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Integrating Renewable Energy

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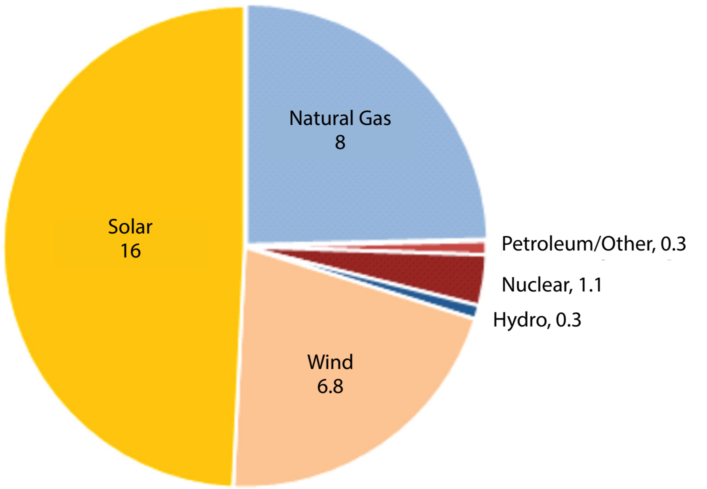
Introduction

State and federal policies, combined with rapidly declining costs, have quickly made wind and solar major players in many state energy portfolios. Both technologies saw rapid expansion in the United States in 2015—wind made up 35 percent of new energy production capacity added to the grid, while solar hit 29.5 percent.[1] Remarkably, both exceeded new natural gas installations, which contributed 25 percent. States, utilities and balancing authorities are taking a number of steps to integrate these intermittent resources, and state policies often can support these efforts. This document investigates how the increase in renewable energy is affecting the grid and explores policy options that support utility and grid manager efforts to integrate wind and solar resources.

Strong Growth for the Future

The rapid pace of wind and solar installations is expected to continue in 2016 (Figure 1). The U.S. Energy Information Administration projects that utility-scale solar energy production will grow 28 percent, while wind production increases 16 percent.[2] New renewable construction will continue to break records, and the U.S. solar market is expected to more than double this year, growing by almost 120 percent, according to GTM Research.[3]

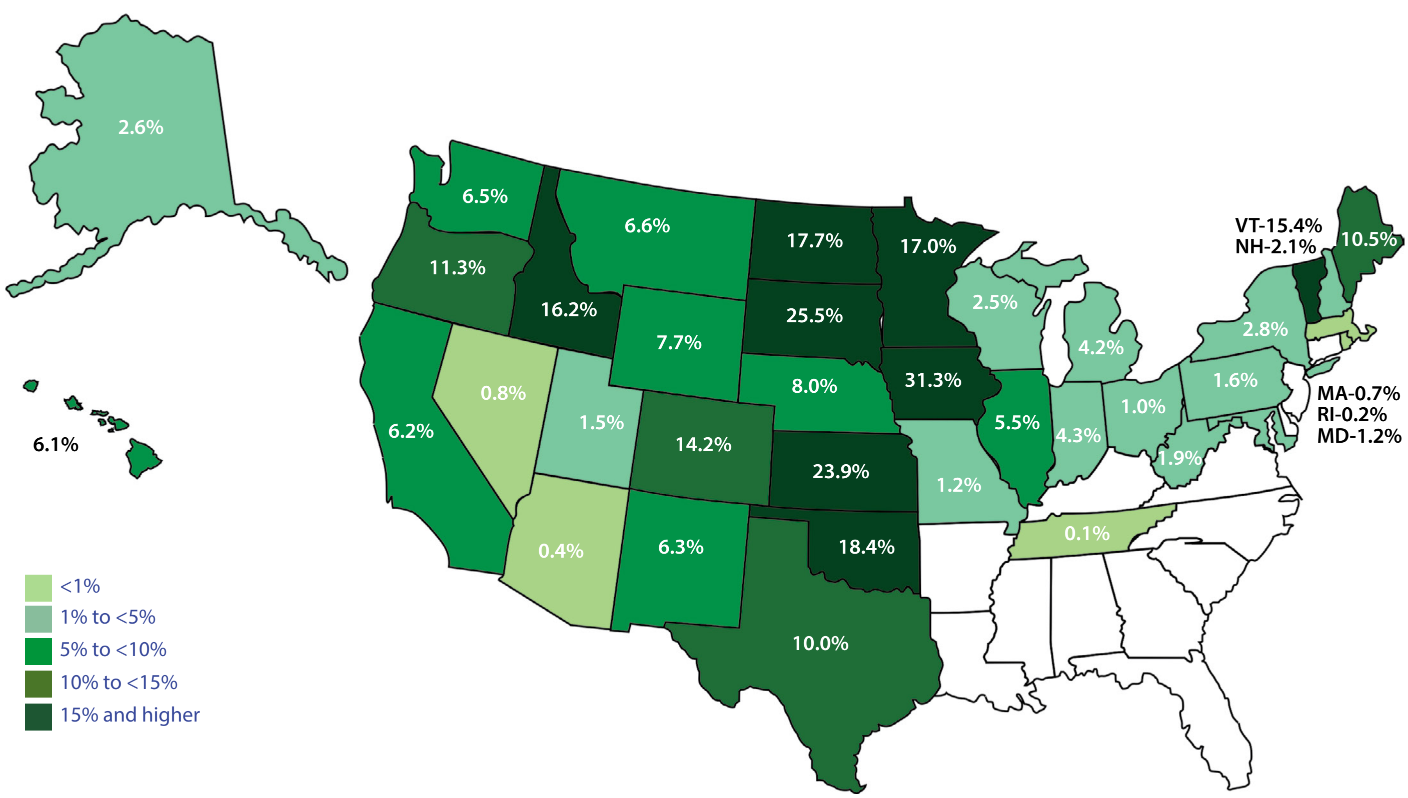
Figure 1. U.S. Capacity Additions Expected in 2016, in Gigawatts



