and nearby solar field capable of producing 15 megawatts. After the hurricane, Public Service Enterprise Group restored energy to the campus long enough for Princeton to restart its generator before the utility grid went out again. The campus was able to serve as a staging ground for firefighters, paramedics, and emergency service workers for a day and half until the larger electric grid was restored to service (Princeton University 2014).

Designing Effective Policies

A number of key issues have emerged from state and PUC efforts to advance grid modernization, including 1) who participates and in what aspects of the grid modernization dialogue; 2) key considerations such as what needs to be considered in design, how to gain operational experience operating a modern grid, and how to fund and make the business case for investments; and 3) how to balance ratepayer costs and benefits.

Participants

- *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 in a given 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.
- *PUCs/utility boards.* PUCs and utility boards of municipal or cooperative utilities oversee goals, investments, and ratemaking for electric utilities. Most of this oversight is found in specific regulatory proceedings, including those for modern grid investments. These proceedings range from those that approve pilot efforts to those that define what resources count toward energy efficiency resource standards, determine AMI investment, or modify rate structures. For investor-owned utilities, PUCs also deliberate on a range of topics—such as transmission and distribution capital plans and planning standards—through periodic general rate case proceedings. PUCs and utility 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 commission 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 and about being compensated 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). (See Section 7.2.) 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.
- *Regional transmission organizations (RTOs)/independent system operators (ISOs).* About 60 percent of U.S. electric power supply is managed by RTOs or ISOs: independent, membership-based organizations that ensure reliability and usually manage the regional electric supply market for wholesale electric power. In the rest of the country, electricity systems are operated by individual utilities or utility holding companies (EIA 2011). RTOs/ISOs engage in long-term planning that involves identifying effective, cost-efficient ways to ensure grid reliability and system-wide benefits. Coordination and cooperation between utilities, state PUCs, and RTOs/ISOs is often required to advance energy efficiency and renewable energy integration goals in grid modernization efforts.
- *Public interest organizations.* Groups representing consumers, environmental interests, and other public interests are often involved in offering technical expertise as well as public perspectives. Consumer advocates are often concerned with maintaining low rates and ensuring equitable treatment of all customer classes. Environmental advocates are often concerned with ensuring that all cost-effective energy efficiency is considered and that robust funding for traditional energy efficiency programming is maintained; in some areas they may also advocate for transmission and distribution investments to

support renewables' integration. Increasingly, public interest organizations are interested in privacy and data access issues associated with AMI as well as in ensuring that utility business models are increasingly aligned with public interest goals.

- *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 including those that work to 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.
- *Customer/general public.* 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, interest in renewable energy, and data access and privacy. In general, it is advisable to provide customers with proactive education and outreach on the installation of AMI meters and any changes to billing or rate structures.

Key Design Considerations

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 and as a result 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 consideration of how to better integrate utility functions and policy goals to achieve the multiple objectives of grid modernization. Key considerations during the design of state or PUC policies for modern grid investments include:

- The prudent level of investment given the state of the market, considering local conditions and system needs, existing investments, the availability of external 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 these technologies and practices.
- How to balance customer rates and utility revenue requirements.

The following section provides more information on these key policy design considerations.

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 planned pilots, and key design considerations moving forward (see *Program Implementation and Evaluation* later in this section). 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 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 identify any regulatory issues, such as how property rights for new assets will be assigned, that will require further legal review or action. PUCs are not normally involved at this stage but can have influence whether such evaluation occurs by calling for an assessment of grid side energy efficiency potential or requesting utilities in their jurisdiction consider pilot efforts to deliver grid side efficiency or improve the integration of distributed renewables.

Gaining operational experience

Most utilities conduct pilot initiatives to gain experience with new technologies and new operational practices before larger-scale investment. A significant number of utilities have already gained some 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 (see *Interaction with Federal Programs* and *Information Resources*, respectively). Pilots and demonstration projects may be subject to PUC or board approval. During pilots it is helpful to establish clear milestones and a process for reviewing progress against them, and to track actual costs and benefits and compare them to expectations. 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, states, PUCs, and utilities have found it helpful to apply a comprehensive benefit-cost analysis that accounts for the risk associated with some of these investments. The Bonneville Power Administration (BPA) recently conducted an interim analysis of the smart grid regional business case for the Pacific Northwest (BPA n.d.) that accounted for the range of uncertainty and evaluated investments based on energy efficiency benefits, reliability benefits, and improved operational efficiency. Importantly, their assessment took into account only the net benefits and costs from adding modern or smart grid capabilities compared to the benefits and costs of traditional technologies/approaches. Their interim assessment found that benefits significantly outweighed costs for modern grid investment and management strategies targeted to improving grid reliability, optimizing voltage and reactive power to achieve energy efficiency, and automating demand response to enable customers to respond to signals provided through the electricity supply chain (BPA n.d.).

Note that costs and benefits will vary by location and specific operating situations. The same technology can have a very different implementation cost 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 broken down into similar groupings of circuits, which can then be separately analyzed in terms of costs and benefits. In addition, modern grid investments often interact with one another, and that needs to be taken into account. Often investment in one technology helps avoid costs in the implementation of another technology. On the benefits side, care needs to be taken to avoid double-counting benefits, particularly when multiple technologies are being considered. In addition, it is often challenging to value the services technologies will enable when they do not yet exist across the population.

