Governors Staying Ahead of the Energy Innovation Curve

A POLICY ROADMAP FOR STATES

NGA
NATIONAL GOVERNORS ASSOCIATION

AHEAD OF THE CURVE
INNOVATION GOVERNORS

Foreword

As a result of new, advanced and connected technologies, our world is rapidly changing. Amazing technologies are transforming our daily way of life and altering how businesses and industries operate every moment of every day. Given the vast and ever-changing implications for our citizens and economies, governors are looking for ideas to help leverage the opportunities these new technologies present while also tackling the challenges to stay "Ahead of the Curve."

I am honored to have been chosen by my peers as the 2017–18 chair of the National Governors Association (NGA). I selected technology innovation – new products and processes that improve quality of life or deliver new value – as the theme for my Chair's Initiative, "**Ahead of the Curve: Innovation Governors.**" This initiative engaged thought leaders and technology experts from across the country to examine how governors and the citizens we govern can stay one step ahead of the rapidly advancing technologies that impact the daily lives of residents and businesses in our states.

Ahead of the Curve focused on two areas: transportation and energy – areas which I have watched change the economy and quality of life for the better in my home state of Nevada. During the past year, we have gathered governors and their staffs to examine opportunities related to innovative energy and transportation technologies, explored the impacts of these technologies on other sectors such as healthcare, education and public safety and considered implications for the workforce, cyber security and advanced communications systems.

These are complex, yet very important topics. I hope the two roadmaps NGA has developed this year, on transportation innovation and on energy innovation, will provide ideas for how governors can support innovation and remain ahead of the curve for years to come.

Nevada Governor Brian Sandoval
NGA Chair, 2017–2018

Executive Summary

An energy technology revolution in the United States is moving us toward a future based on an evolving generation mix of natural gas, wind and solar generation coupled with increasing use of distributed energy resources (DERs), all of which operate in a more tightly coordinated manner because of advances in information and control technologies at all levels. This transformation promises many benefits but also raises challenges and concerns. Governors will play a key role in preparing their states for a smooth transition. They can work alongside other state officials, federal and local governments, utilities, technology providers and others to advance innovation and stay ahead of the curve.

Newer, connected energy technologies and applications are in increasingly widespread use across the country and include efficient natural gas generation (driven by low-cost and plentiful shale gas), utility-scale and distributed renewable energy, advanced energy storage, the emergence of microgrids, a broad mix of energy efficiency and demand-response technologies, the beginnings of electrified transportation, smarter grids and advanced digital metering and sensors applied across the supply chain. Emerging technologies include small-scale nuclear and coal-based generation as well as advanced communications networks that allow for more connected systems and the related use of big data and analytics that inform energy development and usage. The result is a more diverse mix of energy resources that serves a variety of consumer needs and policy goals.

Many states are seeking to advance the use of new technologies and innovative strategies to achieve public policy goals such as creating jobs and enhancing competitiveness, maintaining or enhancing grid reliability and resiliency, reducing costs, enhancing consumer choice and improving environmental sustainability. States are also integrating new energy technologies with more traditional ones (for instance, coordinating the use of solar and natural gas to help lower overall costs and address intermittency concerns or adding sensors to coal generators to improve system efficiency and environmental performance) and looking at ways to maximize the benefits of each.

However, as with any technology transformation, states are experiencing concerns, including those related to resource intermittency, cybersecurity, workforce gaps and strains, data privacy and ownership and various technology limitations.

States face several challenges as they seek to address these concerns and reap the benefits of new energy technologies. One overarching challenge is that the existing regulatory

Energy Technology Transformation Highlights

Evolving Generation Mix:

- **In 2015, natural gas surpassed coal for the first time as the single largest fuel source for electricity generation.[1] Natural gas continues to be the largest source of energy for electricity, accounting for more than 31 percent of total generation in 2017.[2]**
- **Almost 50 percent of new U.S. utility-scale electric generating capacity in 2017 came from renewables, largely because of state portfolio rules.[3]**
- **In March 2017, wind and solar accounted for 10 percent of U.S. electricity generation for the first time,[4] while U.S. residential rooftop solar prices dropped 61 percent from 2010 to 2017.[5]**
- **Coal and nuclear power plant retirements continue because of abundant and inexpensive natural gas used in highly efficient natural gas combined-cycle plants. Additional factors include stagnant energy demand and the growth of wind and solar generation, which have lower variable cost than coal and nuclear.[6]**
- **Microgrid capacity is expected to more than double between 2017 and 2022 in the United States, although it will still be a small total part of the electricity grid at that time.[7]**
- **The first offshore wind farm in the United States came online in 2016; projects in the queue amount to more than 23 gigawatts (GW) of potential capacity – possibly more if costs can be reduced to make such energy more competitive with other sources.[8]**

Storage:

- **Advanced (non-hydro) energy storage capacity in the United States grew from 442 megawatts (MW) in 2012 to 1,554 MW in 2017.**
- **Between 2016 and 2020, costs of lithium-based energy storage are expected to decline by 38 percent, sodium-based energy storage by 37 percent and lead-based energy storage by 49 percent.**
- **In 2020, cumulative installed capacity of non-hydro energy storage may reach 2 GW, growing to a $2 billion market in the United States – although still small compared with total installed central station generation of 1,082 MW.[9]**

Smart Devices, Smarter Grids and Energy Efficiency:

- **By 2020, roughly 40 million U.S. households are expected to have a smart thermostat, 50 million a smart light bulb and almost 14 million a smart home controller.[10]**
- **As of 2016, more than 70 million smart meters were installed in the United States;11 installations were expected to reach 76 million in 2017 and 90 million by 2020.[12]**
- **In 2016, U.S. utilities spent a record high $7.6 billion on energy efficiency,13 which helped some states meet new demand and avoid the cost of new generation and transmission investments.**

Electric Vehicles (EVs):

- **EV sales in the United States grew by 26 percent between 2016 and 2017, with nearly 200,000 vehicles sold in 2017 alone. Nevertheless, EVs remain a small portion of total vehicle sales, which exceeded 17 million in 2017.[14]**
- **Nine global manufacturers and 26 Chinese manufacturers have announced plans to expand EV offerings in next 5 to 10 years.**
- **In total, 40 million to 70 million EVs are projected globally by 2025, if costs of EVs continue to decline.**

structure and related incentives that drive traditional utility business models have not kept pace with the new technologies. Utilities may not be rewarded for enabling or encouraging the adoption of optimal technologies, whether DERs or more traditional generation, transmission and distribution technologies. Moreover, modernizing the electric power system calls for new market structures and financing mechanisms. There may also be gaps in the skill sets of the current workforce, which may not be familiar with new technologies, and impacts to existing workers whose jobs are affected by a decline in the use of older technologies. In addition, consumers may not be comfortable with the pace of change and the amount of choice that they are being offered.

Governors can help prepare their states to embrace energy innovation by pursuing the following seven actions:[a]

- **Support technology innovation.**
- **Modernize legislation, regulations and incentives.**
- **Provide funding and financing mechanisms to drive technology deployment.**
- **Prepare the workforce.**
- **Update communications networks and data systems.**
- **Address cyberthreats.**
- **Educate citizens about the benefits and risks of technological innovation.**

To effectively pursue those actions across the various technologies, governors will need to engage a range of actors in the public and private sectors, including public utility commissioners, legislators, local officials, first responders, consumer advocates, utility executives, technology providers, network service providers, financial institutions, academics, researchers and large electricity end users. They may also want to pursue targeted partnerships, such as collaborating with military commanders who are seeking greater resiliency for base installations.

It is important to recognize that the pace of technology adoption has been accelerating over the past decade. It took about 100 years for landline telephones to reach widespread adoption, just 48 years for the adoption of electric power and 30 years for the adoption of color TV. More recently, it's taken just a decade for widespread use of cell phones, smartphones and tablets.[15]

Figure ES1 illustrates the accelerating pace of adoption for a range of technologies, as illustrated by the steeper lines in recent years. Governors can help their state's regulatory, workforce and communications systems adjust to this new pace by examining how they can update compliance-driven policies with performance-driven alternatives, adopt more data-driven governance and engage more stakeholders with greater transparency.[16]

States are the laboratories of innovation; there is no one-size-fits-all approach to becoming an innovation governor. This roadmap presents pathways to consider: governors can take the actions that fit within their state's context and help them stay ahead of the curve.

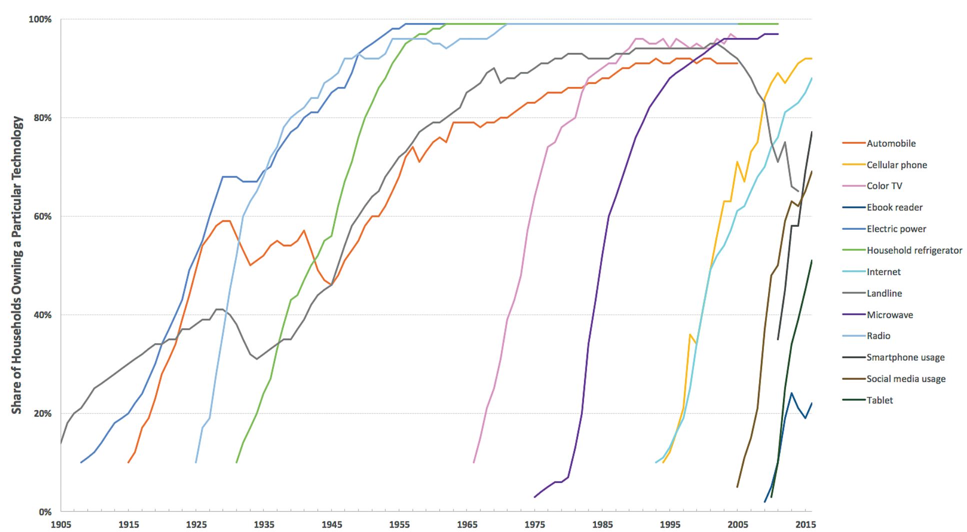

FIGURE ES1: Technology adoption by households in the United States.[17, b]

Source: Desjardins, J. (2018). A brief history of technology. Retrieved from https://www.weforum.org/agenda/2018/02/the-rising-speed-of-technological-adoption

[b] Each curve on the chart represents the span (in years) of technology adoption. The steeper the curve, the more rapid the adoption rate. In recent years, the curves have become steeper than in the past.

[a] The companion roadmap on transportation innovation presents potential actions for the same set of seven actions and may be a useful reference for other ideas that are transferable.

STAYING AHEAD OF THE TRANSPORTATION INNOVATION CURVE: STRATEGIES FOR GOVERNORS

Given the unique characteristics of each state, the following are possible strategies governors can consider as they pursue their policy objectives and adapt to transformations in the energy system.

Support technology innovation:

- ✓ Empower and direct agencies to explore and accelerate the adoption of innovative energy technologies.
- ✓ Appoint and convene working groups to gather stakeholder input on facilitating the adoption of innovative energy technologies.
- ✓ Direct state agencies to enable innovative technologies through energy planning processes.
- ✓ Promote the adoption of state procurement targets for innovative energy technologies.
- ✓ Encourage regulated utilities to pursue innovative energy technologies and offer customers choices.
- ✓ Request that agencies or utilities test and pilot emerging technologies.
- ✓ Directly support research and development (R&D) through innovation programs to develop home-grown technologies and expertise.
- ✓ Promote laws and regulations that drive technological innovation and deployment.

Modernize legislation, regulations, and incentives:

- ✓ Promote grid modernization initiatives.
- ✓ Implement performance incentives that reward utilities for meeting policy goals.
- ✓ Establish new rate design mechanisms and incentives for energy users.
- ✓ Foster competition between traditional utilities and third parties.
- ✓ Include targeted R&D or pilot programs in cost recovery and ratemaking structures.

Provide funding and financing mechanisms to drive technology deployment:

- ✓ Encourage adoption of financial incentives to drive deployment of innovative energy technologies.
- ✓ Support the development of mechanisms that can use scarce public dollars to spur private capital investment.
- ✓ Support the development of mechanisms that make it easier for residents and businesses to pay for deployment of innovative energy technologies on their properties.

Prepare the workforce:

- ✓ Partner with industry to identify skills gaps and workforce availability.
- ✓ Provide state-level incentives for energy sector business opportunities and workforce development programs to support these growing industries.
- ✓ Work with educational institutions at all levels to ensure that training programs are available to meet skills gaps both now and in the future.
- ✓ Identify underserved and high-unemployment groups and geographies to maximize benefits to communities in greatest need.

Update communications networks and data systems:

- ✓ Meet the broadband needs of underserved communities.
- ✓ Develop policies and programs to facilitate the state's transition to a "smart state."
- ✓ Encourage state agencies or utilities to assess infrastructure efficiencies.

Address cyber threats:

- ✓ Coordinate efforts and information sharing among stakeholders, with clearly defined roles.
- ✓ Incorporate cybersecurity into existing planning, including energy assurance plans.
- ✓ Promote practices among utilities that build on standards and guidelines to address unique threats and vulnerabilities.
- ✓ Ensure that state agencies, including public utility commissions, have a thorough understanding of how utilities manage risks.
- ✓ Continuously evaluate and upgrade skills, systems and planning in response to emerging threats.
- ✓ Develop and use the cyber expertise of the state's National Guard.
- ✓ Use expertise with the civilian workforce to assist with responses.

Educate consumers about the benefits and risks of technological innovation:

- ✓ Direct agencies and work with public utility commissions to explore the customer education and outreach activities needed to support the deployment of innovative energy technologies.
- ✓ Direct agencies to support engagement with and education of a range of consumers about the benefits and impacts of innovative energy technologies.
- ✓ Promote efforts by state agencies to create educational campaigns focused on kindergarten through grade 12 schools.


ENERGY
STORAGE

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Introduction

The world is changing rapidly, in large part because of amazing new advanced and connected technologies. These technologies are transforming our daily way of life and altering how businesses and industries operate. From how we heat and cool our buildings to the cars we drive, we are witnessing what some have declared the "Fourth Industrial Revolution."[18] Given the implications for their citizens and economies of these technologies, governors are looking for ways to take advantage of the opportunities these new technologies present and tackle challenges to stay ahead of the curve. They want to know about proactive measures, partnerships and policies that can help them be "innovation governors."

The 2017-2018 National Governors Association (NGA) Chair, Nevada Governor Brian Sandoval, selected technology innovation – new products and processes that improve quality of life or deliver new value – as the theme for his NGA Chair's Initiative. The *Ahead of the Curve: Innovation Governors* initiative examined ways governors can help citizens, businesses and the public sector prepare for the technological transformation of the economy. It highlighted how governors and those they govern can stay one step ahead of the rapidly advancing technologies that affect the daily lives of residents and businesses. The initiative focused on the energy and transportation sectors as the two leading areas of innovation and explored how the innovations and disruptions in these two sectors raise new considerations for governors in other critical areas such as education and workforce, health care, safety and security.

The initiative was informed by the ongoing experiences of Nevada and other states. Additional input was provided at an experts' roundtable in Reno, Nevada, in May 2017, and a listening session in Washington, D.C., in June 2017. These meetings included a cross-section of thought leaders from state government, business, think tank, research and academic organizations.