Note: Solar capacity additions include both utility scale and distributed solar.
Sources: Solar Electric Power Monthly, GTM Research

In some regions, renewables increasingly satisfy a significant portion of state electricity needs (Figure 2). Iowa, the U.S. leader in this regard, passed a major milestone in 2015 by becoming the first state to acquire more than 30 percent of its annual electricity generation from wind. Kansas and South Dakota, which get 26 percent and 24 percent of their power from wind, respectively, are not far behind. For shorter periods of time, some markets are seeing much higher wind contributions. Xcel Energy, a large utility serving much of Colorado, broke a record on Oct. 2, 2015, by meeting 54 percent of its Colorado customers' electricity needs with power generated by wind. The utility also saw wind production in its upper Midwestern system (includes Minnesota and Iowa) soar past 50 percent for an hour and past 40 percent for a full day in November 2015. In Texas, where the massive electricity market dwarfs all other states in electricity production, wind farms supplied more than 40 percent of the state's electricity needs for 17 hours on Dec. 20, 2015. These records are likely to be broken soon as wind generation continues to grow.

Figure 2. U.S. Wind Energy Share of Electricity Generation During 2015, by State

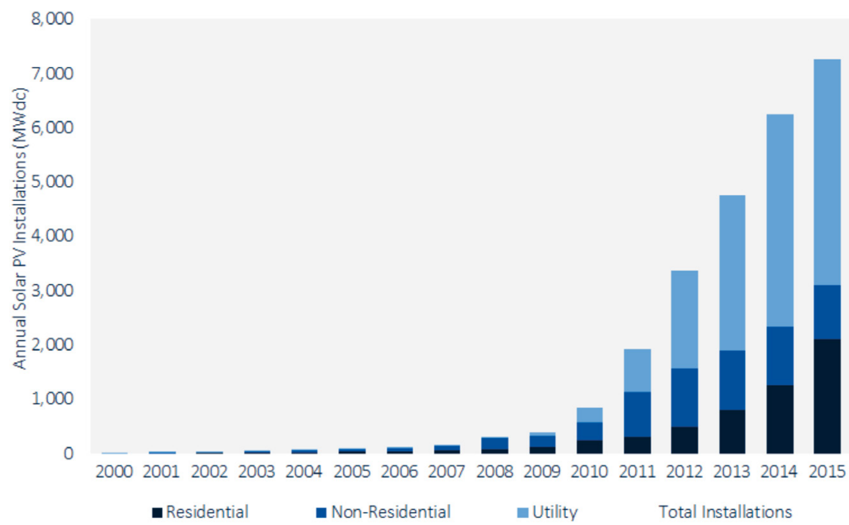


Source: AWEA, http://www.awea.org/MediaCenter/pressrelease.aspx?ItemNumber=8463

Solar and Wind Energy Markets

Solar is experiencing remarkable growth. A record 7.3 gigawatts of solar capacity came on line in 2015, representing nearly four times the amount installed in 2011 (Figure 3). The accelerating growth is forecast to be higher still in 2016, when an additional 16 gigawatts is expected, outpacing wind for the first time.[4] Still, solar has considerable room to expand in most states, since it will represent only about 0.8 percent of the national electricity mix by the end of 2016.[5]

