NCSL
Strong States, Strong Nation

Integrating Renewables

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Introduction

Renewable energy is fast becoming a major source of electricity in the U.S. and now generates 13 percent of the nation's electricity. While hydro has long been the leader in renewable energy production, non-hydro renewables have taken the lead in 2014.[1] Wind and solar energy have grown rapidly and were responsible for 52 percent of new capacity added to the nation's grid in the first six months of 2014. New natural gas plants contributed 44 percent while no new coal or nuclear plants were added during this period.[2] Some states, like Iowa and North Dakota, now get more than 25 percent of their electricity from renewable energy and some markets or utilities have seen wind meet 40-60 percent of power needs at certain times of the day.

Although wind and solar produce emission-free electricity and have no fuel costs, they do pose challenges for grid operators—their energy production is dependent on weather and sun, which can vary quite dramatically over time. Renewable energy has the potential to continue its rapid rise due to declining prices, federal and state policies and incentives, and growing utility interest in creating diverse portfolios. As this growth continues, will the grid be able to manage these variable resources in a reliable and affordable manner? This publication explores this question and investigates how utilities and legislatures are working to address renewable energy integration challenges.

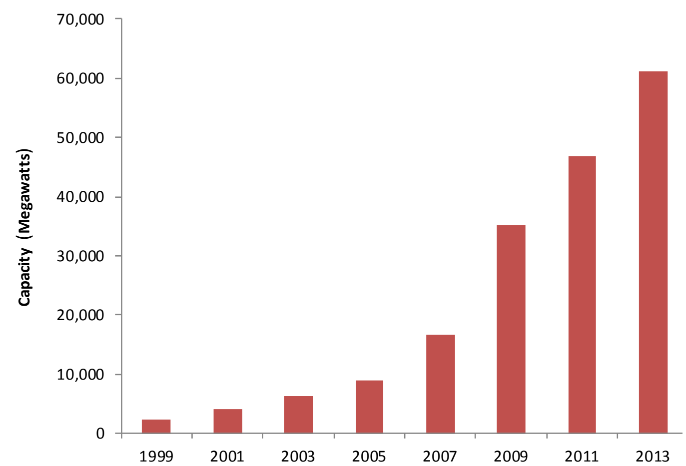
Solar and wind energy in the United States

The United States has an installed wind capacity of nearly 62 gigawatts and an additional 14.6 gigawatts are being built in 21 states across the country.[3] While solar has been deployed more slowly than wind, with 15 gigawatts of capacity, installations are ramping up quickly and have experienced a more than four-fold increase since 2010. Solar led the energy industry for new electric capacity installations during the first half of 2014, outpacing natural gas, which is also growing extremely fast.[4] Some states and regions are now getting large amounts of electricity from renewable sources—Xcel Energy in Colorado has exceeded 60 percent renewable energy at certain times, while Texas, the nation's largest electricity consumer, has seen wind energy satisfy up to 39 percent of its electricity needs.

The Electricity Balancing Act: Ensuring that Production Equals Consumption

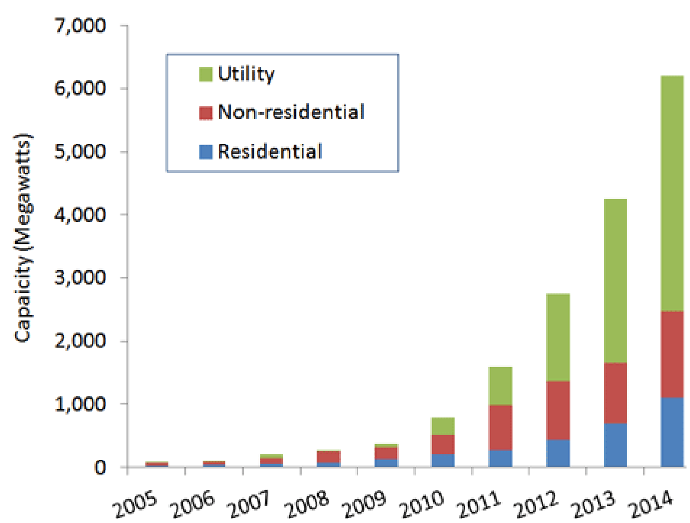
In order to understand how variable energy sources are integrated into the electric system, it is important to first recognize how system operators—the entities responsible for managing the flow of electricity on the grid—keep the lights on by ensuring that electricity supply is always exactly in balance with demand. Since electricity needs for heating, cooling, lighting and electronics vary substantially throughout the day and year, the grid is designed to handle large changes in electricity demand. System operators need to balance the continually changing demand and supply despite daily load cycles and minute-to-minute changes. To ensure that power plants are prepared to increase or reduce electricity production, system operators use weather and historical consumption trends to forecast demand. To accommodate these fluctuations in demand and supply, a certain number of power plants are held in reserve, ready to increase electricity production at a moment's notice. These 'dispatchable' energy sources tend to be natural gas or hydropower. Coal and nuclear plants usually run at full output, unless taken down for repairs or maintenance, and are dependent on more flexible plants to meet changes in demand.