The initiative was launched at the NGA 2017 Summer Meeting in Providence, Rhode Island. The launch featured a session with Elon Musk, CEO of Tesla and SpaceX, to discuss the impact of disruptive technologies such as electric and autonomous vehicles, renewable energy generation, and artificial intelligence (AI). Subsequently, NGA hosted two national summits. The first, an Energy Innovation Summit in Denver, Colorado, in October 2017, included Colorado Governor John Hickenlooper. The second was a Transportation Innovation Summit in Las Vegas, Nevada, in January 2018 to explore innovative trends and state policy strategies in energy and transportation. This second summit included a panel at CES, the annual electricity show, with Nevada Governor Sandoval, Montana Governor and NGA Vice-Chair Steve Bullock and Michigan Governor Rick Snyder. Those summits engaged more than 150 officials from 39 states and 300 participants. The NGA 2017 Winter Meeting continued to engage governors and included a conversation with IBM CEO Ginni Rometty to discuss the effect emerging technologies like AI and blockchain will have on the future workforce. To help visualize the data on technology innovation, NGA developed a set of "story maps" that combined maps with text, images and multimedia content to tell the story of specific energy and transportation technologies and the foundational communications networks and related policy actions to date.

For more information, please visit www.ngaahead.org.

How the roadmaps were developed

This roadmap and a companion document on transportation innovation were developed through extensive research and consultation with senior state officials and experts in the fields of energy and transportation as well as insights gathered through previous NGA activities. They were informed by the two national summits, governors' discussions and the story maps described above. In addition, NGA held an experts' roundtable in San Jose, California, in April 2018, where an array of public and private sector stakeholders provided feedback on the draft versions.

Using the roadmaps

The roadmaps are designed to guide governors and senior state policy officials as they prepare their states for changes associated with technology innovation in the energy and transportation sectors. Each roadmap describes leading new technologies and the related benefits, concerns and challenges that policymakers can expect to encounter, and then highlights existing efforts to address concerns and overcome challenges to reap the benefits. The roadmaps are sources of information and policy development tools, and states can use the portions of the roadmaps that apply to their unique situations and needs. The energy innovation roadmap will help governors prepare for the transition to more distributed, renewable, efficient and connected electricity systems, with effective strategies that enhance resiliency, diversity, consumer choice, economic development and sustainability. Both roadmaps cover electric vehicles (EVs) from an energy and transportation perspective, respectively. Readers may want to consult both roadmaps for a fuller perspective.

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About the National Governors Association

The National Governors Association (NGA) is the nation's oldest organization serving the needs of governors and their staff. The NGA Office of Government Affairs serves as the collective voice of the nation's governors in Washington, D.C., while the NGA Center for Best Practices (NGA Center) – a separate 501(c)(3) organization – functions as a combination think tank and consultancy to help states advance policy objectives by implementing evidence-based best practices. The Environment, Energy and Transportation Division – which produced this publication – is located within the NGA Center.

Acronyms

ACRONYM	DEFINITION
4G LTE	Fourth Generation Long-Term Evolution
5G	Fifth Generation
AC	Alternating Current
AI	Artificial Intelligence
AMI	Advanced Metering Infrastructure
ASREC	American Samoa Renewable Energy Committee
BEV	Battery Electric Vehicle
CEF	Clean Energy Fund
ComEd	Commonwealth Edison
CREED	Center for Renewable Energy Economic Development
DC	Direct Current
DER	Distributed Energy Resource
DOE	U.S. Department of Energy
DOER	Department of Energy Resources
DOT	Department of Transportation

ACRONYM	DEFINITION
DPU	Department of Public Utilities
E-ISAC	Electricity Information Sharing and Analysis Center
EMT	Environmental Mitigation Trust
EPA	Environmental Protection Agency
ESCC	Electricity Subsector Coordinating Council
EV	Electric Vehicle
FCC	Federal Communications Commission
FERC	Federal Energy Regulatory Commission
GPA	Guam Power Authority
GW	Gigawatt
GWH	Gigawatt-hour
ICT	Information and Communications Technology
IT	Information Technology
K-12	Kindergarten Through Grade 12
KW	Kilowatt
KWH	Kilowatt-hour
Mbps	Megabits per Second
MCEC	Maryland Clean Energy Center
MW	Megawatt
MWh	Megawatt-hour
NGA	National Governors Association
NIST	National Institute of Standards and Technology
NYSERDA	New York State Energy Research and Development Authority
OT	Operational Technology
PACE	Property Assessed Clean Energy
PC44	Public Conference 44
PHEV	Plug-In Hybrid Electric Vehicle
PII	Personally Identifiable Information
PPP	Public-Private Partnership
PUC	Public Utilities Commission
PURA	Public Utilities Regulatory Authority
PV	Photovoltaic
R&D	Research and Development
REV	Reforming the Energy Vision
ROI	Return on Investment
ROR	Rate of Return
RPS	Renewable Portfolio Standard
SCADA	Supervisory Control and Data Acquisition
SnoPUD	Snohomish County Public Utility District
TEEN	Tennessee Energy Education Network
TOU	Time of Use
USDA	U.S. Department of Agriculture
UTC	Utilities and Transportation Commission
WIB	Workforce Investment Board
ZEV	Zero-Emission Vehicle

Background

New and innovative technologies are rapidly taking hold in U.S. energy markets, leading to a transformation of the electricity sector. From widespread rooftop solar panels and smart thermostats to storage systems and electrified transportation, states are experiencing a power sector revolution. Natural gas and solar are being combined in new hybrid systems, sometimes with energy storage. Sensors are helping enhance the efficiency of coal generation. Meanwhile, end users are playing a more active role in energy use, and companies are exploring innovative models to save money and produce or use energy in cleaner ways. These changes are moving the United States toward a future that is more diverse, distributed, renewable, efficient and connected.

The future is more diverse, distributed, renewable, efficient and connected

The U.S. power system is evolving from one reliant on large-scale power plants to a more distributed and connected system, with increasing generation source diversity, distributed energy resources (DERs), connected digital devices and communications-enabled capabilities. Existing sources will continue to be used for the foreseeable future and updated, but the new technologies are being adopted quickly. Such momentous change promises compelling benefits as well as concerns and challenges that policymakers will need to address in the coming years.

Technologies

To maximize the benefits of new and upcoming technologies, states are integrating those technologies with more traditional options (for instance, coordinating the use of solar and natural gas or adding sensors to coal generation) and considering potential benefits from renewable hybridization (for example, pairing solar with storage). To enable this integration, states must be able to install advanced control and communication systems.

The following key technologies are being deployed now or are expected to be deployed at scale.

- ***Utility-scale renewables:*** Of the new utility-scale electric generating capacity added to the U.S. power grid in 2017, almost half came from renewables – mostly wind and solar. Since 2012, renewables have made up at least 40 percent of new capacity additions every year, and in 2015 and 2016, the amount was more than 60 percent.[19] In March 2017, for the first time, wind and solar (both utility scale and small scale) accounted for 10 percent of U.S. electricity generation.[20] In addition, the first U.S. offshore wind farm came online in late 2016, and a robust pipeline of projects is in the works, totaling more than 23 gigawatts (GW) of potential installed offshore wind capacity.[21]

- ***Distributed generation:*** Electric power generation on the customer side of the electric meter has been growing rapidly. The United States is expected to deploy more than 77 GW of distributed renewables between 2016 and 2025 (most of which will be solar[22]) – in large part because the costs of distributed solar have been plummeting, with residential system prices dropping 61 percent between 2010 and 2017.[23] Advanced inverters (devices that convert the direct current (DC) that solar panels provide into the alternating current (AC) that flows on the power grid) are being added to improve the performance and management of small-scale distributed generation by better handling abnormal grid conditions (e.g., not tripping off and suddenly returning, disrupting the distribution grid).[24]

Rooftop solar is often the poster child for distributed generation, but many other types of distributed generation technologies are used in the residential and commercial sectors, both renewable and nonrenewable. Other forms include small wind and natural gas-fired fuel cells, engines and turbines.[25] Soon, distributed nuclear generation could be possible, in the form of small modular reactors and microreactors.[26] In addition, DOE recently announced that it is seeking stakeholders to inform a new research and development (R&D) effort to support the design, construction and operation of a small-scale, modular, coal-based, pilot-scale plant.[27]

Figure 1 illustrates the levelized cost of energy for both conventional and new forms of new generation. This illustrates that, while generating technologies such as natural gas remain cost competitive, many alternative forms of energy generation such as wind and utility-scale solar PV are as cheap as the lowest-cost forms of conventional energy, on average. A previous version of this chart included an estimated levelized cost of energy for energy efficiency of $0-50.[28]

Lazard's 'levelized cost of energy' calculations account for more than just the price to build a facility, but includes the costs of operating the plant at net-present-value.

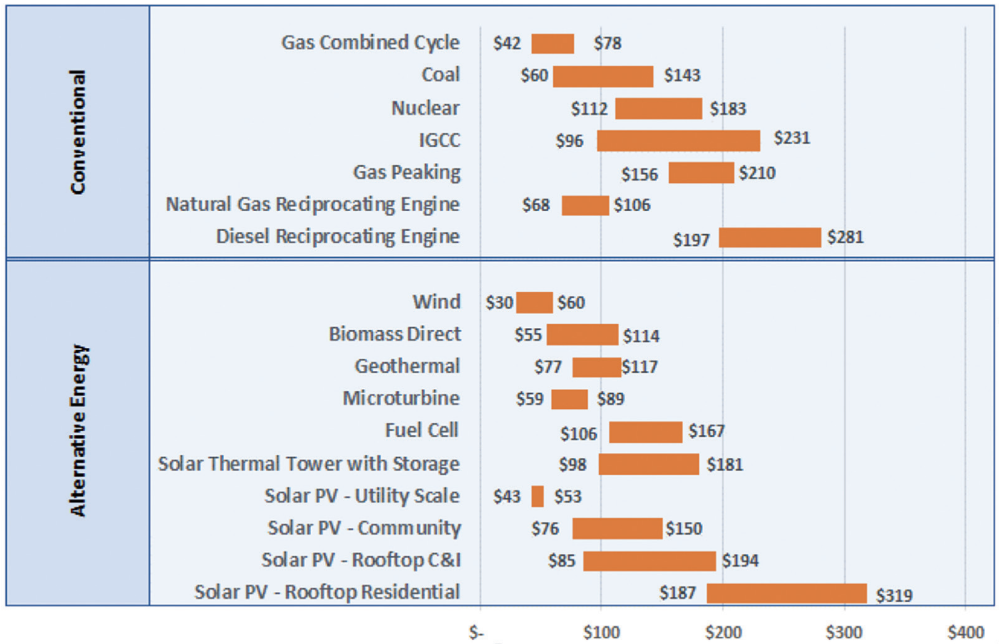


FIGURE 1: Levelized Cost of Energy[29]

Source: Lazard. (2017). Lazard's Levelized Cost of Energy Analysis – Version 11.0. Retrieved from https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf.

- ***Energy storage:*** Advanced energy storage technologies, which are currently dominated by lithium-ion batteries but also include other battery technologies, compressed air, thermal storage, flywheels and pumped (hydro) storage, facilitate greater use of renewables, reduce the need for expensive "peaker" power plants, add greater potential to "virtual power plants" and improve the resilience of the power grid.30 Deployment has increased rapidly because of declining costs, technology improvements and regulatory changes. Advanced (non-hydro) energy storage capacity grew three-fold in five years, from 442 megawatts (MW) in May 2012 to 1,554 MW in May 2017.[31] In megawatt-hour terms, battery storage deployments in the United States grew 100 percent from 2015 to 2016.[32] In addition to state policies, much of this increase in deployment is driven by rapidly declining costs. Costs vary widely by technology, but some projected cost declines are significant. For example, Lazard projects 38 percent declines in costs for lithium-based energy storage, 37 percent for sodium-based storage and 49 percent for lead-based storage between 2016 and 2020.[33] In 2020, cumulative installed capacity of non-hydro energy storage is expected to reach 2 GW, growing to a $2 billion market in the United States.

- ***Energy efficiency and demand response:*** Energy efficiency (technologies and processes that use less energy to perform the same functions) and demand response (activities to reduce electricity use at times of high-priced peak electricity consumption) saved about 200 billion kilowatt-hours in the United States in 2015.[34] Energy efficient technologies, such as light-emitting diode lightbulbs, are experiencing increasing adoption.[35] In 2010, this technology represented 1 percent of the lighting market worldwide; by 2015, that number had reached 28 percent and is projected to reach 95 percent by 2025.[36] Demand response programs and technologies are increasingly being implemented through price signals to utility customers and advanced software systems to allow for the creation of "virtual power plants" that can automatically reduce energy consumption across fleets of buildings at peak times, when power is most expensive.[37]

- ***Smart devices (the internet of things):*** Connecting devices and appliances – whether in homes or in businesses – to the internet (or otherwise allowing them to communicate) allows for more frequent and precise control of those devices and therefore greater system energy efficiency and potential for demand response. Research shows that less than 20 million U.S. households had a smart home device at the end of 2016, but many more are expected to adopt them over the next few years, with more than 40 million households expected to have a smart thermostat, nearly 50 million to have a smart light bulb and almost 14 million to have a smart home controller by 2020.[38]

- ***Electric vehicles:*** In 2017, nearly 200,000 EVs were sold in the United States, an increase of more than 25 percent from 2016, and 2016 sales represented an increase of more than 36 percent over 2015.[39] EVs accounted for 1.1 percent of new U.S.

vehicle sales in 2017, up from 0.9 percent in 2016,[40] and some project that EVs could make up 58 percent of new car sales in the United States by 2040, driven by plummeting battery costs.[41,42] Of note, April 2017 marked 31 months of consecutive sales growth, and 9 global manufacturers and 26 Chinese manufacturers have announced plans to expand EV offerings in next 5 to 10 years.[43] These trends have sparked projections that there could be 40 million to 70 million EVs globally on the roads by 2025.[44] A key barrier to EV adoption is range anxiety: the perception among consumers that charging infrastructure is insufficient, limiting where they can travel and possibly stranding them with a depleted battery. This concern was understandable for early vehicles and infrastructure, but in recent years, both the distance an EV can travel on a single charge and the number of publicly available charging stations have increased significantly. For instance, **Nevada** recently completed the first phase of the Nevada Electric Highway, an initiative to strategically develop public EV charging infrastructure across the state. Higher rates of EV adoption present an opportunity to reduce and shift greenhouse gas emissions, grow and smooth demand and cut costs for consumers both directly and indirectly. However, if inadequately managed, the growing number of EVs plugging in simultaneously could significantly affect electricity usage and peak demand. States are also exploring regional planning approaches to more effectively deploy infrastructure. For example, the governors of eight western states, including **Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah** and **Wyoming**, have signed an MOU to coordinate the development of a regional EV charging networks.[45]

Electric Vehicle Terminology

Several EV technologies exist today. In this report the term "EV" refers to two technologies: battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). BEVs are powered exclusively by an electric battery and PHEVs are powered by a combination of an electric motor and a gasoline engine. Both recharge by plugging-in to an electricity source.

Beyond Electric Cars

Electrified transport also encompasses three growing modes of transportation: electric-bicycles (ebikes), electric scooters and electric ferries. The rise of ebikes and electric scooters in urban areas built on the success of bike-sharingc and represents the increasing diversity of personal mobility devices. In the United States alone, roughly 35 million trips were taken in 2017 on bike-share systems, a 25 percent increase from 2016.[46] Electric ferries are being adopted to capture many of the same benefits EVs offer – namely, reducing harmful emissions, achieving cost savings and minimizing fuel price uncertainty.[d] Washington is currently in the process of evaluating the potential of converting several existing ferries to electric propulsion systems. The Washington State Department of Transportation (DOT) conducted numerous life cycle cost analyses of the retrofit and found cost savings ranging from 1 percent to 25 percent contingent on the number of ferries and docks converted as well as future diesel prices.[47]

[c] Bike-sharing systems enable the short-term, shared use of bicycles at affordable prices. These systems can be fixed, with bicycles locked into docking stations situated throughout a given region, or "dockless," with users locating and unlocking bicycles through their smartphone global positioning system. Bike-sharing systems can be publicly or privately operated.