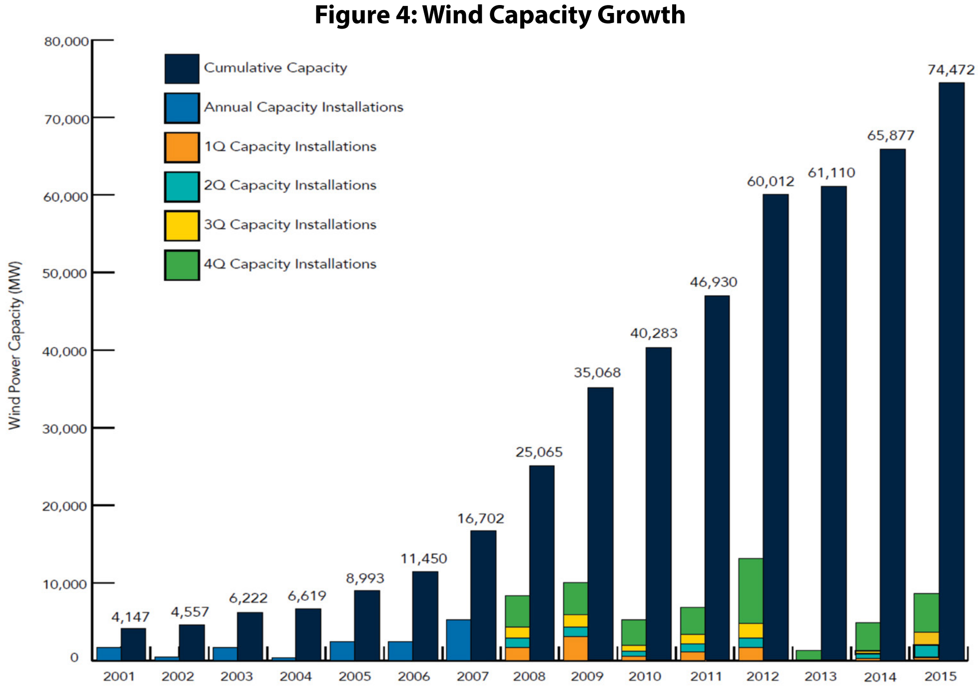
Figure 3: Solar Capacity Growth



Source: The 2015 Year in Review, U.S. Solar Market Insight, http://www.greentechmedia.com/research/subscription/u.s.-solar-market-insight

Utility-scale wind is expected to add 6.8 gigawatts of capacity in 2016 and produce 5.2 percent of the nation's power.[6] Twelve states now obtain more than 10 percent of their energy from wind, and eight of those surpassed 15 percent (Figure 4).