Figure 1. Wind Capacity Growth



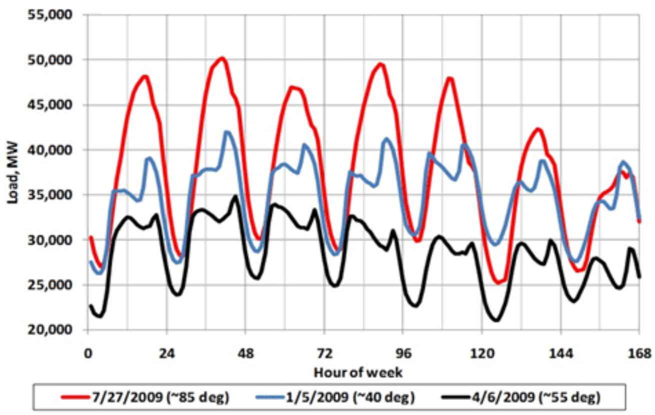
Source: Solar Market Insight, SEIA/GTM Research, 2014.

Figure 2. Solar Capacity Growth



Source: AWEA U.S. Wind Industry Market Report, 2014.

Figure 3. Average Hourly Load, PJM Mid-Atlantic Region



Source: The Fundamentals of Electricity Markets, Pennsylvania State University, www.e-education.psu.edu/ebf200wd/node/151.

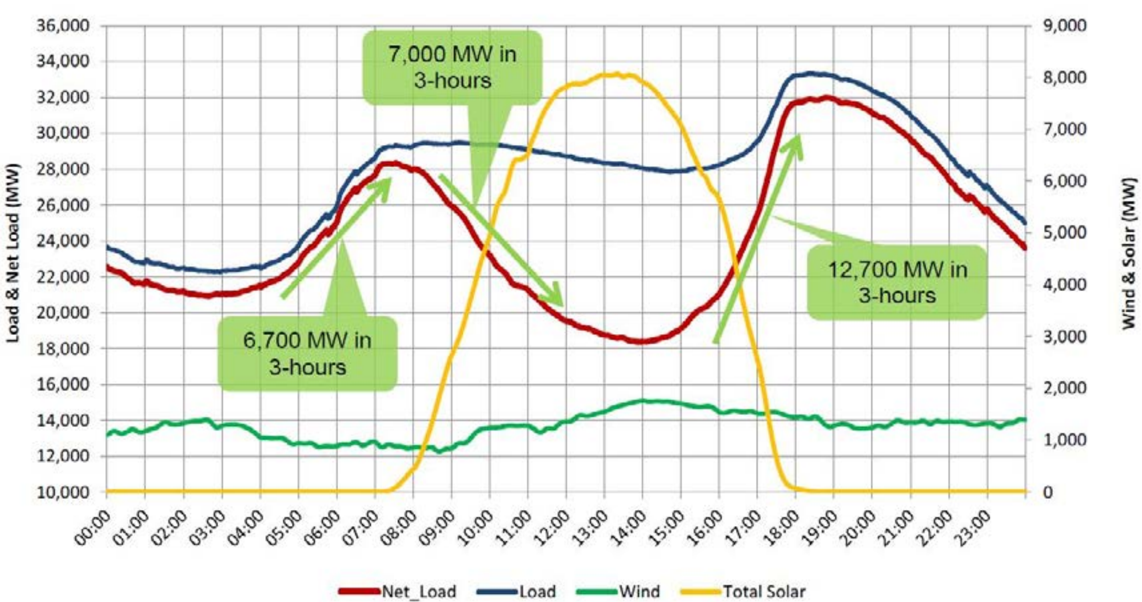
The graph above takes one-week periods in the winter, spring and summer to demonstrate how energy demand, also called "load," varies daily and throughout the year. In the winter and spring, represented by the blue and black lines, there are two peaks each day for the breakfast and dinner periods. Summertime usage, shown by the red line, indicates a single peak that is much higher than other times of the year, which takes place between 3 p.m. and 5 p.m. when air-conditioning use is high. As the red line demonstrates, demand can change quickly and dramatically, such as when a whole city's worth of air conditioners kick in on a hot day.