Funding and cost recovery

Modernizing the electric grid requires an investment of time, money, and human capital. Some believe that, in the long run, a rethinking of the utility business model is needed so that utilities no longer recover fixed operating costs based on the volume of electricity they deliver to customers or receive compensation based on capital investments they make to provide service but for the broader services they provide to customers and society. In most 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 a few 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 as part of a larger conversation about grid modernization (see *State/Regional Examples*).

In the near term, 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 (see Section 7.1) and access to capital has been cited as a key barrier by some utilities (NEEA 2014). 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 energy efficiency benefits to customers. A growing number of utilities receive compensation for revenue lost from reduced sales attributable to their energy efficiency programs (see Section 7.2).

Interaction with Federal Programs

Several federal-level programs and efforts are targeted toward fostering grid modernization. Combined, the Smart Grid Investment Grant and the Smart Grid Demonstration Program (authorized by the Energy Independence and Security Act [EISA] of 2007 and amended through the Recovery Act) authorized $5 billion to accelerate grid modernization activities across the country. Smart Grid Investment Grant projects spanned AMI, customer systems, distribution system upgrades, transmission upgrades, equipment manufacturing, and cross-cutting systems. Smart Grid Demonstration Program projects focused on verifying the viability, costs, and benefits of regional smart grid demonstrations and on projects demonstrating the use of energy storage systems to provide grid services and renewable resource integration.[121] These funding sources were in addition to the direct project funding from the U.S. Department of Agriculture's Rural Utility Service for rural electricity delivery infrastructure. The EISA also called on the National Institute of Standards and Technology to coordinate the development of a framework that includes protocols and model standards for information management so that smart grid devices and systems work together. The resulting Smart Grid Interoperability Panel work is now administered through a public-private partnership (see http://www.sgip.org).

Because of the diversity of technologies and applications that fall under the umbrella of grid modernization, there are several other agency efforts and programs that support different aspects of grid modernization as co-benefits of their primary work, such as energy efficiency, economic development, security, and consumer protection. The Federal Smart Grid Task Force,[122] established under Title XIII of the EISA and led by DOE's Office of Electricity Delivery and Energy Reliability, is designed to ensure awareness, coordination, and integration of the diverse activities of the federal government related to smart grid technologies, practices, and services across federal agencies. Given the nexus between smart grid and the need for rapid data

[121] For information on Smart Grid Demonstration Program projects, see http://www.smartgrid.gov/recovery_act/overview/smart_grid_demonstration_program.

[122] For more information on the Federal Smart Grid Task Force, see https://www.smartgrid.gov/task_force.

communications, the U.S. Department of Commerce, National Telecommunications and Infrastructure Administration's Broadband Technology Opportunities Program (funded through the Recovery Act), has also resulted in partnerships between broadband providers, electric cooperatives, and communities that would otherwise be underserved by broadband deployments.

Interaction with State Policies

Modern grid investments can enable or facilitate a range of state policies focused on reducing costs, improving the environment, promoting innovation, and enhancing reliability. However, some of the policies do not provide the appropriate mechanisms or incentives to capture all of the available capabilities and benefits. As modern grid applications continue to emerge, states are reviewing policies to determine how to take better advantage of the additional capability of the modern grid.

For example, investments that can reduce customer energy use (such as CVR) do not typically count toward a utility's energy efficiency resource standard or similar goals. Other policies that encourage more renewable generation, such as renewable portfolio standards (see Chapter 5), may be facilitated by increased flexible loads and advanced demand response if implemented in a coordinated way. Similarly, customer information programs that use AMI data may improve energy efficiency deployment and encourage energy-saving behaviors. However, many utilities that provide such information programs to customers are not evaluating, measuring, and verifying energy savings.

Program Implementation and Evaluation

Implementation

Within a utility, senior leadership as well as multiple operating units within the company are often involved in deploying, managing, monitoring, and measuring programs or initiatives that leverage grid modernization investments for load reduction or energy efficiency. Utilities have cited establishing coordination across departments as a key step for success. It is helpful for states and their PUCs to understand these operational complexities in setting realistic timeframes for pilot efforts 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 specific 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 incorporated into any demonstration that could 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 also 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 awareness of new technologies among customers, making the business case for implementing modern grid investments for energy efficiency and peak load reduction, and engaging in related regulatory proceedings.

Oversight

The primary oversight of utility distribution modernization efforts is the state PUC or utility board, depending on utility type. These entities generally approve capital investments, establish the policies that govern investment and operation of the electric grid, and ensure fair treatment and equity between the ratepayer and the utility and among ratepayers.

Decision-makers generally have both formal and informal options available for oversight. For example, formal PUC processes are often handled through dockets with evidence-based hearings and opportunities for public comment.[123] 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 processes may lead to formal processes, but in the meantime they allow decision-makers to engage and learn without the limitations associated with rules of evidence, enabling a deeper exploration of the pros and cons of the full range of opportunities.

Evaluation

Some states are requiring utilities to evaluate the benefits of modern grid deployments similarly to other energy efficiency, renewable energy, and CHP initiatives, as illustrated below using CVR as an example.