Figure 4: Wind Capacity Growth



Source: AWEA. *U.S. Wind Industry Fourth Quarter 2015 Market Report*

The Electricity Balancing Act

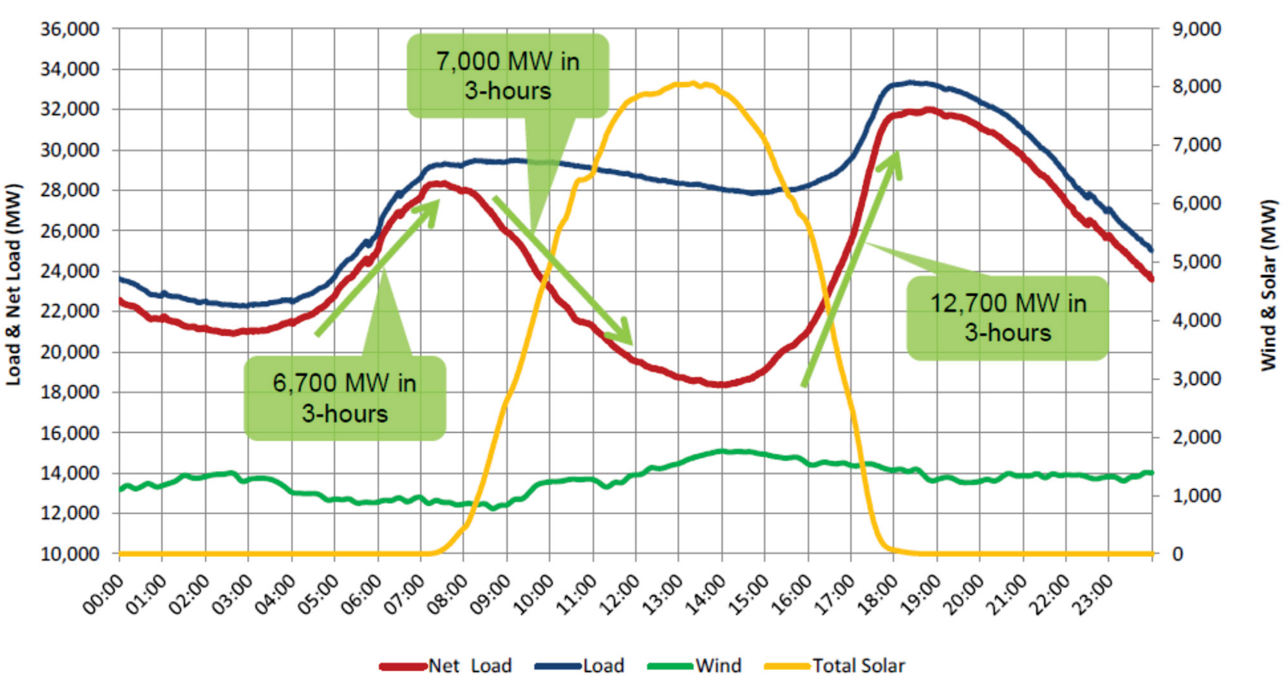
Wind and solar power generation, which can see significant swings in energy output over time, can present integration challenges for balancing authorities. As the proportion of wind and solar energy in the mix increases, more changes in grid operation may be required.

To understand how wind and solar power affect the electric grid, it is important to first understand how the grid works. Balancing authorities—the entities that manage the flow of electricity on the grid—must ensure that electricity supply exactly matches demand. Therefore, they must have power ready to respond as variations in the need for air conditioning, heating, lighting and industrial process change both throughout the day and seasonally. If supply is higher or lower than demand for too long, portions of the grid can shut down, creating a blackout. Since this balancing act is so critical, the grid is designed to quickly match daily and seasonal fluctuations in consumer and commercial electricity demand that occur each day and throughout the year. To ensure power availability, system operators use weather and historical consumption trends to forecast demand. They use this data to determine how many power plants should be held in reserve, ready to increase or decrease electricity production at a moment's notice. These "dispatchable" energy sources tend to be natural gas or hydropower. Coal and nuclear plants typically run at full output and rely on more flexible plants to meet sudden changes in demand.

Grid Flexibility: the Key to Renewables Integration

Because wind and solar energy output varies, based on weather, the time of day and time of year, the grid may require more flexibility. In Figure 5, the blue "Load" line shows the changes in electric demand during the day. Subtracting wind and solar production from this line creates the "Net Load" line, indicated in red. Although less conventional generation is needed to balance the net load, it may be necessary to accommodate larger swings more often—note that the morning and evening ramps on the red Net Load line are steeper than those on the blue Load line. When this occurs, natural gas or hydropower plants may need to adjust their output more quickly to absorb the added variation.

Figure 5. Effect of Wind and Solar Power on Net Energy Demand



Source: North American Electric Reliability Corporation (NERC) and the California Independent System Operator Corporation (CaISO)

The flexibility of the grid across the United States is based on several factors, including the size of the balancing area, the amount of natural gas and hydropower in the energy mix, operational practices and the area over which solar and wind generation are distributed. Texas—which has quick-responding natural gas plants and has implemented fast market operations, demand response programs and advanced wind forecasting techniques—easily produces and integrates the most wind of any state.

Since power plants and power lines can and do fail, extra power reserves, called contingency reserves, are maintained so they are ready to deal with the largest likely outage. Since the changes in wind or solar production generally are far smaller than a power plant outage, balancing authorities do not need to alter the amount of contingency reserves.

Forecasting

Wind and solar forecasts, like energy demand forecasts, reduce integration challenges and costs since they allow balancing authorities to more accurately plan how much electricity will be needed to meet demand. Forecasting can play a significant role in lessening integration challenges because it decreases uncertainty in the planning process by allowing more efficient use of least cost generation units.