Addressing Variability of Wind and Solar

When wind and solar energy—which vary their production based on time of day, time of year and weather conditions—are added to the grid, this creates an added element of variability. As the chart below demonstrates, grid operators don't see this variability as changes in output from individual wind and solar installations, but as 'net load,' or electricity demand minus wind and solar production. Since power plants and power lines can and do fail, contingency reserves are constantly maintained so they are ready to deal with the largest likely outage. Since the changes in wind or solar production are generally far smaller than the possible outages of a power plant, the addition of wind and solar does not alter the amount of contingency reserves.[5] The addition of wind and solar energy, however, may require natural gas, coal or hydropower plants to adjust their output more quickly and more often.

The blue line in the chart below shows the changes in electricity load over time, while the red line shows changes in net load—the electric load minus the solar and wind production. Although less power is needed from conventional generation to balance the net load, there is a need to accommodate larger swings more often—note the steeper ramps on the red net load line caused by the morning and evening changes in solar power production.

Figure 4. Effect of Wind and Solar Power on Net Energy Demand



Sources: North American Electric Reliability Corporation (NERC) and the California Independent System Operator Corporation.

The costs and challenges of integrating large amounts of wind and solar vary based on several factors, including the size of the balancing area, the energy mix, operational practices and the extent to which solar and wind is spread out geographically. Texas, which produces the most wind of any state, for example, is able to integrate large amounts of this variable resource due to its fast market operations, quick-responding natural gas plants, demand response programs and wind forecasting techniques. Regions with limited generating sources, weak interconnections with neighbors and traditional operating practices may find it more difficult to integrate large amounts of wind without altering historical practices and increasing trade with neighbors.

Forecasting

Wind and solar forecasts, like energy demand forecasts, reduce integration challenges and costs since they allow system operators to more accurately plan how much electricity will be needed from a variety of generation sources (natural gas, coal or hydropower plants) to meet demand. Forecasting can play a large part in lessening integration challenges since it provides greater certainty in the planning process, allowing least cost generation units to be more efficiency utilized.

For Xcel Energy, a publicly owned utility with large amounts of renewable energy production in its territory, more accurate wind forecasting has greatly helped with integrating large amounts of wind in the Midwest. 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 highly detailed wind forecasts. Xcel determined that the new system saved the utility nearly $22 million between 2009-2012, partly by allowing system operators to better allocate resources and keep less power plants in reserve.

Demand Response

Demand response programs are already in use across much of the country to cost-effectively meet changes in demand and to balance the variations in solar and wind output. Demand response programs provide utilities and demand response companies with the ability to adjust a bill payer's heating, cooling or other energy services, in exchange for monetary credits on their bill. If a utility suddenly needs more energy due to a sudden spike in demand, or drop in production, it can send an electronic signal that reduces the energy consumption of program participants. Demand response products are tailored in a way that participants are unlikely to notice, but still produce substantial benefits, including reduced system costs, lower emissions and increase system resilience. Using demand response to balance changes in demand or renewable energy production is often less expensive than adjusting the output of dispatchable power plants. For example, demand response can be used during infrequent events where a large amount of wind generation becomes unavailable, which is far less costly than maintaining extra reserves year round. To increase the role that demand response can play in integrating renewable energy, some issues such as a lack of advanced meters and limited participation incentives for ratepayers, must be addressed.