- *Understanding potential.* As discussed previously, the potential of voltage management to deliver energy efficiency to customers will vary by circuit; it is best informed by breaking service territories down into groups of circuits similar in length, current voltage levels, customer class, and other technical characteristics. Utilities often conduct modeling to inform which circuits are best suited to voltage management. Once operational experience is gained on a mixture of circuits, utilities can understand and target high-value circuits for future deployments.
- *Developing tracking metrics and systems*. All evaluations benefit from developing tracking metrics and systems in advance of deployment. These need to be informed by a clear understanding of the multiple objectives of a deployment.
- *Establishing baselines.* As with other energy efficiency investments, establishing credible baselines is critical to claiming program impacts. In the case of CVR, since customer energy use naturally depends on weather and season, it is common to cycle 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.

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[123] See Section 7.1, "Electricity Resource Planning and Procurement," for more information on formal processes PUCs use to approve utility investments.

- *Assessing benefits and costs.* As discussed previously, it can be beneficial to understand the additional costs and the additional benefits that can be realized from implementation using modern grid technology versus traditional approaches. For example, CVR can be implemented with conventional grid technology, however additional energy savings could be realized from modern grid technologies. It is also important to take into account difficult-to-quantify benefits such as increased operational confidence that come from modern grid investments.
- *Understanding how benefits are allocated.* In a modernizing grid, customers are increasingly able to both consume and generate electricity, can both benefit from and provide grid services, and can participate knowingly or passively in energy efficiency or demand response programming. As a result, utilities and regulators are increasingly interested in tracking costs and understanding 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 combined with engineering simulations are useful for estimating the proportion of energy savings the customer will realize (compared to the energy savings the utility will realize from operational improvements).

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

State and Regional Examples

Massachusetts

In October 2012, the Massachusetts Department of Public Utilities began an investigation into what a grid modernization initiative should look like (Massachusetts Department of Public Utilities 2014a). A working group was established to gather input from various grid-facing and customer-facing stakeholders and make recommendations. After further deliberation and review, the Department issued an Order in June 2014 requiring all of the state's utilities to develop and submit 10-year grid modernization plans designed to 1) minimize outages and 2) reduce system and customer costs through optimizing demand, facilitating integration and higher penetration of distributed resources, and improving management of assets and personnel (Massachusetts Department of Public Utilities 2014b). Utilities were also required to submit 5-year capital investment plans in support of these goals. In a separate but related order, the commission requested that utilities establish time-varying rates as their default rates (Massachusetts Department of Public Utilities 2014c).

California

California was an early innovator in grid modernization, with the California Public Utilities Commission (CPUC) producing its first grid modernization plan in 2010 (CPUC 2014b). Utilities are now required to submit annual Smart Grid Deployment Plan updates to CPUC, and CPUC in turn produces an annual Smart Grid Report for the Governor and legislature detailing annual progress. California has become one of the first states to achieve near complete coverage of AMI across all its utility service areas, and CPUC has put forth several measures to address the questions of data access and consumer privacy that AMI brings to the forefront (CPUC 2014c). The California Energy Commission is also exploring policies to expand the amount of automated demand response resources for renewable energy integration (CEC 2013). California, along with other states in the Western Electricity Coordinating Council, has initiated a program to deploy technologies that help operators better integrate renewables through monitoring grid conditions and receiving real-time automated alerts (California ISO 2011).

Maryland

As part of its order transitioning into the next 3-year phase of the Empower MD Energy Efficiency Act of 2008, the Maryland Public Service Commission, "intrigued by the opportunities for highly cost-effective savings that CVR programs could create," approved one proposed utility CVR program and directed all other regulated companies to develop or accelerate CVR programs. In the same order, the Commission requested that utilities recover the costs of their CVR programs in rates rather than through the Empower Maryland Surcharge, allowed the companies to count their projected energy savings generated by their respective CVR programs toward their EmPOWER energy efficiency goals, and requested companies to track and separately report the costs of their CVR programs to determine cost-effectiveness (MD PSC 2011).

Indiana

In Indiana, the legislature created a new tracker, which is overseen by the Indiana Utility Regulatory Commission, to encourage utility investment in transmission, distribution and storage system improvements. Traditionally, these costs would have been included in rates for recovery in a base rate case. The tracker enables utilities to recover these costs on a more regular basis. Before costs can be passed through to consumers, the utility is required to submit a 7-year plan that is subject to public comment and approval by the Indiana Utility Regulatory Commission. The utility is also required to undergo a rate case in that 7-year period (Indiana General Assembly 2013).

Pacific Northwest

The Northwest Power and Conservation Council, in its Sixth Conservation and Electric Supply Plan, targets 400 average megawatts of savings from utility distribution systems by 2029. As a wholesale electric power marketer and transmission operator in the Northwest, BPA contributes to achieving the goals set forth in the plan. Through its Energy Smart Utility Efficiency Program, BPA offers incentives of $0.25 per kilowatt-hour to acquire utility distribution sector energy savings including voltage optimization and high-efficiency transformers (BPA 2012, 2014; NPCC 2010).