More accurate wind forecasting has greatly helped Xcel Energy integrate large amounts of wind in the Midwest and Colorado. The utility partnered with the National Center for Atmospheric Research (NCAR) to develop an advanced forecasting system that uses highly detailed observations of atmospheric conditions, powerful computer models and artificial intelligence to produce accurate wind forecasts. Xcel determined that advanced wind forecasting improved its ability to predict wind availability by 40 percent, saving the utility and its customers $49 million in fuel costs.[7]

Demand Response

Demand response programs already are used across much of the country to cost-effectively meet changes in demand and balance the variations in solar and wind output. Demand response programs enable utilities to adjust a bill payer's heating, cooling or other energy services, in exchange for monetary credits on their monthly bill. If a balancing authority sees a sudden spike in demand or drop in energy production, it can adjust the energy consumption of program participants to balance the system. Demand response operates in a way that participants are unlikely to notice, but it produces substantial benefits, including reduced system costs, lower emissions and increased system resilience. Using demand response is often is less expensive than adjusting the output of dispatchable power plants. Demand response can be used during infrequent events, such as when a large amount of wind generation suddenly drops, which is far less costly than maintaining extra reserves year-round.

Demand response recently received major federal regulatory support. In January 2016, the Supreme Court upheld FERC Order 745, which requires wholesale electricity markets to compensate demand response providers that reduce electricity load at the same rate as energy generators. This action gives a green light to regions with deregulated markets that are considering or already pursuing demand response programs. Barriers to demand response—including a lack of advanced meters and limited participation incentives—remain in many states, especially those that lack deregulated markets.

Are new power plants needed as "backup" when wind and solar are added to the grid?
To maintain the continuous balance between electricity consumption and production, balancing authorities deploy power plants to follow changes in net load (electricity demand less wind and solar production). When wind and solar are added to the system, the operator balances net load using existing reserves. The Midwestern balancing region, operated by the regional transmission organization MISO, includes some of the highest wind power producing states in the country—Iowa obtains 31 percent of its electricity from wind, South Dakota 26 percent, North Dakota 18 percent, and Minnesota 17 percent.[8] MISO has been able to integrate huge amounts of wind without adding power plants to back up their renewable energy production, partly because MISO is a large balancing area with many different energy resources available. The nation's wind leader, Texas, has also been able to integrate massive amounts of wind without building "backup" power plants—relying on its existing fleet of flexible natural gas plants, demand response, adjustments to its energy market and other efforts.

Legislatures in several states have addressed some of these demand response issues as components of energy efficiency and smart grid legislation. California enacted Senate Bill 1414 in 2014, which accelerates the adoption of demand response by requiring utilities and regulators to include it in resource adequacy and long-term procurement plans. The bill also requires regulators to ensure appropriate valuation of demand response resources. Some states include demand response as part of their efficiency efforts. Rhode Island's energy efficiency resource standard, for example, sets targets for demand response. Minnesota encourages demand response by allowing utilities to share in the savings that demand side programs create for customers; the award increases as savings increase, as long as the utility's efforts are cost-effective and meet targets.

Power Plant Flexibility

Since building wind and solar energy resources often is capital-intensive but less expensive to operate due to lack of fuel costs, the least cost approach is to run them as much as possible and use dispatchable generation to adjust to fluctuations in renewable output. Dispatchable power plants that can adjust energy output quickly and efficiently help the system run more effectively and lower operating costs. Natural gas plants are the most flexible; coal and nuclear plants are less so.

Power plants can be built or retrofitted to provide large changes in output more quickly and efficiently. While these technologies add expense, the resulting increase in flexibility can lower the overall cost of the energy system. Since flexibility can provide a market benefit, policymakers may wish to incorporate an evaluation of plant flexibility into energy resource planning or provide incentives for utilities and power plants to invest in flexibility.

Energy Storage

Advances in energy storage could significantly change how variability and uncertainty are managed by the grid. The energy storage market more than tripled in 2015 as energy storage costs rapidly decreased and more vendors entered the market.[9] Energy storage, already cost-effective for some uses, will become more widely affordable within five years.[10] Storage provides the grid with added flexibility and helps with renewable integration by shifting load and generation from periods of surplus to periods of need. It also can help to maintain grid reliability and stability. Although energy storage is not essential to integrate renewable energy, affordable storage could reduce integration challenges, particularly as states strive to meet high renewable energy targets. New battery technologies could significantly increase the value of wind, which often produces electricity during the evening when demand is low. In regions where solar production may peak a few hours before demand is highest, energy storage could allow solar electricity to be used during times of peak demand when electricity is most costly. Batteries also can store or release energy as needed to adapt to the fast changes in solar or wind output, thereby reducing the need to quickly increase or decrease fossil power plant electricity generation.