Legislatures in a number of states have addressed some of these demand response issues as components of energy efficiency and smart grid legislation.[7] Rhode Island's energy efficiency resource standard, for example, sets targets for

Are additional fossil power plants needed when wind and solar are added to the grid?

To maintain the continuous balance between electricity consumption and production, system operators deploy power plants to follow changes in net load (electricity demand minus wind and solar production). When more wind and solar are added to the system, the operator continues to balance this net load using existing reserves. A large amount of wind and solar on the system may require that additional reserves be made available, however, to account for the added variability in net demand. The Midwestern balancing region, operated by the regional transmission organization MISO, includes some of the highest wind power producing states in the country, with Iowa getting 27 percent of its electricity from wind, South Dakota getting 26 percent, and North Dakota and Minnesota getting approximately 15 percent.[6] MISO has been able to integrate this massive amount of wind without adding power plants to 'back up' their renewable energy production. Texas, the national leader in wind power production, which has seen up to 39 percent of its electricity produced by wind during certain hours, has also been able to integrate renewable without requiring the construction of backup generation.

demand response.[8] Minnesota encourages demand response by allowing utilities to share in the savings that the demand side programs create for customers, with the award increasing as savings increase, providing they are cost effective and meet targets.[9]

Power Plant Flexibility

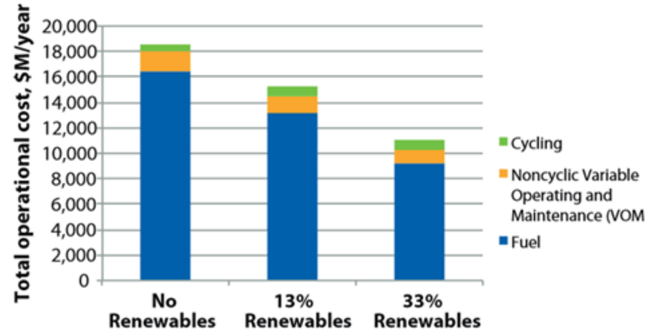
Since renewable energy resources are often capital intensive to build, but are the least costly to operate since they require no fuel, the least cost approach is to run them as much as possible and use dispatchable generation to adjust to fluctuations in renewable output. Dispatchable power plants that can start, stop and ramp their energy production up and down quickly and efficiently, will help the system run more efficiently and lower operating costs. Natural gas plants are the most flexible while coal and nuclear plants are less flexible, although there is a range of flexibility among each category of plant based on the type of technologies that are being used.

Power plants can be built or retrofitted so that they can provide large changes in output more quickly and efficiently, although there is a cost to implementing these more flexible technologies. While the flexibility does come with a cost, increased flexibility can lower the overall cost of the energy system. The challenge is assessing how much flexibility is needed, what the cost will be and how the added cost for flexible plants will be distributed. 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.

Wear and Tear on Fossil Plants

When a large amount of wind and solar are added to the grid, fossil-fueled generators adjust their output to accommodate fluctuations in renewable electricity. Although fossil generation is adjusted to meet fluctuations in electricity demand and outages at conventional power plants, the added cycling caused by high amounts of renewable does result in additional wear and tear on these plants. In Phase 2 of its Western Wind and Solar Integration Study, the National Renewable Energy Laboratory found that renewable penetration of up to 33 percent increases operating cost by 2 percent to 5 percent for the average fossil fuel plant.[10] Much of the costs are due to the increased cycling at coal plants, which tend to be less adaptable than natural gas plants to the added cycling. From a total cost perspective however, cycling costs are quite small compared to the savings from avoiding fuel consumption, which are approximately 70 times higher.

Figure 5. Cycling Costs from a System Perspective



Source: National Renewable Energy Laboratory, 2013.