[d] A fringe benefit is the elimination of engine noise, which may benefit aquatic ecosystems.

Microgrids: Microgrids are localized grids that can disconnect – or "island" – from the bulk power grid and use DERs and control systems to operate autonomously, thereby increasing grid flexibility and resilience.[48] Technologies that microgrids use include solar photovoltaic (PV), battery storage, natural gas generators and fuel cells, combined heat and power systems and smart controls.[49] Installed microgrid capacity in the United States is expected to more than double between 2017 and 2022.[50]

Smart grids and advanced metering: The combination of advanced metering infrastructure (AMI) – an integrated system of smart meters and data-management systems that enables two-way communication between customers and electric utilities (or third-party providers) – and transmission and distribution automation technologies that use data to change how electricity flows through the system are reshaping and modernizing the electric grid.[51] In 2016, U.S. electric utilities had installed more than 70 million smart meters, the vast majority of which were in the residential sector.[52] Installations were expected to reach 76 million by the end of 2017 and are projected to reach 90 million by 2020.[53]

Sensors: Advanced sensors are a fundamental component of smart grids, providing accurate, real-time insights into grid conditions.[54] For instance, sensors can help utilities monitor the real-time two-way flow of electricity on the grid, improve reliability, provide real-time alerts about system disruptions, enhance responsiveness to outages and support the integration of clean energy technologies.[55] Potential applications for such sensors are not limited to the grid itself. For instance, a range of advanced sensor technologies could immediately alert operators of natural gas transmission, distribution and production infrastructure to wasteful leaks.[56] Sensor and control systems are also being applied to coal-fired power plants to improve efficiency, reduce costs and minimize pollutant emissions.[57]

Big data and analytics: Advanced sensors, meters and devices on the grid generate enormous amounts of data. A smart meter that transmits a reading every 15 minutes may require roughly 200 megabytes per year of data storage.[58] With 70 million smart electric meters installed as of 2016,[59] that equates to approximately 14 petabytes (or 14 billion megabytes) per year.[60] That volume will only grow as the grid modernizes. This data gathering has increased the role and potential value of big data analytic software and services, for which North American revenues are expected to grow from about $390 million in 2016 to about $1.2 billion in 2025.[61]

Advanced communication networks: Advanced communication networks are in many respects the foundational infrastructure that supports the technologies in a modernized grid. Digital communications networks that overlay traditional electric power infrastructure to deliver data in addition to electricity enable utilities or grid operators to receive and act on data in near-real time and assets across the grid to communicate with one another and respond to changes in demand, supply and congestion more seamlessly.[62]

The Role of Communications Networks and Connectivity

A decentralized, highly responsive and resilient energy system hinges on a critical piece of enabling infrastructure: a robust wireless broadband network. Smart grid technologies that enable utilities to monitor systems, efficiently allocate capital and respond to and manage demand in real time will transmit and receive substantial quantities of data in interacting with infrastructure and consumers. The two main categories of broadband transmission are physical or fixed broadband and mobile or wireless broadband. In regions with deficient connectivity, new infrastructure investments and policies to facilitate deployment are necessary to capture the beneficial network effects of ubiquitous wireless connectivity. Given the diversity of needs, topography and markets across the country, no single best approach to deploying wireless broadband exists.

Physical Broadband Networks

The four prevalent types of physical broadband networks, with varying connectivity speeds, applicability and associated costs, are:

- ***Buried fiber:*** Fiber-optic cables that require construction equipment to be buried and can transmit information at high speeds; the larger the strand count, the greater the bandwidth (i.e., transmission speed) the fiber route can sustain; active strands are called "lit fiber," and unused strands are called "dark fiber."[e]
- ***Aerial fiber:*** Like buried fiber but with cables strung along poles rather than buried; can take advantage of existing utility poles instead of digging new holes but is more exposed to natural damage.
- ***Coaxial cable:*** Mature technology developed in the early 20th century consisting of a copper wire encased in insulation; stable, reliable and inexpensive, but speeds are slower than fiber.
- ***Microwave:*** Fiber-optic cables run to a telecommunications tower that uses a microwave transmitter to broadcast data to microwave relays that rebroadcast to expand coverage to customers with microwave receivers.

Mobile Broadband Networks

Mobile networks transmit broadband over the wireless spectrum. The Federal Communications Commission (FCC) has authority to allocate spectrum for specific, nongovernment purposes and grants licenses for its use under Title III of the Communications Act of 1934.[63,f] Mobile networks have evolved over time, with data-transfer speeds increasing with each new iteration or generation. The mobile broadband technologies of note for the energy sector include:

- ***Fourth-Generation Long-Term Evolution (4G LTE):*** 4G LTE, often referred to simply as "LTE," is a wireless telecommunications technology standard considered a type of 4G with relatively fast connection speeds, enabling users to transmit and receive data at rates comparable to a home wireless connection. These speeds may be inadequate for energy technologies that require instantaneous data exchange.
- ***Fifth-Generation (5G):*** Although not yet fully defined, 5G uses a high-frequency band of the wireless spectrum that can exchange large quantities of data at very high speeds. High-frequency waves can travel more limited distances than the lower frequency waves used in 4G networks and have difficulty when encountering walls, buildings and other obstacles.

[e] "Dark fiber networks" are separate, private networks controlled by the client rather than a network provider.
[f] The National Telecommunications and Information Administration administers spectrum for federal use.

Three categories describe where the network is connected:

- ***Middle-mile:*** Provides broadband to one or more centralized facilities, enabling last-mile providers to deliver internet access.
- ***Last-mile:*** Provides internet access to end-user devices, often in a home or business.
- ***Community anchor institution:*** Generally public institutions such as schools or libraries that receive a broadband connection and serve as a point of access.

In 2016, 92.3 percent of the total US population had access to fixed terrestrial broadband at speeds of 25 megabits per second (Mbps) download/3Mbps upload.[64,g] (Price of service, however, was likely a major factor in only 53.3 percent of Americans adopting fixed broadband services in 2016.) Within this access-to-broadband statistic is the additional statistic that 30.7 percent of Americans living in rural areas lack access to fixed terrestrial broadband at comparable speeds. Although slower than fixed broadband and incompatible with the needs of some advanced technologies, mobile LTE offers connectivity speeds of 10Mbps/3Mbps to 87.3 percent of the United States, although roughly 40 million Americans still lack access to mobile LTE services.h A current push to roll out 5G, which promises speeds significantly higher than current mobile LTE offerings (and some fixed broadband, as well), is underway, but permitting challenges have slowed the large-scale deployment of small-cell infrastructure to ensure the seamless use of the network.

Although the discussion of the digital divide often and rightly focuses on disparities between urban and rural areas, the digital divide of those in urban areas unconnected to the internet is no less critical. For example, one study found that 18.74 percent of New York City's total population is unconnected and that unconnected urban populations nationwide represent 79.24 percent of total unconnected citizens in the United States.[65]

The benefits of overcoming the current connectivity divides to enable smart grid adoption in the United States are substantial; estimates have found that a more efficient and reliable smart grid could generate $1.8 trillion in revenue for the United States between 2013 and 2020, directly save consumers $40 to $100 annually, smooth and reduce demand and indirectly save consumers $50 per year.[66] Critically, the benefits of access to high-speed connectivity extend well beyond the energy sector, enabling innovation and the delivery of goods and services across the public and private arenas in an increasingly connected society. Consequently, investment in broadband infrastructure has a multiplier effect, exponentially influencing the social and economic welfare of a state.

This map shows the percentage of each state's population with access to broadband communication infrastructure. The darker shading signifies that a greater portion of the population has access to broadband. Importantly, a state with high broadband penetration overall may still have poor rural connectivity. The data originated from FCC's Form 477, a form all broadband providers are required to file with FCC biannually on where they offer Internet access service.[67] While these data represent the best available information, concerns about their accuracy have been raised, and efforts to improve U.S. broadband data, both fixed and wireless, are underway.[68]

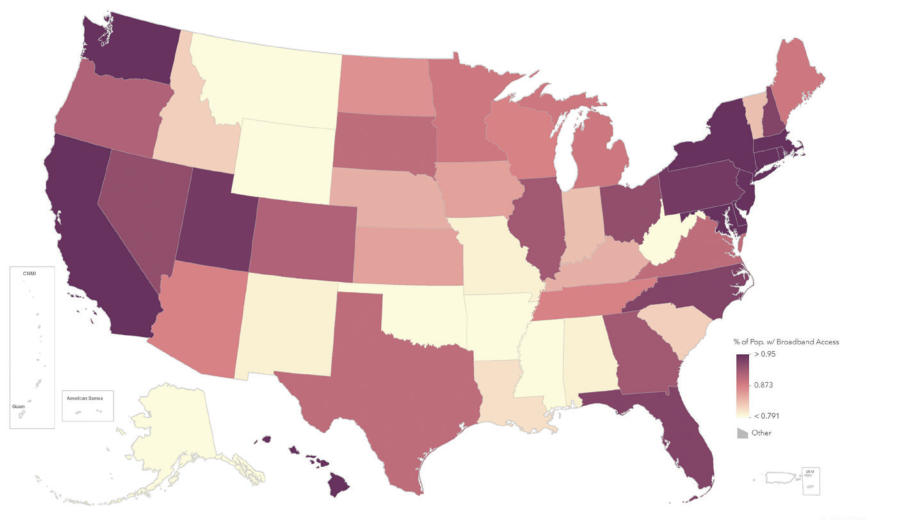


FIGURE 2: Percentage of each state's population with access to physical broadband networks. The darker the shading, the greater percent of the population with access to broadband.

Source: Federal Communications Commission. (2018, February 2). 2018 Broadband deployment report (GN Docket No. 17-199). Retrieved from: https://apps.fcc.gov/edocs_public/attachmatch/FCC-18-10A1.pdf

[g] FCC has found that fixed broadband speeds of 25Mbps/3Mbps meet the statutory definition of "advanced telecommunications capability," "enabl[ing] users to originate and receive high-quality voice, data, graphics, and video telecommunications." 47 U.S.C. §1302(d)(1).

[h] Access to service is defined at the census block level, not the household level, meaning that the whole block is labeled "covered" if a provider offers service anywhere in the census block.

Blockchain

"Blockchain" refers to software technology that uses a decentralized method of recording transactions to enable connected computers to reach agreement over shared data.[69] Transactions today require human processes and institutions, such as banks, lawyers, regulators, brokers and utilities, to establish trust. Blockchain technology enables transactions without the need for paid intermediaries through an immutable distributed ledger of continuously growing data records that facilitates transparency and security. Still in the early-adoption phase, utilities are beginning to pilot blockchain in areas such as metering and billing, EV charging, grid management and decentralized generation. Through these pilots, utilities are exploring ways to reduce transaction costs, improve transparency and increase payment discipline. There is growing awareness of potential blockchain applications in the energy sector, but the technology is most known for enabling the proliferation of cryptocurrencies, such as bitcoin. The computations to produce new coins, a process known as "mining" that involves verifying transactions, is incredibly energy intensive. One study found that in 2018, electricity consumption from mining could rise to 125 to 140 terawatt-hours, or 0.6 percent of global energy consumption.[70] The figure below shows a simple blockchain transaction.

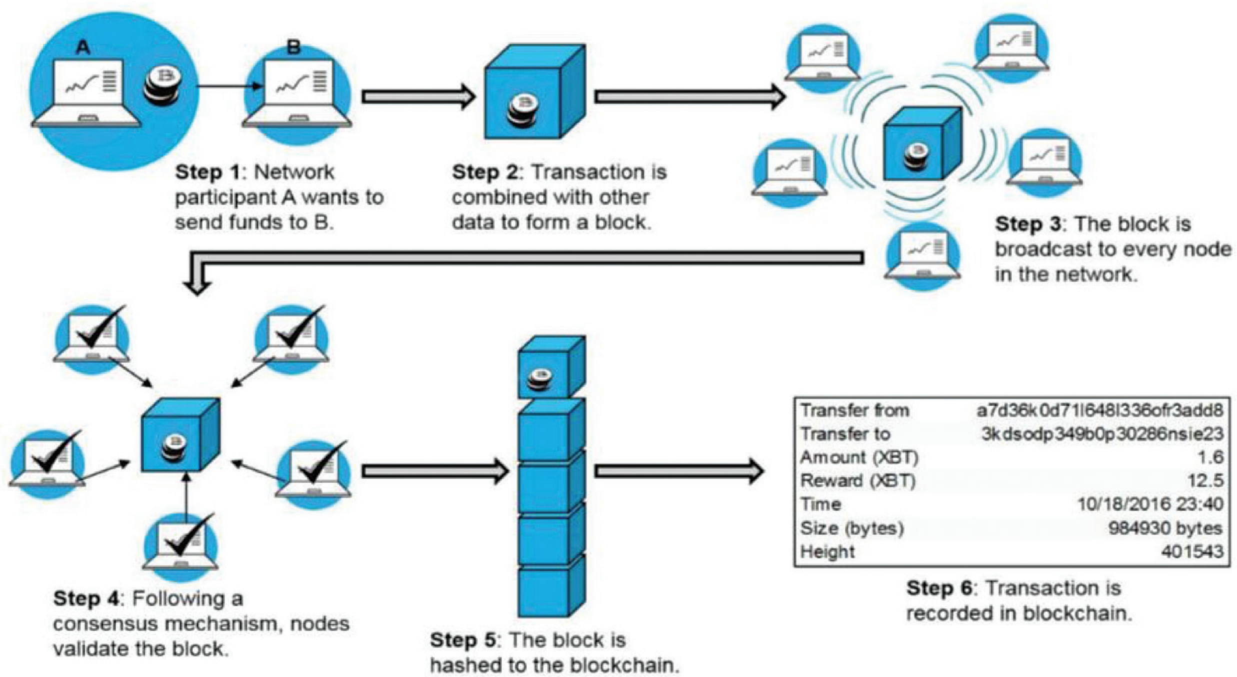


FIGURE 3: Visual illustration of a blockchain transaction

Source: Bloomberg New Energy Finance.[71] Applications for blockchain grow in energy, transport. (2017, December 11). Retrieved from Bloomberg New Energy Finance website: https://about.bnef.com/blog/applications-blockchain-grow-energy-transport/

Motivations, Concerns and Challenges of Energy Technology Innovation

Motivations

The transformations occurring in the U.S. energy system can bring many benefits.[72] The motivations for states to embrace and promote energy innovation can include:

- ***Creating jobs and enhancing economic competitiveness:*** Energy innovation can be a catalyst stimulating economic growth, jobs and competitiveness in states. Lower energy costs, improved efficiency and fewer outages are advantages to state businesses, residents and communities. Clean energy innovation and deployment also create new jobs in technical fields such as data science and information technology (IT) as well as jobs for electrical line workers, electricians and installers. These trends can help attract new talent and businesses to the state, particularly as many innovative companies now seek out and prioritize clean energy sources for their operations. Universities and business that engage in R&D and technology incubation can help support a broader ecosystem for innovation that spurs additional economic activity. In the United States in 2017, energy efficiency provided more than 2.2 million jobs, solar generation provided about 350,000 jobs and electricity storage supported more than 91,000 jobs (53,000 of which were affiliated with battery storage).[73]

- ***Maintaining or enhancing reliability and resiliency:*** Maintaining reliability and resiliency is becoming a greater concern for utilities as grid infrastructure continues to age, natural disasters become more frequent and extreme and DERs lead to higher load fluctuations on the grid. According to the National Oceanic and Atmospheric Administration, the number of natural disasters – to include severe storms, droughts, freezes, and wildfires – is increasing, with 15 or more such events in each of 2016 and 2017.[74]

  Electric reliability measures the ability of the grid to deliver power when and where it is needed. "Resiliency" measures the ability to reduce the magnitude and duration of a disruption to electricity delivery, including maintaining a level of service during non-normal situations such as after a disaster. A modernized grid enables utilities to better understand and address weaknesses in the distribution system, reducing both the frequency and the duration of power outages. Modernized grids give grid operators a much better understanding of the state of the electrical grid at any time – whether during normal operation to prevent faults before they happen or during incidents that damage infrastructure, when sensors and communication systems on the grid can point to affected areas and enable utilities to deploy resources quickly and efficiently to repair outages. The ability of microgrids to island themselves means that sections of the grid remain operational even when the broader grid is down – a particularly useful capability when designed around critical infrastructure. In addition, if properly managed, EVs may have the ability to function as a source of variable demand, complementing and allowing for more variable renewable energy on the grid. EV batteries could provide resiliency and reliability services similar to other forms of storage through vehicle-to-grid interface or second-life applications.