What States Can Do

States and their PUCs interested in advancing grid modernization efforts to achieve energy efficiency benefits and anticipate the need to better accommodate growing renewable resources may wish to consider the following actions:

- *Conduct pilot-scale efforts*. Pilot studies can help utilities gain operational knowledge and an understanding of costs and benefits prior to broader implementation and can inform energy efficiency, CHP, and distributed renewables potential.
- *Assess energy efficiency potential.* Grid-side energy efficiency has not historically been included in energy efficiency potential studies. States can consider including grid-side efficiency deployments such as CVR in existing potential studies or as a separate effort.
- *Integrate in resource/procurement planning.* Modern grid investments 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 resources such as CHP and renewable energy. As such,

these resources deserve increased attention in long-term integrated resource and procurement planning efforts.

- *Review policies to encourage investment:* Particularly for states that have already gained operational knowledge with modern grid deployments, review of the role of existing utility policies in inhibiting or encouraging investment in modern grid technologies can be beneficial to encouraging larger scale deployment. For example, utilities have expressed that crediting customer energy efficiency benefits from CVR as part of their energy efficiency resource standards as an important incentive to moving forward with deployments. Similarly, utilities that have decoupling policies in effect are neutral to the revenue losses from reduced sales associated with both CVR and customer-sided renewables. (See Section 7.2.)
- *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. States may benefit from tracking the proceedings of leading states to understand emerging issues.

Information Resources

Federal Resources

Title/Description	URL Address
A Policy Framework for the 21st Century Grid: A Progress Report. This 2013 report summarizes recent federal government actions to encourage the development of a 21st century grid.	http://www.whitehouse.gov/sites/default/files/microsites/ostp/2013_nstc_grid.pdf
SmartGrid.gov. SmartGrid.gov is the gateway to information on federal initiatives that support the development of technologies, policies, and projects to transform the electric power industry.	http://www.smartgrid.gov
Smart Grid Investment Grants and Smart Grid Regional and Energy Storage Demonstration Projects. These two Web pages provide information on American Reinvestment and Recovery Act grant-funded grid modernization and energy storage demonstration projects across the United States. The projects were awarded from DOE's Office of Electricity Delivery and Energy Reliability.	http://energy.gov/oe/technology-development/smart-grid/recovery-act-smart-grid-investment-grants (investment grants) http://energy.gov/oe/services/technology-development/smart-grid/recovery-act-sgdp (demonstration projects)
Federal Energy Regulatory Commission (FERC). FERC's website provides information on smart grid advancements, including annual assessments of demand response and advanced metering potential.	http://www.ferc.gov/industries/electric/indus-act/smart-grid.asp http://www.ferc.gov/legal/staff-reports/2014/demand-response.pdf
National Forum on Demand Response. The U.S. Department of Energy and the Federal Energy Regulatory Commission sponsored a forum as part of the Implementation Proposal for the National Action Plan for Demand Response. In February 2013, National Forum working groups published a series of reports on cost-effectiveness, measurement and verification, program design and implementation, and tools and methods.	http://energy.gov/oe/services/electricity-policy-coordination-and-implementation/state-and-regional-policy-assistanc-7
USDA Rural Utility Service Loans. USDA loans funds to rural electric utilities for a variety of infrastructure expansions and improvements, including modern grid technologies.	http://www.rurdev.usda.gov/Home.html
Broadband USA. This Web page provides information on American Reinvestment and Recovery Act grant-funded community broadband projects, many of which include smart grid capabilities. The projects were awarded from the U.S. Department of Commerce, National Telecommunications and Infrastructure Administration.	http://www2.ntia.doc.gov/about
State and Local Energy Efficiency Action Network (SEE Action). The federally facilitated SEE Action summarizes information on the importance of customer access to energy use data as a tool for supporting energy efficiency in the residential and commercial sectors, and provides related resources for state and local policy makers and their partners.	https://www4.eere.energy.gov/seeaction/topic-category/energy-use-data-access
National Institute of Standards and Technology (NIST). NIST's website provides an overview of smart grid technology and the development of interoperability standards to make it possible.	http://www.nist.gov/smartgrid/

Title/Description	URL Address
Smart Grid Legislative and Regulatory Policies and Case Studies. This 2011 report highlights the development of the smart grid in the United States and abroad, summarizes U.S. smart grid legislation and regulation, and provides case studies of smart grid pilots and programs in the United States.	http://www.eia.gov/analysis/studies/electricity/
Data Privacy and the Smart Grid: A Voluntary Code of Conduct. Utilities and third parties can voluntary adopt these concepts and principles in order to address privacy related to customer data.	http://www.energy.gov/sites/prod/files/2015/01/f19/VCC%20Concepts%20and%20Principles%202015_01_08%20FINAL.pdf
Grid Energy Storage. This 2013 report describes potential options to improve energy storage, as well as specific actions that could help maintain scientific advancements and a pipeline of project deployments.	http://energy.gov/oe/downloads/grid-energy-storage-december-2013
Integrated Building Energy Systems Design Considering Storage Technologies. This 2009 report analyzes how energy storage technologies can help with the optimization of micro-generation systems. It features examples from New York and California.	http://emp.lbl.gov/sites/all/files/REPORT%20lbnl-1752e_0.pdf