Energy Storage

Advances in energy storage could significantly change the manner in which variability and uncertainty are managed by the grid. Cost–effective energy storage could shift load and generation from periods of surplus to periods of need, and could also assist in maintaining the stability of the system. While energy storage is not essential to integrate renewable energy, affordable storage could reduce integration challenges by smoothing out production and making variable resources able to adapt to changes in demand, like natural gas and coal plants do now. New battery technologies could significantly increase the value of wind, which often produces electricity during the evening when demand is low. For solar, 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 can also store or release energy as needed to adapt to the fast changes in system balance and frequency, reducing the need to quickly ramp fossil plants up and down to meet changes in renewable energy production.

Storage technologies include capacitors, flywheels, batteries, pumped hydro and other technologies. Batteries are seeing some the largest investments and some expect them to soon be a cost effective option.

As storage technologies have advanced and become commercially available, regulations to provide compensation for fast responding resources like energy storage have been changed. As discussed in more detail below, many of the RTOs are altering their markets to allow energy storage to receive payments more closely associated with performance. The Washington Legislature recently updated the state's Integrated Resource Plan to require that utilities assess the value of smart grid and energy storage technologies and how they can lower renewable energy integration costs.

In 2013, the California PUC approved a proposal requiring utilities to invest in energy storage thereby requiring the three major investor-owned utilities to utilize 1.325 gigawatts of 'cost-effective' 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 was passed in 2010. 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.

Federal Activity

The Federal Energy Regulatory Commission (FERC), an independent government agency that regulates interstate electricity transmission, has issued a number of orders in the past few years that are likely to aid in the 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. FERC Order No. 745 created new compensation rules for demand response, a regulation which was recently vacated by the US Appeals Court. The overturning of this rule has created considerable uncertainty in the wholesale markets regarding the participation of demand response in power system operations. Additionally, the Commission modified regulations for the wholesale power market to provide more efficient price signals to resources that provide frequency response and regulation service in Order No. 755. Energy storage from batteries, capacitors and flywheels can respond much quicker to system changes than traditional resources. FERC Order No. 755 revised the compensation rules for frequency response and regulation in the RTO markets to more appropriately value the added response provided by fast ramping resources, like energy storage.[11] FERC Order No. 1000 requires coordinated planning for transmission investments that affect multiple states or utility jurisdictions. The order also required that plans consider state policies on and renewable energy integration and carbon emissions reduction.

Further action was taken in 2012 and 2013 to address operational practices and compensation rules in non-RTO regions to integrate renewables. Order No. 764 required transmission providers that sought to directly allocate reserve costs to wind and solar resources—a dramatic departure from traditional reserve cost allocation rules—to offer sub-hourly transmission scheduling and conduct power production forecasting. This order also included guidance on how differentiated ancillary service rates should be formulated. FERC also Order No. 792 to make energy storage eligible to connect to the power grid under FERC's Small Generator Interconnection Procedures and allows solar projects that meet specific technical requirements to qualify for the "fast track" interconnection process. FERC Order No. 784 requires utilities to consider speed and precision when purchasing ancillary services, a move that provides energy storage with a better opportunity to compete in this market. Utilities purchase ancillary services, which are basically flexible power resources, to help stabilize the grid.

State Action

States are exploring a number of policy actions to help utilities integrate variable renewable resources, including efforts to promote demand response, grid technologies that smooth renewable energy integration, forecasting and transmissions planning. The state of Washington passed House Bill 1826 in 2013 to promote technologies and practices that lower integration costs. The bill requires integrated resource plans to identify methods and commercially available technologies, including energy storage and demand response, for integrating renewable resources. The bill 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.

In an effort to advance metering technologies and practices that streamline the integration of rooftop solar, California passed Assembly Bill 327 in 2014. The bill opens the door for electric corporations to offer demand response programs and time variable pricing for residential customers beginning in 2018. California also passed Senate Bill 96 in 2014, directing the Public Utilities Commission to develop and implement a program that will award funds for projects that benefit electricity ratepayers and lead to technological advancement in the areas of energy storage; renewable energy and its integration into the electrical grid; and accurate forecasting of the renewable energy production for integration into the grid.