As storage technologies have advanced and become commercially available, regulations to provide compensation for fast-responding resources such as energy storage will need to be changed. As discussed in more detail below, many Regional Transmission Authorities (RTOs) are adjusting their markets so that energy storage is fairly compensated for the benefit it provides. The Washington Legislature recently updated the state's integrated resource plan, requiring utilities to assess the value of smart grid and energy storage technologies for lowering renewable energy integration costs.

In 2013, the California Public Utilities Commission (PUC) approved a proposal requiring the three major investor-owned utilities to procure 1.325 gigawatts of "cost-effective" energy storage by 2020. The storage is to be spread across transmission, distribution and customer zones. The mandate was created as a result of Assembly Bill 2514, which passed in 2010. With a renewable energy requirement of 50 percent by 2030, the goal is to help utilities increase reliability and lower costs as they integrate the increasingly large amounts of solar and wind resources that are being installed across the state. Oregon, which enacted legislation creating a 50 percent renewable energy mandate in March 2016, also passed a bill in 2015 that created an energy storage requirement.

The Texas Approach

Texas' balancing authority, the Electric Reliability Council of Texas (ERCOT), expects more than 10,000 megawatts of new wind in 2016 and 2017, far surpassing any previous year. It also expects to add 1,725 megawatts of utility-scale solar during the same time period, increasing their solar capacity more than six-fold.[11] To help integrate the rapid growth of variable resources, Texas is redesigning its ancillary services market. The ancillary services market provides a collection of services that are purchased by ERCOT to balance the grid and maintain electric reliability. The new design will unbundle balancing services traditionally provided by fossil generators into separate services to help address the needs of a more renewable-heavy grid and use new grid technologies, including energy storage. The new market will be far more efficient. The Brattle Group, a widely respected electricity market analyst, calculated that the new ancillary services market would save $137 million over 10 years.

Texas already has implemented several other strategies to better integrate variable resources, including:

- Moving to a dynamic, 5-minute market, where power and services are traded on shorter intervals to produce a more accurate market and better reflect rapid changes in energy demand and production.
- Creating competitive renewable energy zones (CREZ) to streamline transmission line development that would maximize access to wind resources. The CREZ process was initiated in 2005 by the state Legislature.
- Advancing wind forecasting efforts.
- Expanding its demand response programs.[12]

Federal Activity

The Federal Energy Regulatory Commission (FERC), an independent government agency that regulates interstate electricity transmission, has issued several orders in the past few years that are likely to aid integration of renewable energy resources. These orders have addressed a variety of wholesale-transmission activities, including regional transmission planning, demand response, energy storage and operational practices.

In 2011, FERC issued three significant regulations. The first, FERC Order No. 745, created new compensation rules for demand response. As noted earlier, the recent Supreme Court decision upholding this rule provides a green light for wholesale markets to incorporate demand response. The second, Order No. 755, requires the wholesale power market to provide more efficient price signals to resources that provide frequency response and regulation services such as demand response. The goal is to more appropriately value fast ramping resources, including energy storage that can respond much more quickly to system changes than traditional resources. The third, Order No. 1000, requires coordinated planning for transmission investments that affect multiple states or utility jurisdictions. The order also requires plans to consider state policies on renewable energy integration and carbon emissions reduction.

In 2012 and 2013, FERC addressed operational practices and compensation rules to help integrate renewables in non-deregulated regions. Order No. 764 requires transmission providers that assign reserve costs to wind and solar resources to offer sub-hourly transmission scheduling and conduct power production forecasting. This step was a dramatic departure from traditional reserve cost allocation rules. FERC Order No. 792 made energy storage eligible to connect to the power grid under FERC's Small Generator Interconnection Procedures. FERC Order No. 784 requires utilities to consider speed and precision when purchasing ancillary services, a move that provides a better opportunity for energy storage to compete in this market. Utilities purchase ancillary services to help balance and stabilize the grid.

State Action

States are exploring a number of policy actions to help utilities integrate variable renewable resources. These include efforts to promote demand response, drive grid modernization, advance energy storage, improve forecasting and promote better transmission planning.