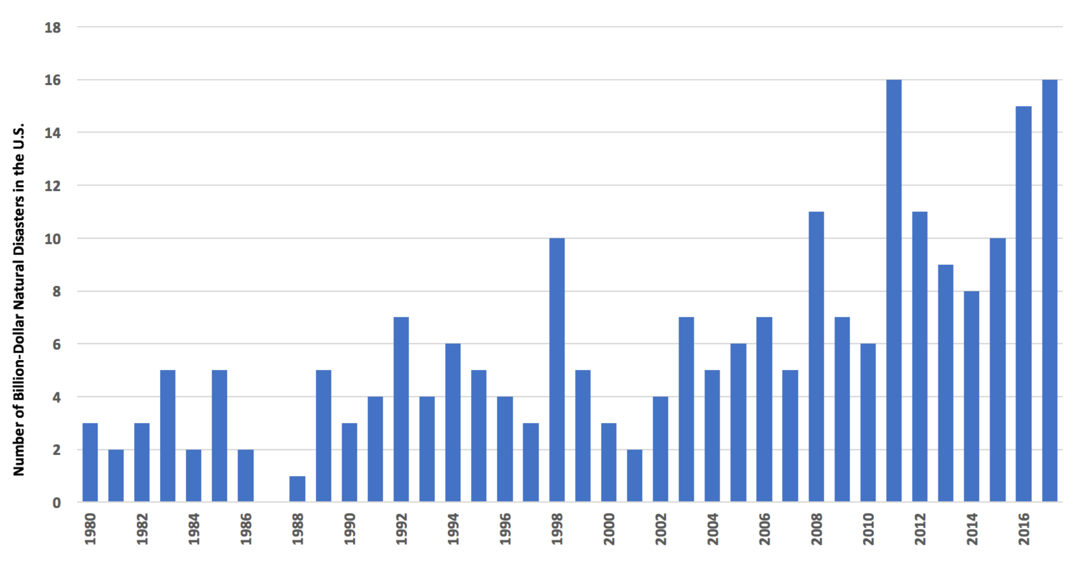


FIGURE 4: Number of Billion-Dollar Natural Disasters in the U.S. Over Time[75]

Source: NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2018). https://www.ncdc.noaa.gov/billions/

- ***Reducing costs:*** Electricity demand has slowed in recent years, but growth in demand at times of peak consumption (e.g., summer afternoons) has grown, driving up the costs of electricity because expensive power plants are used inefficiently and infrequently. Modern technologies can help the grid become more cost efficient by delivering power to end users more efficiently, more accurately balancing demand with the lowest cost supply available, communicating data to end users that facilitate reductions in energy consumption during high-cost periods and requiring less investment in grid operations and maintenance. Better knowledge of conditions on the grid and at the meter can enable predictive asset maintenance and replacement, identifying imminent faults before they result in outages or more costly equipment failures. In a simpler fashion, cost-effective energy efficiency policies directly reduce customers' energy costs. Increasingly, well-designed distributed renewable energy policies can lower costs to the distribution system and displace expensive peaking power plants. In addition, large-scale EV adoption has the potential to provide a substantial increase in electricity load; adding load, particularly when the grid is underused, can benefit all customers by spreading fixed costs over a greater volume of sales without the need for new investments.
- ***Enhancing customer choice:*** Energy innovation enables consumers to better manage their energy use and adopt new technologies. The traditional pricing of electricity encourages customers to consume electricity in a predictable fashion, albeit one that does not optimize for cost, system efficiency or environmental impacts. The data that advanced meters unlock enables utilities and third-party providers to create new tools and technologies that offer customers greater understanding of and control over their energy consumption choices. Customers can use these technologies and services to more effectively undertake energy efficiency upgrades or save money by reducing use during peak power periods where rate designs allow. Energy innovation also enables greater and better integration of distributed renewable energy technologies that customers are increasingly demanding, as seen in the deployment of rooftop solar systems that enable customers to play a more active role in the electric power system but that also can strain dated power grid equipment as power flows in manners beyond their design specifications.
- ***Lowering emissions:*** States continue to look at ways to decrease the environmental impact of electricity generation by improving efficiency, shifting consumption and using lower emitting sources of generation. A modernized system that reduces consumption and facilitates the integration of distributed resources such as energy efficiency and renewable generation can help states lower energy consumption and increase the levels of lower emitting generation on the grid. Electrifying transportation shifts emissions from the tailpipe to an electricity generating source, where they are easier and less expensive to control.[i] The health benefits are also of interest, with studies suggesting that internal combustion engine vehicle emissions of nitrogen oxides (NOx), particulate matter and other pollutants can lead to a host of respiratory diseases, premature death and cardiovascular morbidity.[76] In addition, EVs are highly efficient at converting energy into motion, typically consuming less than half the energy an internal combustion engine vehicle uses.[77] Importantly, the environmental and health benefits from electrification can continue to improve over the vehicle's lifetime if the power sector continues to move toward cleaner sources of electricity.[78] The benefits of electrification are applicable to a range of vehicles as well as ports and airports, which can install electric-powered terminal equipment and provide energy to ships and planes in lieu of oil- and diesel-powered engines.[79]
- ***Manufacturing resurgence:*** The U.S. shale revolution has driven a resurgence in and growth of U.S.-based petrochemicals manufacturing because of low-cost, abundant natural gas.[80] Ethane, a natural gas derivative, is a key feedstock for chemical companies. Low ethane prices have spurred investment in petrochemical facilities across the country (see Figure 5).[81, 82]

Concerns

Multiple motivations drive states, industry and citizens to deploy innovative energy technologies, but legitimate concerns exist about new technologies that could hinder deployment or unnecessarily increase costs to consumers. Concerns that states will need to address to ensure a transition to modern energy systems that is smooth, effective and protective of consumers include the following:

- ***Variable generation:*** To reliably provide power to millions of customers on the grid, power generation must be carefully balanced in real time to match demand. However, power demand changes over time and seasons, and to match that changing demand, energy markets provide price signals to generators that indicate when more or less generation is needed. As long as they have fuel supplies, traditional power plants that run on coal and natural gas can ramp up or down as needed at any time, generating more or less power based on the demands energy consumers place on the grid. In contrast, some renewable and distributed forms of energy generation, such as wind and solar, cannot be called on to generate power on demand — at least not without storage capabilities. Rather, solar panels generate power when the sun shines and wind turbines when the winds blow.

[i] Emissions may even be zero when using renewable energy sources like solar and wind as the electricity source for EV charging.

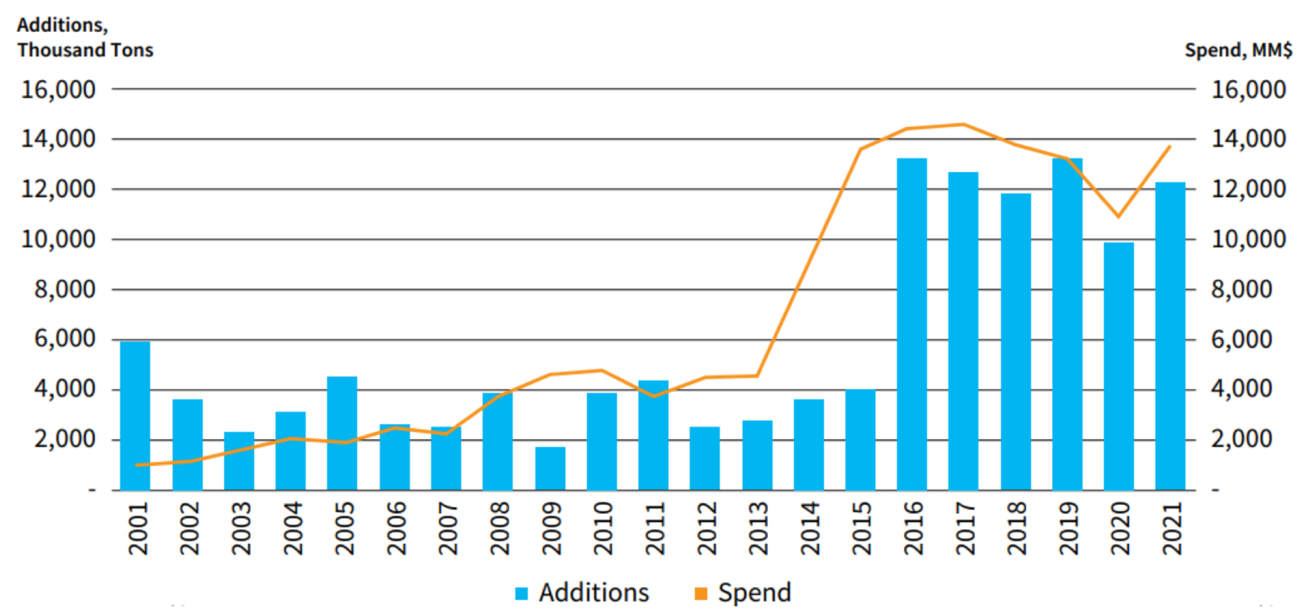


FIGURE 5: U.S. chemical capacity additions and spending (planned and forecast)

Source: Witte, D. (2017). The enduring effects of shale on petrochemical manufacturing. Retrieved from https://ihsmarkit.com/research-analysis/the-enduring-effects-of-shale-on-petrochemical-manufacturing.html

Sunlight and wind can both be forecasted in the near term, which means that the variability of their generation can be accounted for in daily system planning, but their variable generation can make it more difficult to align electricity production and load as needed to keep the grid stable. As more renewables, both utility scale and distributed, are added to the grid, concerns about accounting for variability grow.[83, 84]

One example of this effect has been demonstrated in **California** by the California "duck curve," illustrated in Figure 6, although that effect varies by state and region. The chart shows that as solar generation increases, it can offset more and more centralized power generation during the middle of the day, but when the sun goes down and the evening peak demand hits, the ramp-up required of traditional power-generation sources to meet load becomes larger and steeper (again, assuming the absence of significant energy storage capabilities).

Utilities and grid operators have been preparing for the influx of variable renewable power sources on the system.[86] Possible solutions include increasing deployment of utility-scale power storage, which can store solar power generation mid-day for use during times of peak demand; increasing demand response programs to reduce peak demand and shift demand to off-peak times; providing customer price signals to encourage pairing solar with distributed storage; and expanding the geographic range of the grid, including by building long-distance transmission lines to capture more areas where the sun

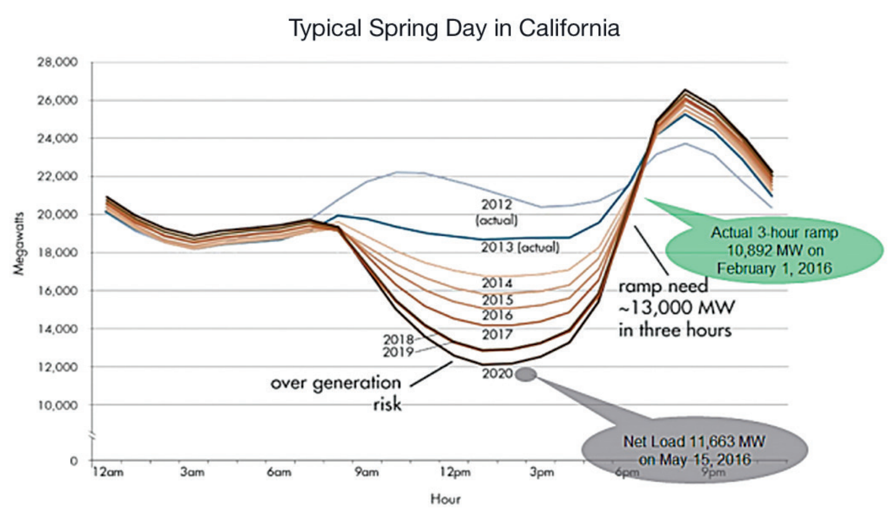


FIGURE 6: The California "duck curve" illustrates the impacts of increased solar generation on net load in California[85]

Source: California Independent System Operator. (2016). What the duck curve tells us about managing a green grid. Retrieved from https://www.caiso.com/documents/flexibleresourceshelprenewables_fastfacts.pdf is shining or the wind is blowing.[87] Advanced inverters (devices that convert the DC that solar panels supply into the AC that flows on the power grid) are being added to improve the performance and management of small-scale renewable energy systems so that these generation resources play a part in maintaining power quality on the distribution grid (and more importantly, not making it worse) and can better handle abnormal grid conditions (e.g., not tripping off and suddenly returning, thus disrupting the distribution grid).[88]

- ***Cybersecurity:*** An energy system that relies more on digitally connected devices and components may be more vulnerable to cyberintrusions and attacks. Two broad types of systems are at risk: IT systems, which contain sensitive financial and personal information, and operational technology (OT) systems, including Supervisory Control and Data Acquisition (SCADA) systems, which remotely monitor and control plants or equipment. The vulnerabilities of these two systems differ and so call for different types of protections and responses.

  Cyberattacks on OT systems can interrupt fuel production and supply, shut down large power plants or cause outages. This concern became a reality in Ukraine in 2015, when Ukrainian Kyivoblenergo, a regional electricity distribution company, experienced a cyberintrusion into its SCADA systems that remotely triggered outages for approximately 225,000 customers.[89]

  The cyberthreat is also real in the United States, where utilities and grid operators must deal with thousands of attempted cyberattacks and IT system intrusions every month.[90] The proliferation of connected, smart devices exacerbates this risk, as highlighted by the October 2016 distributed denial of service attack that disabled many websites around the world by using the internet connections of devices such as baby monitors and security cameras.[91]

- ***End-user data privacy:*** A smarter electric grid allows for generation of more – and more granular – data, including consumption data at (or more frequent than) 15-minute intervals and metered data at more points across the grid. These data can provide a host of benefits to consumers, utilities and system operators. Smartphone apps and advanced energy management systems can give customers unprecedented views into and control over their energy consumption, allowing for the deployment of energy efficiency, demand response and time- and location-based pricing. Energy consumption data can also help system operators more effectively deliver power and manage the grid.