States are also looking to advance energy storage as a way to better integrate renewables. In 2013, New Mexico passed Senate Join Memorial 43, requesting the Energy, Minerals and Natural Resources Department to convene a working group to identify and prioritize legislative and regulatory incentives that encourage the development of renewable energy storage. Minnesota House Bill 729 enacted in 2013, creates a study exploring the potential costs and benefits of utility-managed, grid-connected energy storage devices in residential and commercial buildings. The bill also requires all transmission companies and electric utilities to conduct an engineering study on increased renewable energy integration. Hawaii passed House Bill 1942 in 2014, which allows the issuance of revenue bonds to help finance the planning, design and construction of a renewable energy project with energy storage technology on the island of Molokai.

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

For a list of legislative action relating to renewable integration see the tables below.

Glossary

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.

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

Electric Load—The amount of power being consumed on the grid at any given time. Electricity demand.

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

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

Notes

1. U.S. Energy Information Administration, *Short-Term Energy Outlook* (Aug. 12, 2014), www.eia.gov/forecasts/steo/report/electricity.cfm.

2. Federal Energy Regulatory Commission, *Energy Infrastructure Update* (June 2014), www.ferc.gov/legal/staff-reports/2014/jun-infrastructure.pdf.

3. American Wind Energy Association, *U.S. Wind Industry Second Quarter 2014 Market Report* (July 2014), awea.files.cms-plus.com/FileDownloads/pdfs/2Q2014%20AWEA%20Market%20Report%20Public%20Version%20.pdf.

4. GTM Research and the Solar Energy Industries Association, *U.S Solar Market Insight Report – Q2 2014* (September 2014), www.seia.org/research-resources/solar-market-insight-report-2014-q2.

5. Michael Milligan et al., *Cost-Causation and Integration Cost Analysis for Variable Generation* (Golden, Colo.: National Renewable Energy Laboratory, June 2011), www.nrel.gov/docs/fy11osti/51860.pdf.

6. American Wind Energy Association, *U.S. Wind Energy: State maps and rankings* (2014), www.awea.org/resources/statefactsheets.aspx?itemnumber=890.

7. www.ncsl.org/research/energy/regulating-and-encouraging-smart-grid-technologies.aspx and www.ncsl.org/research/energy/smart-grid-state-action-update.aspx.

8. R.I. Stat. §39-1-27.7, webserver.rilin.state.ri.us/Statutes/TITLE39/39-1/39-1-27.7.HTM.

9, Minn. Stat. §216B.16, www.revisor.mn.gov/statutes/?id=216B.16.

10. National Renewable Energy Laboratory, *Western Wind and Solar Integration Study* (September 2013), www.nrel.gov/electricity/transmission/western_wind.html.

11. Federal Energy Regulatory Commission, *Order 755, Frequency Regulation Compensation in the Organized Wholesale Power Markets* (2011), www.ferc.gov/whats-new/comm-meet/2011/102011/E-28.pdf.