Potential and Business Case

Title/Description	URL Address
Evaluation of Conservation Voltage Reduction (CVR) on a National Level. This 2010 report presents an estimate of the benefits of CVR for individual feeder types, as well as an extrapolation of the benefits on a national level.	http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19596.pdf
BPA Study of Smart Grid Economics Identifies Attractive Opportunities and Key Uncertainties. This primer summarizes a white paper documenting the interim results of an economic assessment for smart grid technologies in the Pacific Northwest.	http://www.bpa.gov/Projects/Initiatives/SmartGrid/DocumentsSmartGrid/BPA-Smart-Grid-Regional-Business-Case-Summary-White-Paper.pdf
Estimating the Costs and Benefits of the Smart Grid. This 2011 technical report, a partial update of an earlier report, documents the methodology, key assumptions, and results of a preliminary quantitative estimate of the investment needed to create a viable smart grid.	http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001022519
Costs and Benefits of Conservation Voltage Reduction: CVR Warrants Careful Examination. This 2013 report investigates the CVR deployment experience at four rural electrical cooperative utilities and uses their data to develop and calibrate a hybrid power flow-economic model, which is used to derive a cost-benefit analysis methodology for CVR.	https://smartgrid.gov/sites/default/files/doc/files/NRECA_TPR2_Costs_Benefits_of_CVR_0.pdf
Market Analysis of Emerging Electric Energy Storage Systems. This research paper evaluates the economics of two emerging electric energy storage systems: sodium sulfur batteries and flywheels.	http://netl.doe.gov/File%20Library/Research/Energy%20Analysis/Publications/DOE-NETL-2008-1330-MarkAnalyElectEnergyStorageSys-FinalRpt.pdf

Stakeholder Processes

Title/Description	URL Address
Illinois Energy Infrastructure Modernization Act of 2011. Provides Illinois Investor Owned Utility plans to make significant upgrades and investments to the electric grid while meeting performance metrics. Stakeholder groups engaged to ensure that related consumer and environmental benefits, including greenhouse gas benefits, are to be tracked and reported for these investments.	http://www.icc.illinois.gov/electricity/infrastructureinvestmentplans.aspx
Smart Grid Roadmaps. This series lays out a path and technical vision for the discovery and deployment of smart grid technologies. It includes links to current and past stakeholder processes.	http://www.caiso.com/informed/Pages/CleanGrid/SmartGridRoadmap.aspx
Report to the Governor and the Legislature: California Smart Grid—2012. This report, published in May 2013, is the third annual report providing the Governor and legislature with information on CPUC's and California investor-owned utilities' progress toward modernizing the state's electric grid.	http://www.cpuc.ca.gov/NR/rdonlyres/7AB03474-E27C-4EB6-AB8D-D610A649C029/0/SmartGridAnnualReport2012Final.pdf
The Future of the Grid: Evolving to Meet America's Needs. These materials were compiled in 2014 in advance of the "Future of the Grid—Evolving to Meet America's Needs National Summit." They consolidate key findings from four regional workshops that were held to obtain stakeholder views on the ways in which the grid must evolve to meet America's energy needs and customer expectations by the year 2030.	http://www.pdf.investintech.com/preview/92816eb2-f883-11e3-9de8-002590d31986/index.html
The Smart Grid Stakeholder Roundtable Group: Perspectives for Utilities and Others Implementing Smart Grids. This 2009 document provides general guiding principles for utilities and other smart grid project developers as they begin to plan and implement upgrades to their metering infrastructure and transmission and distribution networks, with the goal of helping developers better communicate how and why smart grid technologies will provide benefits.	http://www.epa.gov/cleanenergy/documents/suca/stakeholder_roundtable_sept09.pdf

Environmental Benefits and Other Policy Considerations

Title/Description	URL Address
Is It Smart If It's Not Clean? Strategies for Utility Distribution Systems. Part one of a two-part series on smart grid's potential benefits for energy efficiency and distributed generation. This issue letter discusses questions that PUCs and stakeholders can ask if they want smart grid investments to improve system distribution efficiency, focusing on CVR and optimizing voltage and var control.	http://www.raponline.org/document/download/id/656
Is It Smart If It's Not Clean? Smart Grid, Consumer Energy Efficiency, and Distributed Generation. Part two of a two-part series on smart grid's potential benefits for energy efficiency and distributed generation. This issue letter explains smart grid opportunities to advance end-use energy efficiency and clean distributed generation.	http://www.raponline.org/docs/RAP_Schwartz_SmartGrid_IsItSmart_PartTwo_2011_03.pdf