  However, with this abundance of new data about customers that utilities are gathering and storing comes a need for enhanced data governance to address data protections, security and ownership. Data that smart meters and sensors gather can in theory be used to discern household behaviors and sensitive information about industry often deemed proprietary. Further, this information is connected to sensitive personally identifiable information (PII) that includes names, addresses, bank accounts and other information that utilities use for billing and other business purposes. With the advent of connected smart meters and devices and potentially new, third-party companies requesting access to those data to deliver services to customers, it is increasingly important that proper data protections be put in place to keep PII and other sensitive information from being made public or inappropriately shared or accessed.[92] Utilities and other stakeholders in the United States (and elsewhere) have been pursuing efforts to address these data privacy concerns, such as DOE's DataGuard Energy Data Privacy Program.[93] In addition, policies that clarify ownership of data, which refers to both possession and responsibility, are necessary to facilitate sharing and ensure data integrity.[94]

- ***Workforce:*** Workforce development and job creation are major motivators for energy innovation and infrastructure modernization. However, innovation does not affect the workforce in all geographies equally. A new technology may create a net increase in jobs in one region but displace jobs in another, as shown in Figure 7. As this figure shows, based on data from DOE's "U.S. Energy and Employment Report," employment per capita for traditional power generation technologies such as coal, natural gas and other fossil fuels is concentrated in the Midwest, mountain and southern regions of the country, while newer generation technologies like solar are shifting energy employment to western and northeastern regions (with some remaining in the Midwest).[95]

  Even if the geographies of the jobs do not change, new technologies may shift employment away from traditional industries and specializations to new and emerging industries and specializations, leaving some workers without suitable employment. Similarly, automation, as it becomes more prevalent, can lead to job losses as machines replace human workers. For example, as more smart meters are installed, fewer workers will be needed to drive out to locations to manually read meters.

- ***Equitable access:*** Innovative technologies can provide multiple benefits, but these technologies can also be cost prohibitive for certain populations on a first-cost basis, even when they are cost-effective in the long run. For example, the Lawrence Berkeley National Laboratory found that in 2016, the median residential solar system cost around $24,800 for a 6.2 kilowatt system (excluding the 30 percent federal tax credit and state and utility incentives),[97] which is a substantial expense when the median household income is approximately $60,000.[98] Likewise, energy efficiency, which saves customers money by reducing their

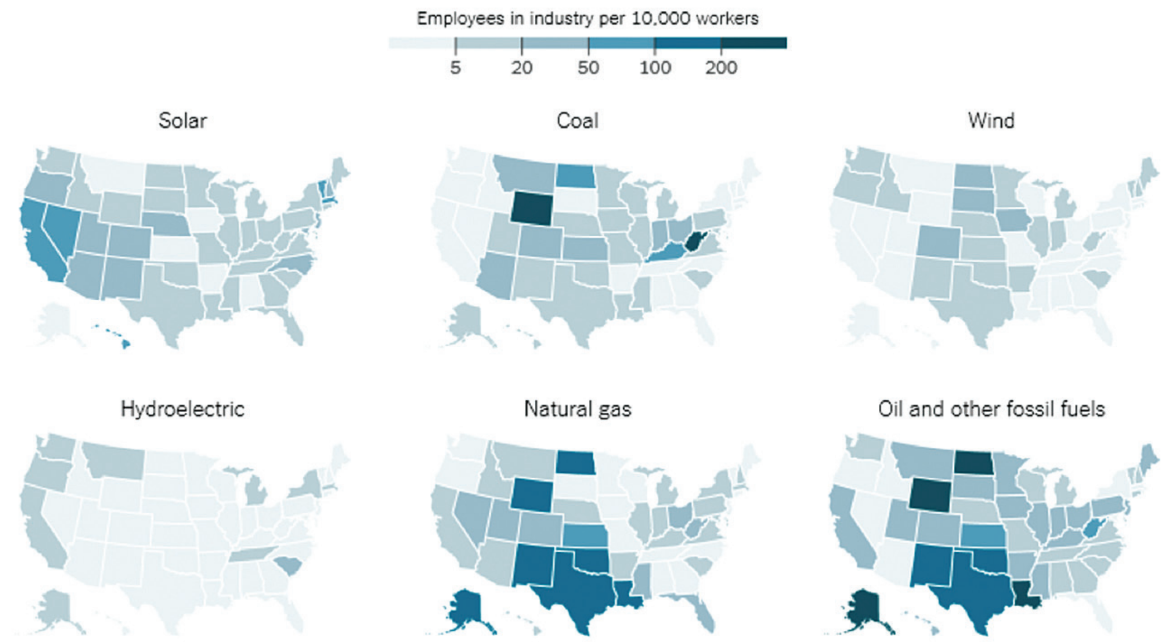


FIGURE 7: Employment by electricity generation technology[96]

Source: Popovich, N. (2017, April 25). Today's energy jobs are in solar, not coal. The New York Times. Retrieved from https://www.nytimes.com/interactive/2017/04/25/climate/todays-energy-jobs-are-in-solar-not-coal.html

energy usage, often involves some upfront capital investment. Without suitable financing, lower or even moderate-income households and small businesses may not be able to access new technologies and the benefits they provide.

This access challenge creates a potential cross-subsidization concern. In many states, customers with solar generation receive subsidies in addition to compensation (at the retail rate) for the energy they produce and sell back to the grid. Some assert that these incentives are needed to encourage the installation of rooftop solar, while others assert that those who do not have on-site generation are subsidizing other customers (whose median household income is generally higher).[99] This debate is ongoing in front of many public utility commissions, resulting in the exploration of new compensation methods in some states.[100] The situation is similar for EVs, which currently are purchased predominantly by higher income consumers, which means that purchase incentives can be perceived as a taxpayer subsidy for wealthier citizens.[101] Utilities that construct EV charging equipment and incorporate the cost into the rate base essentially have customers who do not own EVs help finance infrastructure they typically do not use. In contrast, many argue that deployment of rooftop solar, EVs and other innovative technologies benefit the system as a whole, not just the individual consumers who own the technologies, and that it is therefore appropriate to broaden the base of those who help support such deployment. In addition, some options, like community solar, give customers who rent, have low credit scores or lack adequate housing stock the opportunity to invest in and reap the benefits of solar assets.[102]

Challenges

The adoption of new technologies in the U.S. energy sector is accelerating, but the transformation faces challenges:

- ***Regulatory models:*** Electric utilities are facing a fundamental challenge to their profitability and long-term viability because the business models shaped by state regulation and legislation have not kept pace with contemporary technologies, customer preferences and state policy goals. Further, a transition in many areas toward less energy-intensive industries, increased energy efficiency and more distributed generation has led to near-flat or even declining load growth.[103] Under many traditional rate designs, this evolution may strain utilities' profitability and potentially increases the rate impacts of new utility investments because the fixed costs for those investments cannot be recovered through additional growth in electric sales. These higher rates may in turn make investments in new distributed generation and energy efficiency more cost-effective, leading to a cycle known as the "utility death spiral." Complicating the situation for utilities, much of the ongoing power sector transformation is being driven by new, third-party market entrants, which are often treated differently than utilities in the state regulatory framework and deploying new technologies at increasing scale.[104] A 2016 survey found that 97 percent of utility executives believe that their utility's business model needs to evolve, and executives generally view the existing regulatory model as the main obstacle to that evolution.[105]

- ***Markets and financing:*** The range of technologies being deployed as the grid is modernized means that different services of significant value can be provided to utilities and customers (e.g., ensuring that the energy is of the right quality in terms of voltage and other qualities, reducing emissions and improving grid resilience), but electricity markets often do not compensate these technologies for the full value they provide to the smooth, reliable and clean operation of the grid.[106] In addition, modernizing the grid and deploying innovative technologies at scale are costly, even when those technologies are cost-effective in the long run. Estimates of the amount of investment needed for grid modernization range from about $350 billion to about $500 billion. Inadequate capital could hinder the transition.[107]

  Moreover, some infrastructure investment and ownership models have potentially harmful market and economic impacts. For example, the cost of installing a nationwide public EV charging network is considerable, with estimates suggesting that 8,000 additional DC fast chargers are needed for a minimum level of coverage.[108] (Home charging is an option for some, but less than half of all drivers have access to dedicated off-street parking.[109]) On the one hand, if regulated utilities are permitted to build the public EV charging network, their monopolistic structure may grant them a competitive advantage over independent suppliers, potentially hindering innovation.[110] On the other hand, excluding utilities, which are experts at deploying electricity-providing infrastructure, from the EV charging opportunity could hinder deployment. Policymakers will have to assess the investment and market dynamics in their state to find appropriate investment models.

- ***Technology:*** Technological challenges can hinder the energy transition, one of which is interoperability. Electric utilities, third-party service providers and consumers are installing new technologies with two-way communications on the grid, and these technologies must work seamlessly with one another. If they are not integrated and communicating properly, grid performance and efficiency can suffer.[111]

  Other challenges are related to obsolescence. Formulating, adopting and implementing policies and regulations typically involve lengthy processes, but technology is advancing at an unprecedented rate. State officials need to make sure that policies and regulations do not specify deployment of certain technologies that become obsolete soon after they are installed.

  In addition, new digital technologies enable two-way communications that can improve the efficiency of electricity generation by better matching generation with demand, but many areas in the United States do not have broadband access and so cannot take advantage of these advanced grid technologies. The FCC has found that 30.7 percent of rural Americans lack access to high-speed data connectivity services.[112]

- ***Consumer acceptance:*** Innovative technologies and programs can open the door to achievement of widespread benefits, but they have little impact until customers adopt them. Accordingly, consumer resistance to grid modernization technologies (e.g., concerns about health or privacy implications from smart meters) or programs (e.g., concerns about privacy when utilities can control thermostats for demand-response purposes) could present a barrier to the transformation of the energy system.[113] Limited knowledge or acceptance of these technologies among utility staff can also hinder technology adoption.

- ***Workforce:*** As new, advanced energy technologies are deployed and experienced workers retire from energy companies, states will face a shortage of skilled workers in the energy sector. DOE's "2017 U.S. Energy and Employment Report" reported that 73 percent of energy companies had trouble finding qualified candidates.[114] Technology transformation also affects state workers, who may require training in new skills to adequately fulfill their regulatory and oversight responsibilities and to be effective communicators with the public. Similarly, if a state requires a significant regulator overhaul, it may require additional staff capacity to meet the challenge.

The Way Forward: Strategies for Governors

Because of the nature of our nation's energy system and the authority states hold, governors have a key role to play when it comes to addressing the challenges and concerns these technological advances pose – and they are poised to capitalize on their benefits. The pace of technology adoption has been accelerating over the past decade; therefore, states must respond much more quickly than in the past.[115] It took about 100 years for landline telephones to reach widespread adoption, just 48 years for the adoption of electric power and 30 years for the adoption of color TV. More recently, it's taken just a decade for widespread use of cell phones, smartphones and tablets.[116] Governors can help their state's regulatory, workforce and communications systems adjust to this new pace of technology by examining how they can update compliance-driven policies for performance-driven policies, adopt more data-driven governance and engage more stakeholders with greater transparency (see Figure 8).[117]

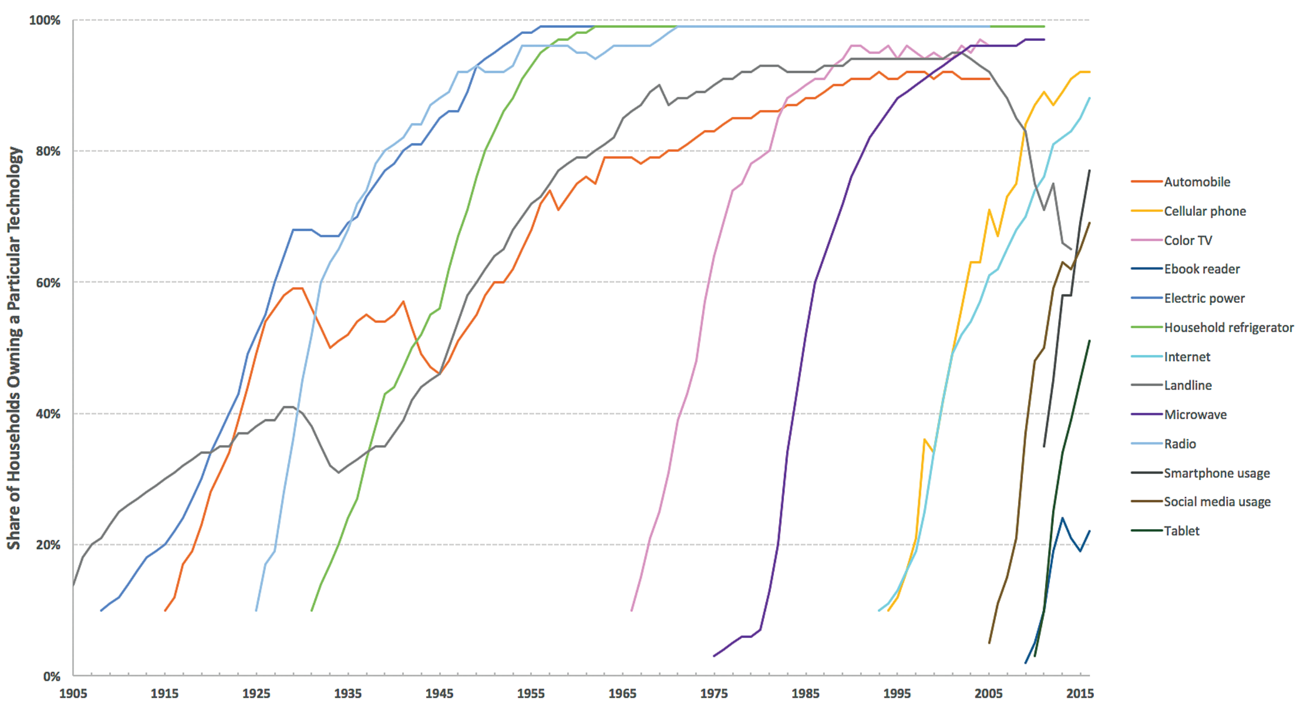


FIGURE 8: Technology adoption by households in the United States.[118, j]

Source: Desjardins, J. (2018). A brief history of technology. Retrieved from https://www.weforum.org/agenda/2018/02/the-rising-speed-of-technological-adoption

[j] Each curve on the chart represents the span (in years) of technology adoption. The steeper the curve, the more rapid the adoption rate. In recent years, the curves have become steeper than in the past.

Governors can guide and drive measures to help their states prepare for and embrace the rapid pace of energy innovation through the following seven strategies, alone or in combination:

- **Support technology innovation.**
- **Modernize legislation, regulations and incentives.**
- **Provide funding and financial mechanisms to drive technology deployment.**
- **Prepare the workforce.**
- **Update communications networks and data systems.**
- **Address cyberthreats.**
- **Educate citizens about the benefits and risks of technological innovation.**

To successfully develop and implement an appropriate strategy, a multi-stakeholder process is required. It is important to consider the key actors across the public and private sectors and the roles they can play. Table 1 identifies several categories of actors that can be helpful in developing, supporting and implementing an energy innovation strategy.