Table 1. 2014 Enacted and Pending Legislation, as of August 12, 2014

State	Bill Number	Summary
California	Senate Bill 96 (Enacted);	Directs the Public Utilities Commission to develop and implement the Electric Program Investment Charge (EPIC) program. Among other responsibilities, the program will award funds for projects that will benefit electricity ratepayers and lead to technological advancement in the areas of energy storage; renewable energy and its integration into the electrical grid; energy efficiency; integration of electric vehicles into the electrical grid; and accurately forecasting the availability of renewable energy for integration into the grid.
California	Assembly Bill 407 (Pending)	Requires the State Energy Resources Conservation and Development Commission, in consultation with the Public Utilities Commission and the Independent System Operator, to convene a stakeholders group to identify impediments and recommended steps that should be taken to properly maintain, develop, integrate and transmit electricity generated by eligible renewable energy resources located in and around the Salton Sea Known Geothermal Resource Area and the Geysers Geothermal Field. Requires the State Energy Resources Conservation and Development Commission to include its evaluations and recommendations in the next integrated energy policy report or update.
California	Assembly Bill 1935 (Pending)	Requires the Public Utilities Commission to study and submit a report on a biennial basis to the Legislature and the Governor on the impacts of distributed generation, including clean distributed energy resources, on the state's distribution and transmission grid**.**
California	Assembly Bill 2363 (Enacted)	Requires the Public Utilities Commission to direct electrical corporations to include in their proposed procurement plans the cost of integrating an eligible renewable energy resource. Requires the Commission to adopt a methodology for determining the costs of integrating eligible renewable energy resources by October 2015.
Hawaii	House Bill 1942 (Enacted)	Authorizes the issuance of special purpose revenue bonds to assist the financing of the planning, design and construction of a renewable energy project with energy storage technology on the island of Molokai.
Hawaii	Senate Bill 2196 (Enacted)	Establishes an Energy Systems Development Special Fund to develop an integrated approach and portfolio management of renewable energy and energy efficiency technology projects to increase energy security. The fund can be used for activities that include enhancing reliability and storage capabilities, among other projects.
Hawaii	House Bill 1943	Relates to electric grid modernization; requires the Public Utilities Commission to enable a diverse portfolio of renewable energy resources, expand customer options to manage energy use, maximize interconnection of distributed generation to the state's electric grids on a cost-effective basis at reasonable rates, determine fair compensation for electric grid services by distributed generation customers and maintain grid reliability and safety through modernization of the state's electric grids.
Nebraska	Legislative Bill 1115 (Enacted)	Appropriates funds to the Nebraska Power Review Board for a study of state, regional and national transmission infrastructure and policy, and future needs for transmission infrastructure and policy to serve Nebraska electric consumers and utilities and generation facilities in Nebraska seeking to export electricity outside of the state. Established a working group to contribute to the study.

State	Bill Number	Summary
New Jersey	Assembly Bill 2059 (Pending)	Requires the Board of Public Utilities to establish standards requiring that developers constructing grid-connected renewable energy generation systems ensure, prior to the commencement of construction or billing for services, that systems would be functionally integrated to the electric grid upon completion of construction. Allows a renewable energy generation system developer to charge fees to recover reasonable costs associated with the process of making the determination of whether a completed system would be functionally integrated to the electric grid.
New York	Assembly Bill 1932 (Pending)	Enacts the New York Grid Modernization Act, which creates a smart grid advisory council and a transmission and distribution coordinating council, among other provisions. The smart grid advisory council will promote deployment and integration of distributed energy resources and generation and energy storage, among other objectives.
South Carolina	Senate Bill 1189	Provides for a distributed energy resource program, a net energy metering program, the lease of renewable electric generation facilities program and fuel costs; requires each electric cooperative to investigate the relationship between costs and charges attributable to distributed energy resources; provide that no customer-generator or lessee shall operate an electric generation unit in parallel phase and synchronization with any electrical utility without written approval; relates to wholesale contracts.

Table 2. 2013 Enacted Legislation

State	Bill Number	Summary
California	Assembly Bill 327 (Enacted)	Allows the Public Utilities Commission (PUC) to authorize electric corporations to offer demand response programs and time-variant pricing for residential customers beginning in 2018. Expands existing net metering programs for customers of electric corporations. Requires electric corporations to submit distributed resources plans to the PUC, identifying optimal locations for additional distributed generation resources. As a part of resource plans, electric corporations must identify any additional spending necessary to integrate cost-effective distributed resources into distribution planning with the goal of yielding net benefits to ratepayers.
Connecticut	House Bill 6360 (Enacted)	Among other provisions, includes thermal energy storage and electricity storage in renewable energy and energy efficiency finance programs offered by the Clean Energy Finance and Investment Authority.
Hawaii	Senate Bill 120 (Enacted)	Authorizes the Public Utilities Commission to establish policies to encourage greater utilization of lower cost renewable energy when available through considering policies such as an energy curtailment mitigation mechanism.
Minnesota	House Bill 729 (Enacted)	Among other provisions, creates a solar thermal rebate program that includes energy storage. Establishes a study exploring the potential costs and benefits of utility-managed, grid-connected energy storage devices in residential and commercial buildings. Requires findings to be submitted by January 2014. Establishes a study to explore the use of renewable energy, energy efficiency and energy storage to achieve a non-fossil fuel energy portfolio; findings must be submitted by January 2014. Requires all transmission companies and electric utilities to conduct an engineering study on increased renewable energy integration. Requires findings to be submitted by November 2014.