Title/Description	URL Address
Nation Association of Utility Regulatory Commissioners (NARUC) Smart Grid Resources. NARUC's website contains resources about smart grid deployment, including congressional testimony, reports, policies, and links to federal agencies.	http://www.naruc.org/smartgrid/
The Future of the Utility Industry and the Role of Energy Efficiency. This study estimates future electricity sales, identifies options for the future role of utilities, and evaluates the role of energy efficiency in the utility of the future.	http://www.aceee.org/research-report/u1404
Advancing Grid Modernization and Smart Grid Policy: A Discussion Paper. This white paper, developed from the Advanced Energy Economy Grid Modernization forum held in 2013, identifies the most relevant barriers to broader smart grid adoption, as well as corresponding policy options put forward for consideration.	http://info.aee.net/advancing-grid-modernization-and-smart-grid-policy
The Smart Grid: An Estimation of the Energy and CO_2 Benefits. This report highlights nine mechanisms by which the smart grid can reduce energy use and carbon impacts associated with electricity generation and delivery.	http://energyenvironment.pnnl.gov/news/pdf/PNNL-19112_Revision_1_Final.pdf
The Green Grid: Energy Savings and Carbon Emissions Reductions Enabled by a Smart Grid. This paper quantifies the energy savings and carbon dioxide emissions reduction impacts of smart grid infrastructure. Integrating Smart Distributed Energy Resources with Distribution Management Systems. This paper describes ongoing research by the Electric Power Research Institute to ensure that distribution management systems can more effectively use distributed energy resources.	http://www.smartgridnews.com/artman/uploads/1/SGNR_2009_EPRI_Green_Grid_June_2008.pdf http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001024360
Evaluation Framework for Smart Grid Deployment Plans: A Systematic Approach for Assessing Plans to Benefit Customers and the Environment. This document provides a template to evaluate the Smart Grid Deployment Plans that California's investor-owned utilities are required to file under CPUC's Decision 10-06-047.	http://www.edf.org/sites/default/files/smart-grid-evaluation-framework.pdf
Redefining Smart: Evaluating Clean Energy Opportunities from Products with Grid Connected Functionalities. This paper maps out clean energy opportunities for certain types of appliances and uses the framework as a tool to estimate the greenhouse gas emissions reduction potential of opportunities along the spectrum.	http://aceee.org/files/proceedings/2014/data/papers/11-969.pdf

Industry Resources

Title/Description	URL Address
Smart Grid Interoperability Panel (SGIP). 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.	http://www.sgip.org
Smart Grid Demonstration—Integration of Distributed Energy Resources. This initiative conducts regional demonstrations and supports research focusing on smart grid activities related to integration of distributed energy resources. These resources include distributed generation, storage, renewable, and demand response technology.	http://smartgrid.epri.com/Demo.aspx
The Gridwise Alliance. 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.	http://www.gridwise.org
National Electrical Manufacturers Association (NEMA). NEMA maintains a variety of smart grid fact sheets, as well as policy position papers that apply at the state and federal level.	http://www.nema.org/Policy/Energy/Smartgrid/Pages/default.aspx
Association for Demand Response & Smart Grid (ADS). This site provides links to ADS-generated reports and case studies, as well as major reports issued by government and others.	http://www.demandresponsesmartgrid.org/reports-research
Advanced Energy Management Alliance (AEMA) Demand Response Resources. AEMA is a demand response advocacy group that maintains a directory of industry demand response resources.	http://aem-alliance.org/demand-response/resources/
State Proceedings. The Energy Storage Association maintains a listing of state regulatory proceedings that relate to energy storage.	http://energystorage.org/policy/state-policy/state-proceedings?page=1

Understanding the Modern Grid

Title/Description	URL Address
What Is the Smart Grid? This website is a resource for information about the smart grid concepts and government-sponsored smart grid projects.	https://www.smartgrid.gov/the_smart_grid
Governors' Guide to Modernizing the Electric Power Grid. This paper looks at ways in which governors can help better understand and communicate the costs and benefits of grid modernization.	http://www.nga.org/cms/home/nga-center-for-best-practices/center-publications/page-eet-publications/col2-content/main-content-list/governors-guide-to-modernizing-t.html
The Smart Grid: An Introduction. This publication provides a "plain-English" exploration of the nature, challenges, opportunities, and necessity of smart grid implementation.	http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_SG_Book_Single_Pages.pdf

Title/Description	URL Address
Smart Grid. The Center for Climate and Energy Solutions is a nonprofit organization that advocates for policies and actions to address the twin challenges of energy and climate change. This fact sheet describes key smart grid technologies and applications, and explains how these components can provide economic and environmental benefits.	http://www.c2es.org/technology/factsheet/SmartGrid