TABLE 1: Actors and the roles they can play in implementing energy innovation

Federal Government	State Government	Local Government	Private Sector	Nonprofit Organization
Congress	State Legislature	Mayor and city council	Investor-owned electric utilities	Community advocacy organizations and associations
U.S. Department of Transportation (USDOT)	Public utility commission (PUC)	County council	Natural gas distribution utilities	Rural electricity cooperatives
U.S Department of Energy (USDOE)	State Department of Transportation	Metropolitan planning organization	Construction companies or contractors	Academia
Environmental Protection Agency (EPA)	State energy office	City and county administrators and executives	Network service providers	Regional energy efficiency and clean energy advocacy organizations
U.S. Department of the Interior	State department of environmental quality	Municipal transit authorities	Financial institutions	Technology incubators
U.S. Department of Commerce	State budget office	Local public works departments	Insurance providers	National Energy Reliability Council
U.S. Department of Homeland Security	State economic development or commerce department	Local departments of environmental quality	Vendors	Regional transmission organization or independent system operator
Federal Energy Regulatory Commission (FERC)	State chief information or technology official	Municipal or public power utilities	Logistics and transportation industry	–
Federal Emergency Management Agency (FEMA)	State insurance commissioner	First responders	Technology providers	–
U.S. Department of Agriculture (USDA)	State motor vehicle administrator	Chief data officer	Equipment manufacturers	–
National labs	Emergency management agencies	–	Energy service companies	–
Military	National Guard	–		–
–	Public safety or highway patrol	–	–	–
–	State chief data officer	–	–	–
–	Consumer service office	–	–	–

Support technology innovation

OPPORTUNITIES FOR ACTION

- ✓ **Empower and direct agencies to explore and accelerate the adoption of innovative energy technologies.**
- ✓ **Appoint and convene working groups to gather stakeholder input on facilitating the adoption of innovative energy technologies.**
- ✓ **Direct state agencies to enable innovative technologies through energy planning processes.**
- ✓ **Promote adoption of state procurement targets for innovative energy technologies.**
- ✓ **Encourage regulated utilities to pursue innovative energy technologies and offer customers choices.**
- ✓ **Request that agencies or utilities test and pilot emerging technologies.**
- ✓ **Directly support R&D through innovation programs to develop home-grown technologies and expertise.**
- ✓ **Promote laws and regulations that drive technological innovation and deployment.**

Innovative energy technologies need to be explored, tested and enabled in support of state policy goals. Governors can help to guide the consideration of trade-offs by ensuring that decision makers and stakeholders explore new technologies and direct action when needed. Governors can also promote policies and processes that facilitate deployment of these technologies, with agencies acting in an aligned manner toward common goals. Governors can do so in several ways:

- ***Empower and direct agencies to explore and accelerate the adoption of innovative energy technologies:*** Governors can empower their agencies to explore how innovative energy technologies could be usefully deployed in their states. For example:
  - **Vermont** Governor Phil Scott signed Act 53 into law in May 2017. The act required the Department of Public Service to submit a report to the legislature "on the issue of deploying energy storage on the Vermont electric transmission and distribution system." The final Department of Public Service report includes information about the benefits and costs of energy storage, ownership options and other considerations for energy storage; potential programs and policies to encourage storage in Vermont; and recommendations of reasonable next steps to further understanding of the role storage could and should play in the state in the near and longer term.[119]
  - **Colorado** Governor Hickenlooper's July 2017 executive order, D2017-015, on supporting the state's clean energy transition directed the Colorado Energy Office, the Regional Air Quality Council and the Colorado Department of Public Health and Environment to develop a statewide EV plan to build out key charging corridors.[120] The resulting EV plan sets out a series of actions and strategies to electrify Colorado's corridors as well as goals and strategies to further accelerate adoption of EVs.[121]
  - Government agencies in the **Northern Mariana Islands** are required by law to assist the Commonwealth Utilities Corporation (the publicly owned utility) to locate potential renewable energy sites.[122]
- ***Appoint and convene working groups to gather stakeholder input into facilitating the adoption of innovative energy technologies:*** Governors can bring stakeholders together to explore ways in which innovative energy technologies can be deployed in their state, gather input about adoption of these technologies and lay the groundwork for making such input actionable. For example:
  - **New York**'s effort to restructure electric utility incentives and markets, known as "Reforming the Energy Vision" (REV), has relied on public-private working groups, including one on market design and platform technology, to provide recommendations to regulators.[123]
  - **Minnesota**'s Department of Commerce and the Legislative Energy Commission provided guidance to a broad, diverse stakeholder advisory committee to generate a 2025 Energy Action Plan that reflects consensus-driven strategies to strengthen the state's clean energy leadership, including the state's approaches related to transportation, energy supply, grid modernization, efficient buildings and integrated energy systems. The strategies focused on enabling and deploying technologies such as EVs, advanced metering infrastructure, energy storage, energy efficiency, demand response, combined heat and power, bioenergy and distributed generation.[124]
  - **Nevada** Governor Sandoval issued an executive order in 2016 creating a task force to provide recommendations on policies that will encourage clean energy development and integrate renewable energy technologies into Nevada's energy sector, advance cost-effective grid modernization and resilience and support distributed generation and energy storage.[125] The task force, which included technical advisory committees consisting of utility, environmental, industry, governmental and other stakeholders, delivered a report recommending a range of actions to the governor.[126]
  - **South Carolina**'s Energy Office directed development of a state energy plan that included a range of actionable policy recommendations, including formation of a study committee of stakeholders to consider, among other things, modifications needed in DER programs for "an advanced, integrated grid to manage and optimize the increasingly dynamic flow of electricity" and opportunities for policy changes that would "further expedite infrastructure modernization."[127]

Ideas to consider...

- **Identify nontraditional stakeholders for inclusion in working groups, such as military base commanders who are looking to enhance resiliency.**
- **Catalogue existing incentive programs that can be brought together and potentially revised and used under a new, common vision.**
- **Determine how state agencies can help test new technologies such as EVs to help businesses and citizens understand how they can help meet their needs.**

- The **Maryland** Electric Vehicle Infrastructure Council was established through legislation in 2011[128] and consists of officials from the Maryland Department of Transportation, Department of Planning, Department of the Environment, Department of Commerce, Energy Administration and Public Service Commission as well as state legislators, stakeholder groups, trade associations, academia and utilities.[129] The council is tasked with producing an action plan to facilitate the successful integration of EVs into the state's transportation network and developing recommendations on infrastructure deployment, increasing consumer awareness, EV incentives, charging solutions for multi-unit dwellings, supporting fleet purchases, shifting charging to clean energy resources and other items to promote the use of EVs in the state.[130] In 2015, the council's authorization was extended through 2020.[131]

- ***Direct state agencies to enable innovative technologies through updated interconnection processes and energy planning processes:*** Governors can direct state agencies to ensure that innovative energy technologies are included in the various processes their state uses to plan its energy future and integrate new technologies into the grid. Such activities can be undertaken in collaboration with the private sector when relevant. States should approach such energy planning holistically, considering the range of available technologies and the impacts of and opportunities for those technologies across sectors. In addition, energy planning should be linked with other planning efforts for environmental goals, economic development, and so on to align the efforts of state agencies. For example:
  - **Washington** Governor Jay Inslee issued an executive order in April 2014 that, among other things, asked the Washington Utilities and Transportation Commission (UTC) to actively assist with and support a reduction in the use of coal-fired electricity within the scope of its jurisdiction and authority.[132] Noting this, in addition to changing technologies and policies, the UTC released a policy statement in March 2017 declaring that "utilities must be able to demonstrate in any prudence determination for a new resource acquisition that their analysis of resource options included a storage alternative." This statement applies to all generation and distribution investments and some transmission investments. The UTC also identified modeling refinements in integrated resource planning to ensure that energy storage is fairly evaluated.[133]
  - **New Mexico**'s Public Regulation Commission issued an order in August 2017 amending the integrated resource planning rules to explicitly include energy storage resources, including directing utilities to consider energy storage when identifying additional resource options and determining the most cost-effective resource portfolio.[134]
  - **Massachusetts**'s Department of Public Utilities issued an order in May 2018 approving grid modernization investments to improve reliability and facilitate distributed generation growth. The order initiated a process to determine cost-effective deployment of AMI meters to targeted ratepayers.
  - **Minnesota** became the third state in the Midwest in the last three years to adopt comprehensive reforms to the state interconnection procedures. The state's early challenges connecting community solar garden projects to the grid led to backlogs and increased delays and costs. The new interconnection reforms also streamline the interconnection process for smaller distributed generation, which constitutes the majority of interconnection applications in the state.[135]

- ***Promote adoption of state procurement targets for innovative energy technologies:*** Governors can use the purchasing power of their state to support the deployment of innovative technologies in state facilities. For example:
  - **Colorado**'s Executive Order D005 05[136] directed all state agencies and offices to reduce energy consumption by 20 percent between 2006 and 2012. Having met that goal, the state pressed forward in 2015 with Executive Order D 2015-013[137] to pursue an additional 12 percent energy savings by 2020 from a 2015 baseline. This order also created a "greening government" council to examine how to improve the sustainability of government operations.
  - **Pennsylvania** has directed that state equipment and purchasing account for the energy use of products; the state's Department of General Services must procure Energy Star products where economical.[138]
  - In **Guam**, the Guam Power Authority (GPA) is undertaking an effort to switch all light-duty vehicles to EVs. GPA purchased two Nissan Leaf vehicles in 2017 and installed a charging station at its headquarters in Fadian as part of a pilot program under its Energy Sense Program and has plans to purchase additional vehicles and install additional charging stations at other customer service centers. GPA is conducting surveys on the use of the EVs and monitoring the mileage and trips taken to inform its future purchases and decisions on where to install additional charging stations.[139]

- **Tennessee** requires 25 percent of new vehicles the state purchases to be hybrid-electric or fuel-efficient compact vehicles, with a target of 100 percent. It met the 100 percent target in 2015.[140]

- ***Encourage regulated utilities to pursue innovative energy technologies and offer customers choices:*** Governors, with utility commissions and legislatures as appropriate, can establish targets and goals for the regulated utilities in their state. For example:
  - As of the end of 2017, four states – **California, Massachusetts, New York** and **Oregon** – had set a target for energy storage or had put a process in motion to set one.[141] In 2013, California's PUC, for instance, set a target for the state's investor-owned utilities to install more than 1.3 GW of energy storage by 2024.[142] Oregon, meanwhile, adopted a law in 2015 requiring each of the state's electric companies to have at least one energy system by 2020 with the capacity to store at least 5 megawatt-hours (MWh) of energy.[143] Other states are exploring such a target. For instance, Nevada passed SB 204 in 2017, which directs the PUC to study and establish, if found to be in the public interest, annual targets for energy storage that increase over time.[144]
  - Renewable portfolio standards (RPS), which require retail electricity suppliers to supply a minimum amount of their load with renewable energy, are in place in 29 states and Washington, D.C.[145] **Hawaii**'s RPS, for example, calls for achieving 100 percent renewables by 2045.[146]
  - As part of **American Samoa**'s goal to significantly reduce the territory's reliance on imported fuels (and thus reduce retail power prices, which are up to four times the national average), the governor signed an executive order establishing the American Samoa Renewable Energy Committee (ASREC). ASREC led the creation of American Samoa's Energy Action Plan, which calls for 100 percent renewable energy by 2040, with distinct interim goals for each of the territory's islands.[147]

- ***Request that agencies or utilities test and pilot emerging technologies:*** Governors can encourage the creation of pilot projects to promote learning about how innovative energy technologies can best be deployed in their state. Findings of such pilots should be made broadly available to share the experiences and lessons learned and should include consideration of deployment at scale and pathways to market. Technologies are advancing rapidly, so states should balance the testing and demonstration of technology with the need to deploy technologies quickly to best capture benefits in the short and long term. For example:
  - In December 2016, **Iowa** released a new state energy plan that recognizes that "[a]s Iowa explores opportunities to pursue grid modernization efforts and deploy modern grid technologies, there will be a need to test how various technologies and approaches integrate with Iowa's existing grid systems." The plan called for the Iowa Economic Development Authority and other key stakeholders to encourage all of Iowa's utilities to pursue a range of pilot projects "to examine modernization of the grid, microgrid and energy storage technologies, load management, cyber-security, and opportunities to enhance resiliency and integration of renewables to the grid."[148]
  - **Michigan**'s Public Service Commission has an open EV infrastructure docket that includes a focus on utility EV charging pilot programs.[149]
  - Governors and agencies also can use pilot studies and demonstration projects in other states and through DOE national laboratories. For example, DOE's smartgrid.gov website contains case studies from 131 demonstration projects and technology deployments funded between 2009 and 2015. Those case studies cover transmission and distribution systems as well as advanced metering deployments, providing states with data on a range of technology choices and electricity market types. In addition, DOE's Grid Modernization Lab Consortium, in conjunction with the national labs, brings together experts to collaborate on grid modernization issues.

- ***Directly support R&D through innovation programs to develop home-grown technologies and expertise:*** Governors can back efforts to support the growth of in-state expertise on innovative energy technologies directly, such as through tech incubators, state energy R&D funding programs and the work of state universities. States can also work to attract businesses operating in the advanced energy space or procuring advanced energy sources. For example:
  - In **New York** State Energy Research and Development Authority (NYSERDA) has made millions of dollars available for R&D on energy storage and battery innovations.[150]

- **Washington** has a Clean Energy Fund (CEF) that among other activities funds a research, development and demonstration program that provides matching funds for projects on new and emerging technologies, including solar technology, advanced bioenergy and biofuels, advanced energy storage, battery component recycling, new renewable energy technology and new energy efficiency technologies.[151]
- Many states provide tax credits for research and development, including for advanced energy technologies. **West Virginia**'s Strategic Research and Development Tax Credit, for example, fosters economic development through a credit of up to 13.5 percent on specified R&D expenses in the state.[152]

- ***Promote laws and regulations that drive technological innovation and deployment:*** Governors can deploy other tools to drive the deployment of innovative energy technologies. For example:
  - In November 2017, **Oregon** Governor Kate Brown signed an executive order that, among other things, directs the Department of Business and Consumer Services Building Codes Division to amend the state building code to require all newly constructed buildings to be ready for the installation of solar panels by 2020 for residential structures and 2022 for commercial. It also requires that all parking structures for new residential and commercial buildings be ready to support EV chargers by 2022.[153]
  - **California**'s energy commission approved a rule in May 2018 that requires most homes built from 2020 onward to have solar panels. Exemptions will exist where homes are shaded or where it would be cost ineffective to do so, and the rule allows for batteries and community solar as alternatives. At the time of writing, this rule is still subject to adoption into the state's building codes.[154]
  - **Maine** and other states require utilities in the state to use energy efficiency before any other traditional resource, with the goal of "capturing all cost-effective energy efficiency resources available for electric and natural gas utility ratepayers."[155]

Modernize regulations, legislation and incentives

OPPORTUNITIES FOR ACTION

- ✓ **Promote grid modernization initiatives.**
- ✓ **Implement performance incentives that reward utilities for meeting policy goals.**
- ✓ **Establish new rate design mechanisms and incentives for energy users.**
- ✓ **Foster competition between traditional utilities and third parties.**
- ✓ **Include targeted R&D or pilot programs in cost recovery and ratemaking structures.**

State PUCs regulate all investor-owned and some consumer-owned utilities (municipal utilities and rural electric cooperatives). These regulated utilities must seek approval to recover investments through rates and are subject to other requirements that regulators place on them. In most states, public utility commissioners are appointed by governors for set terms – often four to five years – while 14 states have elected commissioners. PUCs are tasked with regulating multiple public utility sectors, typically including electricity and natural gas, and often landline telecommunications, water, cable, transportation (e.g., taxis) and railways.