Washington passed House Bill 1826 in 2013 to promote technologies and practices that lower integration costs. The law requires integrated resource plans to identify methods and commercially available technologies, including energy storage and demand response, for integrating renewable

resources. It also requires electric corporations to identify additional spending necessary to integrate cost-effective distributed resources into plans, with the goal of yielding net benefits to ratepayers.

Washington also authorized $28 million in funding with House Bill 1115, enacted in 2015, to support research, development and demonstration projects that use energy storage, demand response, smart grid and other technologies that support renewable integration. The funds include matching grants for utilities to develop projects that use and demonstrate these technologies.

Connecticut passed SB 1078 in 2015, allowing the Commissioner of Energy and Environmental Protection to solicit long-term contracts for energy resources—including demand management and energy storage—that will help the state meet its Comprehensive Energy Strategy. It allows for coordination with other states in the region and gives preference to options that improve reliability, are cost effective and meet environmental goals, such as carbon emissions reductions.

Vermont enacted House Bill 40 in 2015, raising its renewable standard to 75 percent by 2032. As part of this mandate, 12 percent of the standard can be met with energy transformation projects, which potentially could include energy efficiency, energy storage or demand response.

California took a big leap forward on the integration front, passing Senate Bill 350 in 2015, which increased utility renewable requirements to 50 percent. The law requires utilities to put together portfolios that meet the new requirement and utilize low emissions technologies and practices—such as energy storage and demand response—where cost-effective to do so. In 2014, California passed Assembly Bill 327 to advance metering technologies and practices that help with rooftop solar integration. The law allows energy corporations, beginning in 2018, to offer demand response and time variable pricing programs to residential customers. As discussed earlier, California utilities are beginning to implement their energy storage mandate; some of the first projects are to be delivered in 2017.

Minnesota enacted an omnibus bill, HF 3, in 2015. As part of the State Transmission and Distribution Plan, it requires utilities to submit a biennial transmission project report that outline their transmission plans and identifies investments in grid modernization—including energy storage, demand response technologies and advanced meters.

States also are exploring how transmission can help integrate more renewable energy. Nebraska passed Legislative Bill 1115 in 2014, which funds the Nebraska Power Review Board to conduct a study of future transmission needs and policies to export renewable electricity outside the state. The purpose of the study is to identify electric transmission and generation constraints and opportunities for exporting electricity to national and regional electricity markets.

A list of legislative action related to renewable integration is included in the appendix.

Appendix
Legislative Action Related to Renewable Integration

Bills Introduced in 2016

Hawaii

Senate Bill 2739

Establishes an energy storage mandate and aims to increase solar energy storage planning to address greater renewable energy deployment and over-generation. Includes long-duration energy storage as a first priority preference for utility and electric cooperative procurement in generation, transmission and distribution system changes. Establishes criteria for the evaluation of determining whether storage is commercially viable.

Oklahoma

House Bill 3145

Allows electricity consumers access to wholesale Oklahoma-produced renewable energy resources. Authorizes the Oklahoma Corporation Commission to determine a distribution access fee but sets criteria for fee maximums. Requires the Legislature and the commission to collaborate with entities to expand renewable energy transmission and distribution facilities.

Oregon

House Bill 4036

Among other provisions, increases the state renewable portfolio standard to require at least 50 percent of retail electric sales to derive from renewable energy. Requires the Public Utility Commission to adopt rules encouraging least-cost and least-risk resource acquisition and encouraging diverse ownership of renewable energy sources. Authorizes cost recovery for energy storage projects by electric utilities.

Rhode Island

House Bill 7006

Prohibits distribution companies from charging an interconnecting renewable energy customer for system modifications that are not directly related to interconnection, except certain accelerated modifications. Requires customer interconnection to be completed no later than 270 days after an impact study or 360 days from initial interconnection application.

Bills Enacted in 2015

California

California Senate Bill 83

Affords electrical utilities additional time when interconnecting renewable energy facilities located on a U.S. Armed Forces base or facilities that are greater than one megawatt in capacity. Additional time is granted to study interconnection-related impacts and the possible need for transmission or distribution system. Determines that the costs of such upgrades be borne by the U.S. Armed Forces base or facility.

California Senate Bill 350

Increases the state renewable portfolio standard to 50 percent of electricity sales by 2030 and includes energy storage as a possible resource for increased system reliability and capacity. Initiates the transition of the California Independent System Operator to into a regional transmission organization to achieve, among other measures, increased reliability and renewable energy integration.

California Senate Bill 697

Requires regular reports from the PUC on utilities' progress in achieving the state renewable portfolio standard, including renewable energy procurement plans, the status of siting and permitting renewable resources and corresponding transmission, and recommendations to expedite siting and permitting.