References

Title/Description	URL Address
Bokhari, A., et al. 2014. Experimental Determination of the ZIP Coefficients for Modern Residential, Commercial and Industrial Loads. IEEE Transactions on Power Delivery (Volume 29, Issue: 3).	http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6648709
BPA. n.d. BPA Study of Smart Grid Economics Identifies Attractive Opportunities and Key Uncertainties. Bonneville Power Administration.	http://www.bpa.gov/Projects/Initiatives/SmartGrid/DocumentsSmartGrid/BPA-Smart-Grid-Regional-Business-Case-Summary-White-Paper.pdf
BPA. 2010. Transmission Asset Management Strategy. Bonneville Power Administration.	http://www.bpa.gov/Finance/FinancialPublicProcesses/IPR/2010IPRDocuments/May%2017%20Transmission%20strategy%20for%20IPR2010.pdf
BPA. 2012. 2012 Update to the 2010–2014 Action Plan for Energy Efficiency. Bonneville Power Administration.	http://www.bpa.gov/EE/Policy/EEPlan/Documents/BPA_Action_Plan_FINAL_20120301.pdf
BPA. 2014. Energy Efficiency Implementation Manual. Bonneville Power Administration.	http://www.bpa.gov/EE/Policy/IManual/Documents/FINAL_October_2014_Implementation_Manual.pdf
California ISO. 2011. Five Year Synchrophasor Plan. California Independent System Operator.	http://www.caiso.com/documents/fiveyearsynchrophasorplan.pdf
CEC. 2013. Lead Commissioner Workshop on Increasing Demand Response Capabilities in California. California Energy Commission.	http://www.energy.ca.gov/2013_energypolicy/documents/2013-06-17_workshop/presentations/
CEE. 2014. 2014 CEE Behavior Program Summary—Public Version. Consortium for Energy Efficiency.	http://library.cee1.org/content/2014-cee-behavior-program-summary-public-version
CPUC. 2014a. Energy Storage. California Public Utilities Commission.	http://www.cpuc.ca.gov/PUC/energy/electric/storage.htm
CPUC. 2014b. California's Smart Grid. California Public Utilities Commission.	http://www.cpuc.ca.gov/PUC/energy/smartgrid.htm
CPUC. 2014c. Annual Report to the Governor and the Legislature: California Smart Grid.	http://www.cpuc.ca.gov/NR/rdonlyres/2F5149C6-885A-4211-8CBA-A4F88F02CEA7/0/SmartGridAnnualReport2013final.pdf

Title/Description	URL Address
DOE. 2012. Application of Automated Controls for Voltage and Reactive Power Management—Initial Results. U.S. Department of Energy.	https://www.smartgrid.gov/sites/default/files/doc/files/VVO%20Report%20-%20Final.pdf
EIA. 2011. About 60% of the U.S. Electric Power Supply Is Managed by RTOs. U.S. Energy Information Administration.	http://www.eia.gov/todayinenergy/detail.cfm?id=790
EIA. 2012. State Electricity Profiles 2010. U.S. Energy Information Administration.	http://www.eia.gov/electricity/state/pdf/sep2010.pdf
EPA. 2013. Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units. U.S. Environmental Protection Agency.	https://www.federalregister.gov/articles/2014/06/18/2014-13726/carbon-pollution-emission-guidelines-for-existing-stationary-sources-electric-utility-generating
EPA. 2014. Market and Industry Scoping Report for Medium Voltage Transformers, February 2014. U.S. Environmental Protection Agency.	www.energystar.gov/scoping
Indiana General Assembly. 2013. Senate Enrolled Act No. 560.	http://www.in.gov/legislative/bills/2013/SE/SE0560.1.html
Massachusetts Department of Public Utilities. 2014a. Welcome to the Massachusetts Department of Public Utilities' Grid Modernization Homepage.	http://www.mass.gov/eea/energy-utilities-clean-tech/electric-power/grid-mod/grid-modernization.html
Massachusetts Department of Public Utilities. 2014b. Investigation by the Department of Public Utilities on Its Own Motion into Modernization of the Electric Grid.	http://www.mass.gov/eea/docs/dpu/orders/dpu-12-76-b-order-6-12-2014.pdf
Massachusetts Department of Public Utilities. 2014c. Investigation by the Department of Public Utilities upon Its Own Motion into Time Varying Rates.	http://www.mass.gov/eea/docs/dpu/orders/d-p-u-14-04-b-order-6-12-14.pdf
MD PSC. 2011. Order No. 84569. Public Service Commission of Maryland.	http://webapp.psc.state.md.us/Intranet/Casenum/NewIndex3_VOpenFile.cfm?ServerFilePath=C:\CaseNum\9100-9199\9153\268.pdf
NEEA. 2014. Long-Term Monitoring and Tracking Distribution Efficiency. Northwest Energy Efficiency Alliance.	http://neea.org/docs/default-source/reports/long-term-monitoring-and-tracking-distribution-efficiency.pdf?sfvrsn=5
NEMA. n.d. Volt/VAR Optimization Improves Grid Efficiency.	https://www.nema.org/Policy/Energy/Smartgrid/Documents/VoltVAR-Optimazation-Improves%20Grid-Efficiency.pdf
NPPC. 2010. Sixth Northwest Conservation and Electric Power Plan. Northwest Power and Conservation Council.	http://www.nwcouncil.org/media/6365/SixthPowerPlan_Ch4.pdf
PEEC. n.d. Is Disaggregation the Holy Grail of Energy Efficiency? The Case of Electricity. Precourt Energy Efficiency Center. Technical Paper Series PTP-2012-05-1.	http://web.stanford.edu/group/peec/cgi-bin/docs/behavior/research/disaggregation-armel.pdf