When considering processes and regulations to encourage innovation, it is important to understand the relationship between governors and commissioners. PUCs are quasi-judicial bodies that operate independently of governors and other executive-branch agencies. PUCs are prohibited from discussing open cases and dockets outside of formal hearings and are required to balance the rights and needs of the multiple parties that come before them, including utilities and ratepayers.[156] These commissions are independent, but opportunities exist for governors to appropriately influence regulatory outcomes or have their requests heard in formal regulatory proceedings.

With regulatory independence in mind, governors have many opportunities to work with PUCs, legislators and others to modernize regulatory processes and pursue regulation that can advance implementation of innovative energy technologies:

- ***Promote grid modernization initiatives:*** Governors can promote efforts to examine regulatory structures that encourage investments in new power grid technologies and systems and align those investments with policy goals. These efforts can either be comprehensive proceedings or more targeted, sequential ones. Regardless of their scope, grid modernization proceedings are large undertakings that require careful analysis of energy systems, input from many stakeholders and careful planning to ensure that the investments made maximize benefits to customers, taxpayers and utilities. More comprehensive grid modernization efforts may take longer than a typical governor or regulator's term, so establishing a process that can accommodate leadership turnover is important. Similarly, technologies will continue to evolve, so the process should have adequate flexibility to avoid obsolescence.

Ideas to consider...

- **Introduce or champion legislation that provides direction, guidance or requirements for PUCs on how they should advance energy innovation when considering cases that come before them.**
- **Become a formal party on open dockets and submitting oral and written testimony that supports innovation that aligns with energy policy goals. PUCs can only consider information put before them through verbal or written testimony and filings, so it is incumbent on governors and state agencies to ensure that economic development and other policy objectives are on the record.**
- **Convene working groups to provide input into more formal proceedings to allow for a more open exchange of ideas.**
- **Direct staff to participate actively in working groups and less formal engagements with PUC staff.**
- **Work with regulators and legislators to increase regulatory transparency, including through online tracking tools and databases of PUC proceedings.**
- **Ensure that PUCs have adequate staffing, financial and training resources to address the added workload and complexity that come with grid modernization proceedings and other changes to the electric and natural gas sectors.**
- **Petition your PUC to update distributed energy interconnection rules to align with national guidance[157] to accommodate new technologies, improve transparency and streamline the process.**

During a grid modernization proceeding, it is important for governors to work with their PUCs to ensure that the technologies being deployed deliver benefits that align with governor's goals, initiatives provide clear guidance and a framework to ensure goals are met over the long term, and rules and standards are in place to implement these goals (for example, interconnection standards and most recent IEEE 1547 codes). Governors may want to pursue grid modernization for any reason described earlier in this roadmap, including job creation, enhanced reliability and resilience, cost reduction, improved customer choice and reduced emissions. The relevant benefits and goals should be explicitly recognized in qualitative and quantitative screenings, including cost-benefit tests, to ensure that the right mix of technologies is pursued.

Governors can also encourage a diverse group of stakeholders to participate in PUC working groups and open dockets. Such parties could include state agencies, such as energy offices and departments of transportation; ratepayer advocates and other consumer and business advocacy groups; electric utilities; third-party service and technology providers; environmental advocates and other nongovernmental organizations; local governments; and others as relevant.

Several states are already undertaking broad grid modernization proceedings; the most comprehensive, by **New York**, is described more in the Appendix. Other examples include:

- **Rhode Island** Governor Gina Raimondo asked the state's PUC, the Office of Energy Resources and the Division of Public Utilities and Carriers to design a new regulatory framework for the state's electricity system considering the transformation that is underway. The state's Power Sector Transformation Initiative seeks to control the long-term costs of the electric system; give customers more energy choices and information; and build a flexible grid to integrate more clean energy generation by modernizing utility business models, building a connected distribution grid, better using data and advancing electrification of other sectors.[158]
- The **Maryland** Public Service Commission has initiated Public Conference 44 (PC44) to ensure that the state's evolving grid is customer-centered, affordable, reliable and environmentally sustainable. PC44 focuses on rate design, EVs, competitive markets and customer choice, the interconnection process, energy storage and distribution system planning.[159]
- In response to Hurricane Maria in 2017, **Puerto Rico** is seeking to rebuild its grid in a comprehensively more resilient manner, including such technologies as microgrids and smart metering to ensure that the grid is less prone to the geographically large disruptions it saw in 2017.[160] The commonwealth's utility commission has initiated dockets on some of the recommendations of the Puerto Rico Energy Resiliency Working Group,[161] such as encouraging greater deployment of microgrids,[162] as it seeks to meet Puerto Rico's long-term energy needs.

- ***Implement performance incentives that reward utilities for meeting policy goals:*** Traditional cost-of-service ratemaking allows utilities to earn an established rate of return (ROR) on any reasonable investments that PUCs deem prudent. Also known as the "rate-of-return regulation," this model repays utilities for operating expenses and allows them to recover their costs for prudent capital investments, with a return on those investments to satisfy shareholders. To offset the economic impact to utilities from declining load growth and new market entrants and to provide incentives for utilities to invest in technologies that align with state policy goals (e.g., improved resilience or reliability, reduced emissions, better economic performance), PUCs are beginning to explore new regulatory models, including models that provide performance incentives to utilities. These generally models fall into four categories, summarized in Table 2:[163]

    - **ROR regulation:** The basis of most regulatory systems used today, this model compensates utilities through rates that a regulatory commission sets based on utilities' reasonable costs plus a return on their investments.
    - **Adjusted ROR regulation to reduce utility revenue loss:** This category adjusts the traditional model to minimize utility revenue losses resulting from declining sales. Approximately 20 states currently use this model, which includes ratemaking adjustments such as decoupling, increased fixed charges and value-of-solar tariffs.
    - **Added utility profit opportunities:** This category allows utilities to earn an equivalent profit from investing in clean energy (if they are in restructured states that do not typically allow utility ownership of assets) or to profit from the facilitation or allowance of third-party investments in clean energy (in both regulated and restructured states) through reforms such as performance-based compensation. At least 24 states have adopted one or more profit incentive.
    - **Transformative models:** This category captures business models that are dramatically different from U.S. regulatory systems and include the use of performance-based regulation, smart system integrators and energy service utilities.

    Of relevance to this roadmap is the third model: added utility profit opportunities. Public utilities can provide performance incentives to utilities, such as adjustments to their RORs, to give utilities the flexibility to identify and deploy the best technologies to meet policy goals. For example, under a model known as "performance-based compensation," states can compensate utilities based on the quality of the power they provide or another public policy goal, not just the investments they make. States can do this in many ways, such as allowing utilities to earn a percentage of energy savings achieved through energy efficiency programs or providing profit margin bonuses or penalties if measurable performance metrics, such as emissions or system reliability, are or are not met. As part of these performance metrics, governors and their energy office staff can encourage PUCs to include metrics that address risk reduction, cybersecurity and other steps that can help mitigate concerns. For example:

    - **Hawaii**'s PUC has a performance incentive mechanism for procurement of renewable energy at prices below set benchmarks. "The shared-savings incentive will be based on an 80% customer/20% utility split of the savings from each [power purchase agreement] PPA, compared to benchmarks established by considering recent low-cost renewable energy projects, up to a cap of $3,500,000."[164] Hawaii's PUC opened a docket to investigate the economic and policy issues associated with performance-based regulation.[165]
    - In **Minnesota**, a nonprofit-led stakeholder process, referred to as the "e21 initiative," has examined new utility business models given the growth of DERs and demand-side management. The initiative is unique because the state has a vertically integrated electricity market. The e21 initiative is currently in phase 3. Phase 1 set the priorities for this initiative to focus on a more consumer-centric, performance-based regulatory approach and utility business model. Phase 2 focused on how to implement phase 1 recommendations, and the state released a series of papers on performance-based compensation, integrated systems planning and grid modernization. Phase 3 began in January 2017 and concentrates on bringing stakeholders together to develop innovative pilot projects.[166]
    - Utilities in **Georgia** can recover a higher rate on their investment for energy efficiency projects that meet certain criteria for energy savings. This amount is based on the energy savings of the project, granting utilities a percentage of a program's or project's energy cost savings – typically, 8.5 percent – when the program or project achieves at least 50 percent energy savings.[167]

TABLE 2: FOUR CATEGORIES OF UTILITY REGULATORY MODELS[168]	
Category	**Description**
ROR regulation	• Rates based on utilities' reasonable costs plus a return on investment (ROI). • Used under vertically integrated or restructured systems (with or without clean energy standards).
Adjusted ROR regulation to reduce utility revenue loss	• Decoupling or lost revenue adjustment mechanism. • Increased fixed charges. • Value-of-solar tariff. • Time-of-use (TOU) rates.
Added utility profit opportunities	• Ownership of assets. • Treat expense as assets (aka, regulatory asset). • Partnerships with third-party providers. • Performance-based compensation.
Transformative models	• Performance-based regulation. • Smart system integrator. • Energy service utility.

- ***Establish new rate design mechanisms and incentives for energy users:*** As described in the National Association for Regulatory Utility Commissioners guide *Distributed Energy Resources Rate Design and Compensation,* "Regulators are often tasked with two, potentially competing, goals: (1) ensuring the financial health and viability of the regulated electric utility; and (2) developing policies, rates, and compensation methodologies for DER." Governors interested in compensating the owners of DERs based on the value they provide or providing time- or location-based price signals to DER owners can work with PUCs, utilities and stakeholders to explore new DER compensation regulatory and rate design strategies to do so, encouraging commissioners to take up new rate design discussions and tasking their energy offices with participating on their behalf in active dockets on the topic.

  New rate design mechanisms, such as time-variant rates, can take advantage of the data that smart grid technologies produce to provide price signals. These rates can be used to optimize energy consumption in buildings and the adoption and optimal use of distributed energy resources such as distributed generation and EVs. The rates can be implemented during times when load and price spike, such as in demand-response programs, or more regularly to correspond with the situation on the grid, such as in real-time pricing models.

  PUCs can also have utilities charge different rates to customers who have onsite generation, recognizing the unique costs and value of those technologies. For example:

  - Time-variant rates have been piloted or implemented in states and utilities across the country, including **Arizona, California, Hawaii, Maryland, Massachusetts** and **Oklahoma**.[169]
  - **Nevada** in 2017 reinstated net metering to compensate those who generate their own electricity from rooftop solar.[170]
  - **Arizona**'s largest utility, Salt River Project, offers an experimental TOU electricity rate for the first 10,000 customers who have a qualified EV. The TOU rate is for the super off-peak hours between 11 p.m. and 5 a.m. daily.[171]

- ***Foster competition between traditional utilities and third parties:*** Much of the innovation in the electricity sector is being driven by new market entrants seeking access to existing infrastructure and ratepayers. Utilities may try to limit new entrants accessing the market by supporting rules to limit the size of resources that third parties can provide or limit third-party access to customers or customer data. Learning from other sectors in which monopolists faced technological innovation, governors can work with regulators to ensure that entrants have fair access to the market where competition is warranted[172] – for example:

  - In 2017, **Illinois**' PUC, the Illinois Commerce Commission, approved a data sharing program from Commonwealth Edison (ComEd) that would allow third parties, including companies and researchers, to access anonymous, smarter meter-generated usage information. This action, which ComEd proposed, will broaden service and product offerings to utility customers from smart home device and appliance manufacturers and others.[173] This action follows an "Open Data Access Framework," originally filed by Illinois' consumer advocate, the Citizens Utility Board, and the Environmental Defense Fund in 2014.[174]

- In **Pennsylvania**, the PUC authorized third-party access to smart meter data, subject to opt-in by customers, to expand the information available to those customers and encourage energy conservation.[175]

- ***Include targeted R&D or pilot programs in cost-recovery and ratemaking structures:*** In addition to requesting that utilities test and pilot emerging technologies, governors can encourage regulators to allow cost recovery for those efforts or, at a minimum, provide a safe space for structured experimentation. Such an action would introduce risk and potentially added costs, so to avoid undue impacts on ratepayers, the state should oversee such activities by having utilities report on the outcomes of pilots and lessons learned (successes and failures). PUCs can also implement evaluation, measurement and verification protocols to ensure that results and lessons learned are documented and monitored – for example:
  - The renewable energy portfolio standard in **North Carolina** allows up to $1 million annually in cost recovery for costs an electric power supplier incurs to fund R&D that encourages the development of renewable energy, energy efficiency and improved air quality.[176]
  - A range of state commissions, including in **Massachusetts**, have set guidelines for cost recovery related to EV infrastructure investments.[177]

Overview of Federal and State Electricity Jurisdiction

Regulation of electricity in the United States falls under the jurisdiction of both the federal government and state governments (also local governments, in the case of municipal utilities). Under the Federal Power Act, wholesale markets and transmission in interstate commerce fall under federal jurisdiction (particularly under FERC), while retail sales, generation and distribution fall under state jurisdiction. States play a significant role in the overall electric power system. New, innovative energy technologies, however, are creating jurisdictional tensions, with some of them (e.g., distributed generation, storage, demand response) providing many different services across the categories of generation, transmission and distribution. The question of where jurisdiction lies to regulate them is thus far less clear.[178] The U.S. Supreme Court has had to rule to address some of these jurisdictional fights, such as when it ruled in 2016 that FERC had jurisdiction to regulate wholesale market operators' compensation of demand response bids and that Maryland intruded on FERC's authority over interstate wholesale rates by trying to change the capacity price paid to new in-state generation.[179]

Provide funding and financing mechanisms to drive technology deployment

OPPORTUNITIES FOR ACTION

- ✓ **Encourage adoption of financial incentives to drive deployment of innovative energy technologies.**
- ✓ **Support the development of mechanisms that can use scarce public dollars to leverage private capital investment.**
- ✓ **Support the development of mechanisms that make it easier for residents and businesses to pay for deployment of innovative energy technologies on their properties.**

Innovative energy technologies often require funding support or other financial mechanisms to accelerate their deployment. Governors can promote policies and programs that provide such support in several ways:

- ***Encourage adoption of financial incentives to drive deployment of innovative energy technologies:*** Governors can encourage adoption of financial incentives designed to spur technological deployment directly, such as through tax credits. These incentives can be self-correcting (e.g., the level of incentive declines as deployment increases) and should consider equity concerns (e.g., by including underserved populations). Examples of state financial incentives include:
  - **Texas** S.B. 1731, was signed into law in August 2017. This bill creates an incentive program for alternative-fuel vehicles. The program will provide a grant of $2,500 per vehicle for the purchase of eligible light-duty vehicles powered by electricity or hydrogen fuel cells and $5,000 per vehicle for those fueled by compressed natural gas or liquefied petroleum gas.[180]

Ideas to consider...