Connecticut

Connecticut Senate Bill 1078

Authorizes the commissioner of the Department of Energy and Environmental Protection to solicit long-term contracts to meet energy planning goals, including securing reliable and cost-effective resources. Eligible technologies include renewable energy, passive demand response and energy storage.

Connecticut Senate Bill 1502

Includes energy storage in the definitions of a "distributed energy resource" and a "grid-side system enhancement." Requires utilities to file proposals to build, own or operate grid-side system enhancements to demonstrate how distributed energy resources can be reliably and efficiently integrated into the electric grid and provide public benefit.

Minnesota

Minnesota House Bill 3a

Includes distribution planning in annual transmission reports completed by utilities. Requires that utilities include investments considered necessary to modernize the transmission and distribution systems in annual reports. Energy storage and two-way meters are listed as possible investments.

Oregon

Oregon House Bill 2187

Declares it is the policy position of the state that any regional transmission planning that wholly or partly encompass the state shall adequately consider electricity transmission from ocean renewable energy generated within state or adjacent federal waters.

Oregon House Bill 2193

Establishes energy storage technology mandate that directs utilities to procure at least five megawatt-hours of energy storage capacity by 2020, following approval by the Public Utility Commission. Utilities cannot procure more storage than 1 percent of their peak load in 2014. Permits utilities to collaborate in meeting this requirement to reduce costs and share benefits. Charges the Public Utility Commission with adopting guidelines for utility energy storage proposals by January 2017.

Rhode Island

Rhode Island House Bill 5900

Extends the timeline from 2017 to 2024 for a requirement for utilities to submit triennial plans for system reliability and energy efficiency and conservation procurement. Authorizes the distribution company to seek advice of the commissioner of the Office of Energy Resources and the Energy Efficiency and Resources Council when developing plans. Requires plans to be publicly available and be submitted to the General Assembly.

Vermont

Vermont House Bill 40

Creates a renewable energy requirement (modified from a voluntary target) that renewable energy comprise 75 percent of electric utility sales by 2032. Includes a set-aside for distributed renewable generation of 10 percent by 2032. Permits 12 percent of the final requirement to be met with "energy transformation projects," which includes energy storage.

Washington

Washington House Bill 1115

As a portion of the capital budget for fiscal years 2016-2017, authorizes $23 million from the state building construction account. Appropriates $13 million to advance renewable energy technologies and transmission and distribution control improvements for increased reliability, resiliency and integration of intermittent renewable energy resources. Appropriates $10 million in matching funds to research, develop and demonstrate clean energy technologies, including advancing energy storage and solar technologies.

Washington Senate Bill 5024

Prioritizes "innovative measures" in public schools, public universities and state buildings. Defines innovative measures as meaning advanced or emerging technologies, systems or approaches that may not yet be in common practice but improve energy efficiency, accelerate deployment of new technologies or reduce energy usage, and become widely commercially available in the future if proven successful in demonstration programs without compromising the guaranteed performance or measurable energy and operational cost savings anticipated. Examples of innovative measures include, but are not limited to, advanced energy and systems operations monitoring, diagnostics and controls systems for buildings; novel heating, cooling, ventilation and water heating systems; advanced windows and insulation technologies, highly efficient lighting technologies, designs and controls; and integration of renewable energy sources into buildings and energy savings verification technologies and solutions.

Washington Senate Bill 6052

Authorizes $6 million in general funds for creation of a clean energy institute, which will integrate physical sciences and engineering with a research focus on energy storage and solar energy.

Glossary

Ancillary Services—Ancillary services, such as frequency and voltage control, help maintain the reliability and resiliency of the electric grid.

Balancing Area—Refers to a region of interconnected electric transmission and distribution lines over which electricity demand and supply must be balanced.

Balancing Authority—The responsible entity that integrates resource plans ahead of time, maintains load-interchange-generation balance within a balancing authority area, and supports Interconnection frequency in real time.

Electric Load—Represents the amount of power being consumed on the grid at any given time; also known as electricity demand.

Dispatchable Power Plants—These power plants can easily be turned off and on or adjusted to meet the variations in electricity demand and power generation that occur on the grid.

RTO (regional transmission organization)—An organization authorized by the Federal Energy Regulatory Commission (FERC) to manage the reliability of the electric transmission system and the operation of the wholesale electricity market in a defined area.

Notes

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