Title/Description	URL Address
PNNL. 2010. Schneider KP, JC Fuller, FK Tuffner, and R Singh. 2010. Evaluation of Conservation Voltage Reduction (CVR) on a National Level. PNNL-19596, Pacific Northwest National Laboratory, Richland, WA.	http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19596.pdf
PNNL. 2012. Evaluation of Representative Smart Grid Investment Grant Project Technologies: Summary Report. PNNL-20892, Pacific Northwest National Laboratory, Richland, WA.	http://gridlabd.me.uvic.ca/gridlabd/src/filedetails.php?repname=GridLAB-D+(SourceForge)&path=%2Fanalysis%2FPublishedReports%2F2012+-+SGIG-Summary+Report.pdf&rev=4364&peg=4364
Princeton University. 2014. Two Years After Hurricane Sandy, Recognition of Princeton's Microgrid Still Surges. October 23.	http://www.princeton.edu/main/news/archive/S41/40/10C78/index.xml?section=featured
SEE Action. 2012. A Regulator's Privacy Guide to Third-Party Data Access for Energy Efficiency. State and Local Energy Efficiency Action Network.	https://www4.eere.energy.gov/seeaction/system/files/documents/cib_regulator_privacy_guide_0.pdf
SEE Action. 2013. A Utility Regulator's Guide to Data Access for Commercial Building Energy Performance Benchmarking. State and Local Energy Efficiency Action Network.	https://www4.eere.energy.gov/seeaction/publication/utility-regulators-guide-data-access-commercial-building-energy-performance-benchmarking
SEE Action. 2014. Insights from Smart Meters: The Potential for Peak-Hour Savings from Behavior-Based Programs. State and Local Energy Efficiency Action Network.	https://www4.eere.energy.gov/seeaction/publication/insights-smart-meters-potential-peak-hour-savings-behavior-based-programs
Solar Oregon. 2014. What Is a Smart Inverter Anyway?	http://solaroregon.org/news/what-is-a-smart-inverter-anyway
Washington House of Representatives. 2013a. HB 1289: Regarding the Use of an Energy Storage Facility to Meet Annual Targets Under RCW 19.285.040.	http://apps.leg.wa.gov/billinfo/summary.aspx?bill=1289&year=2013
Washington House of Representatives. 2013b. HB 1296: Requiring Integrated Resource Plans Developed by Electric Utilities to Include an Assessment of Energy Storage Systems.	http://apps.leg.wa.gov/billinfo/summary.aspx?bill=1296&year=2013

Glossary

Distribution systems deliver electricity to end customers. In the United States, the electric distribution system is alternating current at 60 Hz. At distribution substations, high-voltage electricity is received from the transmission system and converted into the lower-voltage electricity needed for distribution to customers. From distribution substations, distribution circuits (also called lines or feeders) are used to distribute electricity at a lower voltage. The secondary transformers on the distribution circuits are used to convert voltage to an even lower voltage for delivery to end customers. For residential customers, that voltage is 120 volts (+/- 5 percent).

Current is movement of electric charge, measured by the number of electrons passing a single point in one second.

- Alternating current is electricity that periodically reverses direction. In the United States, the alternating current is a 60 Hz sinusoidal wave form.
- Direct current is electricity flowing in a constant direction.

Voltage for an electrical system is the difference in electrical potential between any two points on the system.

Power is the rate at which energy is used (measured in watts or kilowatts); electric energy is usually sold by the kilowatt hour.

Reactive power occurs in alternating current systems when there is a shift between voltage and current (when voltage and current are not in phase). Reactive power must be supplied to most types of magnetic equipment (such as products with motors) and to compensate for the power losses in distribution and transmission systems. It typically is expressed in volt-ampere reactive (var).

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 conditions in real time.

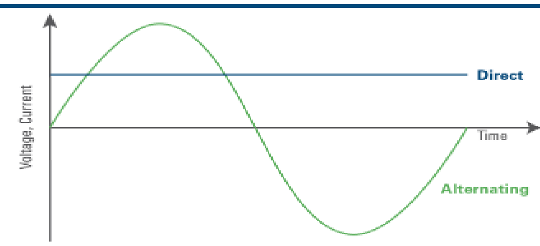
System controls include *load tap changers,* which are installed on transformers and raise or lower voltage at the beginning of the feeder; *voltage regulators,* which are installed on substations or feeders, and raise or lower downstream voltage; and *capacitor banks,* which are installed at the substation 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., SCADA systems that monitor and control distributions systems and information systems that collect and store AMI data) and 2) analyze the data (on- or offline) to determine how to optimize the distribution system, and send control signals.

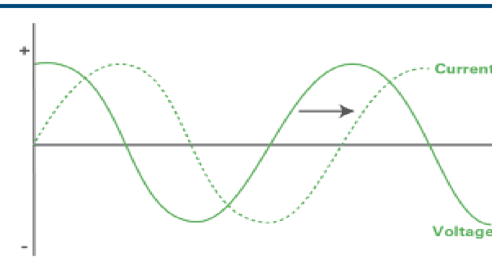
Adapted from DOE (2011).

Figure 7.5.1: Illustrative Overview of Direct and Alternating Current



Direct current is often depicted as a straight line. Alternating current is often depicted as a sine wave.

Figure 7.5.2: Illustrative Overview of Reactive Power



Reactive power occurs when voltage and current are out of phase.

Conservation voltage reduction is the reduction of feeder voltage (within allowable standards) on a distribution circuit to reduce energy consumption. CVR is different from voltage reduction required during periods of inadequate generation supply.

Volt/var optimization refers to the simultaneous and optimized control of voltage and reactive power (var) on the distribution system to minimize system losses.

Inverters convert direct current (DC) to alternating current (AC) electricity and vice versa. Inverters are used to connect renewables and storage to the electric grid. They require certain functionality to ensure safety.