- **Inventory existing incentive programs that can be realigned to support new technologies.**
- **Seek partnerships with the private sector to take advantage of public monies through public-private partnerships (PPPs) or other approaches.**

- **Maryland** creating created the first tax credit for energy storage in the country: a 30 percent tax credit for energy storage – up to $75,000 for corporations and $5,000 for individuals. The credit is valid for installations made between January 2018 and December 2022; the total amount of credit awarded to all taxpayers cannot exceed $750,000.[181]

- ***Support the development of mechanisms that can use scarce public dollars to leverage private capital investment:*** Governors can support new mechanisms, such as green banks, to accelerate the deployment of innovative energy technologies by using public dollars to attract larger amounts of private capital – for example:
  - **Connecticut** launched the nation's first green bank in 2011. The Connecticut Green Bank uses tools such as green bonds and loan loss reserve funds to attract private capital investment in clean energy deployment in the residential, commercial, industrial, institutional and infrastructure sectors. Projects through fiscal year 2016 show that every $1 of public funds the Green Bank committed yielded an additional $6 in private investment.[182]
  - **New York** Governor Andrew Cuomo announced the creation of the New York Green Bank (a division of NYSERDA) in 2013. Focused on addressing market gaps and barriers, the New York Green Bank offers products such as warehousing and aggregation credit facilities, term loans and investments, credit enhancements and construction finance. Key asset classes include clean energy generation, energy efficiency, clean transportation and clean energy storage. As of the end of 2017, the New York Green Bank had supported clean energy projects with total project costs between $1.27 billion and $1.5 billion based on investments of $457.5 million, mobilizing capital at a ratio at or above 3 to 1.[183]
  - The **Mississippi** Development Authority operates a leasing program for energy-efficient equipment that public entities and nonprofit hospitals can use to lease efficiency equipment and services for up to 15 years from the authority using a third-party financier.[184]
  - **Nevada** passed Senate Bill 407, which established an independent, nonprofit corporation or green bank called the Nevada Clean Energy Fund to help finance clean energy projects in the state.[185] The Nevada Governor's Office of Energy is charged with establishing the organization.

- ***Support the development of mechanisms that make it easier for residents and businesses to pay for deployment of innovative energy technologies on their properties:*** Governors can support state agencies, legislatures and PUCs in developing and promoting mechanisms that make it easier for residents, businesses and others to handle the financing involved in deploying innovative energy technologies on their properties while remaining alert against consumer fraud and deceptive contractor practices. For example:
  - **Missouri** adopted Property Assessed Clean Energy (PACE) programs in 2010, which allow property owners to finance on-site renewable energy projects and energy efficiency improvements through a special assessment on their property tax bills. Local governments cover the upfront costs, paid for through the issuance of bonds (or other sources of capital), and the voluntary property tax assessment is secured by a senior lien on the property. Missouri's various PACE financing districts cover some combination of residential, commercial, industrial, agricultural, multifamily, not-for-profit and public facilities.[186] PACE programs are currently active in 20 states plus Washington, D.C., and legislation enabling PACE is active in more than 30 states.[187]
  - **North Carolina** Governor Roy Cooper in 2017 signed H.B. 589 into law, which enabled third-party leasing arrangements for rooftop solar in the state.[188] More than 20 states have policies authorizing such arrangements, which help customers avoid paying substantial money up front to get rooftop solar.[189]
  - The **Kentucky** Public Service Commission in 2010 approved an on-bill financing pilot program by four electric co-ops to allow customers to pay for energy efficiency improvements on their regular electric bills at a level below the expected energy savings (essentially paying for the retrofits through the savings that result from those retrofits).190 The program, known as How$martKY, was made permanent in 2012 and modified so that the retrofit investment now runs with the property (as opposed to being tied to the individual at that property).[191] On-bill financing of some sort is currently available in more than 30 states.[192]
  - The **Colorado** Energy Office runs a comprehensive Energy Performance Contracting program for public facilities whereby improvements to facilities are paid for out of guaranteed energy, water and operations and maintenance savings. The Energy Office has helped create standardized processes and contracts, prequalified a pool of energy service companies

and offers free coaching and technical assistance to facility owners throughout each project. Since Colorado established its performance contracting program in the mid-1990s, nearly 200 projects have yielded almost $33 million in annual utility savings.[193] All 50 states have statutes allowing for energy performance contracting, but some are more effective than others.[194]

- **Utah** has a State Building Energy Efficiency Program that uses a revolving loan fund of more than $2 million from which state agencies and institutions can borrow for energy efficiency projects at their facilities. Since 2008, more than 19 projects have used this fund, with an average simple payback of just over four years and with average annualized ROI of more than 27 percent.[195] More than 30 states have set up revolving loan funds for energy efficiency and renewable energy improvements at government or private sector facilities.[196]
- The **Alaska** Housing Finance Corporation established a $250 million Energy Efficiency Revolving Loan Program to finance audits and energy efficiency upgrades on more than 1,500 public facilities as part of an effort to address high-energy-use buildings.[197]
- The **Alabama** PUC approved an optional rate rider for Alabama Power customers with plug-in EVs. The rate rider allows customers to charge their EV at a discounted rate during off-peak hours. Alabama Power also offers a Business EV TOU rate for electricity purchased to charge EVs used for fleet purposes.[198]
- The **Nevada** Governor's Office of Energy sponsored Assembly Bill 5 as PACE-enabling legislation that provides for the creation by a local government of a local improvement district that includes an energy efficiency improvement project or a renewable energy project on commercial private property.[199]

Volkswagen Clean Air Civil Settlement

An important funding source to encourage EV adoption has emerged with the Volkswagen Clean Air Civil Settlement. In 2015, EPA resolved a civil enforcement case against Volkswagen for cheating on federal emissions tests. A $14.7 billion settlement against Volkswagen was reached, with $2.7 billion allocated to establish the Environmental Mitigation Trust (EMT).[200] States receive a portion of the funds from the EMT, prorated based on their vehicle population, for emissions-reduction efforts and can use up to 15 percent on public charging infrastructure. Eligible mitigation expenditures include a variety of transportation and electrification projects, such as marine transport and port operation electrification.[201] Although the EMT is a substantial financing opportunity for states, critical planning decisions remain to maximize value.

Prepare the workforce

OPPORTUNITIES FOR ACTION

- ✓ **Partner with industry to identify skills gaps and workforce availability.**
- ✓ **Provide state-level incentives for energy sector business opportunities and workforce development programs to support these growing industries.**
- ✓ **Work with educational institutions at all levels to ensure that training programs are available to meet skills gaps both now and in the future.**
- ✓ **Identify underserved and high-unemployment groups and geographies to maximize benefits to communities in greatest need.**

There is a growing demand for skilled workers across a range of energy sector occupations, including work related to the oil and natural gas industries, electricity generation and transmission, renewable energy production, energy efficiency deployment and carbon capture and storage. This demand is expected to continue to grow as several factors play out, including the retirement of baby boomers employed in the electric power industry, the acceleration of new technologies and the continued push for increasing amounts of cleaner energy resources. The clean energy industry is currently struggling with a shortage of qualified workers to design, install, operate and maintain machinery, equipment and devices, and the industry is expected to face growing demand in the coming years. The shortage exists for both existing occupations that are transforming through retraining (e.g., electricians retrofitting buildings for energy efficiency, machine operators crafting wind turbine components, technicians maintaining them) and emerging occupations that require a new range of skill sets and training (e.g., home energy raters, energy auditors, solar panel installers). States may experience workforce challenges, as well, because workers may lack the skills and training needed to develop new regulations and policy and to oversee development.

Changes in technology may also lead to jobs departing from one locality to another. Policymakers need to be aware of shifts in the geographies of employment and be prepared to meet retraining needs or even population shifts as people move to where new, higher paying jobs exist. States are working to develop curriculum and certification programs, provide training and support workforce development for the energy sector in collaboration with companies as part of their overall effort to remain economically competitive. Partnerships among multiple stakeholders are critical to the development and rollout of effective clean energy workforce programs because they enable states to use and align existing workforce training efforts and help identify future industry needs. Each state will have a different mix of players based on the industries and organizations active in the state and the population the state is targeting. The U.S. Department of Labor's Energy Sector Partnership and Training Program emphasizes working through a cross-section of stakeholders, including state energy, workforce and economic agencies; energy efficiency and renewable energy businesses; educational organizations; labor and trades; and related nonprofits. Each entity brings to the table its own knowledge, experience and resources to ensure a coordinated and regionally consistent approach to training workers for jobs in the clean energy sector. For example:

- State energy offices provide information about clean energy projects in the state and where funding is being allocated, which can then be used to identify workforce training needs.
- Employers and industry representatives help identify current and future labor needs, design training curricula based on workforce needs and hire people who successfully complete training.
- Workforce Investment Boards (WIBs) and their associated one-stop career centers serve as coordinating hubs, connecting people to jobs and to the skills necessary to secure a job. WIBs consist of public and private sector members who can provide strategic leadership on clean energy workforce development issues in their communities.
- Community colleges help develop courses and curricula that prepare workers to fill the specific needs clean energy industries identify.
- Labor unions connect participants to opportunities in union apprenticeship programs.
- Community-based and nonprofit organizations help recruit the target population, identify participant needs and barriers to success, deliver training and evaluate outcomes.
- State government can foster effective and productive workforce development and avoid stranded skills by:
- ***Partner with industry to identify skills gaps and workforce availability:*** Businesses in the energy sector will have a much greater understanding of the skills and staffing needed for objectives and will better understand how difficult it could be to attract an appropriately skilled workforce. Active communication and coordination among energy workforce stakeholders are critical to linking the demands of the clean energy sector with the available supply of workers. Historically, many workforce development programs have struggled to incorporate robust stakeholder input into their plans and thus have strained to identify current and future labor shortages and design training curricula to accurately meet industry needs. The diversity of energy workforce stakeholders, which includes government at all levels, community partners, industry, educational institutions and unions, exacerbates the challenge of effective communication and coordination and can lead to duplicate training or failure to provide comprehensive training that covers the key skills that workers will need. Interacting with businesses in the state – or of the sort a state hopes to attract – can ensure that workforce development programs are meeting the actual needs, in terms of both skills and numbers, that the sector will need to meet objectives.

  There is often a lack of available data and tools to measure the need for energy workers and to assess where the greatest need for energy projects will be located geographically. Several states have commissioned reports or sought grant money to study the best way to develop their clean energy sector. Limited knowledge exists about the types of jobs needed, where job demands will be in the future, the education and skill requirements of those jobs and the related curriculum development needs. For states to develop effective clean energy workforce programs, they must compile information about where clean energy jobs will be located and which skills will be needed for those positions. These assessments must start with a careful analysis of states' existing capabilities and strengths and the opportunities to build on them.

Ideas to consider...

- **Coordinate across state agencies to take advantage of existing economic development and workforce programs and expand to include advanced energy elements or inform development of new programs.**
- **Identify dual-use programs that can be leveraged for advanced energy skills development without the risk of creating stranded assets or skillsets (e.g., advanced maritime welding certifications useful for offshore wind or ship repair).**

The industry's workforce needs are varied, and many academic and workforce training institutions as well as policymakers developing programs to expand the workforce may not be fully aware of the diverse industry needs specific to their state. For example:

- The **North Dakota** Workforce Development Council advises the governor and the public on the state's workforce needs, consulting with business and government to establish goals and evaluate progress. The council's work is not limited to the energy sector, but energy is a significant part of its work.[202]
- **Washington**'s Proposed Strategic Plan for the Clean Technology Sector establishes a goal and action steps for "encouraging a 21st century workforce ready to meet clean technology needs." In collaboration with the CleanTech Alliance, the plan calls for communications plans, identifies sources of stakeholder support and sets metrics for measuring success.[203]
- To support the influx of wind turbine manufacturing in **Kansas**, Cloud County Community College created the Wind Energy Technician Program, which offers distance learning, field training and support for traditional and nontraditional students to help them gain the skills necessary to work in the renewable energy industry. Kansas State University is home to the Kansas Wind Applications Center, which offers opportunities for students and other institution to incorporate wind energy studies into their curricula. At Wichita State University, research on turbine blade composites and blade material fatigue is ongoing.[204]
- **Nevada** Governor's Office of Workforce Innovation was formed through executive order to develop career pathways in key, innovative technology sectors,[205] including renewable energy and energy efficiency.[206] Career pathways align academic and technical courses, training programs, support services and workforce preparation activities to help individuals enter or advance within a given industry.[207]
- Four **South Dakota** organizations, including the Department of Labor and Regulation, created the South Dakota Partnership for Student Success to provide a new technology workforce development program that offers paid internships or apprenticeships while using online and classroom-based courses to provide participants with bachelor's degrees, associate degrees or academic certificates in fields like cybersecurity, software development and network and security administration.

- ***Provide state-level incentives for energy sector business opportunities and workforce development programs to support these growing industries:*** Some states are using PPPs to expand and build on their existing clean energy workforce development programs. Taking advantage of private sector funding, these PPPs have an opportunity to expand the impact of state programs and ensure their fiscal sustainability over a longer timeframe. For example:
  - **Idaho** offers a range of tax credits for job expansion, investment and clean technology R&D. The state also provides grants for workforce training and infrastructure improvements.[208]
  - **Arkansas**' wind energy manufacturing incentive applies to facilities that invest at least $150 million and hire 1,000 new employees within six years, and Michigan's Renewable Energy Renaissance Zone program exempts certain businesses from paying corporate, education or property taxes provided they build facilities within certain jurisdictions.[209]
  - Some states, including **Hawaii, Maryland, Massachusetts, New York, Virginia** and **Wisconsin**, have adopted clean energy centers or clean energy technology incubators to help startups commercialize technology and address other priorities.[210]
  - The **Maryland** Clean Energy Center (MCEC) was established by legislation in 2008. The MCEC has focused its efforts on convening business interests and policymakers, addressing financing barriers, serving as an information hub and offering business development and technology commercialization support.[211]
  - Governor Cuomo of **New York** announced in his 2018 state address that the state will issue solicitations in 2018 and 2019 to develop at least 800 MW of offshore wind projects to foster the offshore wind industry and its workforce in New York state.[212] NYSERDA will be investing millions of dollars to train workers for jobs in offshore wind construction, installation, operation, maintenance and design.[213]
- ***Work with educational institutions at all levels to ensure that training programs are available to meet skills gaps both now and in the future:*** Training a skilled energy workforce requires the availability of curricula across many occupations. It also requires sufficient training and certification providers, such as community colleges, technical and vocational schools and universities with courses targeting energy sector needs. Recent efforts have begun to address these needs, but many states face shortages in one or both areas.

For example, a study in Washington state found that few postsecondary programs or courses have been specifically designed for the renewable energy sector. Vocational programs and applied technical courses in secondary schools and some colleges preparing students for careers in the energy industry also have been consolidated or eliminated over the years, creating a gap in training.[214] Another study of the energy efficiency sector found that most courses offered by community colleges and technical schools and through union apprenticeship programs lack a specific focus on energy efficiency and do not meet the demand for energy efficiency-specific training. Out of 492 education and training programs, this study could identify only 43 educational organizations offering a certificate or degree program directly related to energy efficiency and only two energy efficiency-related courses and energy efficiency training organizations offering explicit energy efficiency courses or programs.[215] Furthermore, employers in the residential energy efficiency industry have expressed concerns that existing training programs in many community colleges do not have the capability and resources to combine classroom and lab training with field training, producing graduates with limited practical experience and hands-on training[216]. For example:

- **Louisiana**'s H.B. 1033, which was enacted in 2014, established higher education funding for certain high-demand degree programs and required a workforce gap analysis in the state. Another bill included in this category is New Mexico's H.B. 182, also enacted in 2014, which created a new apprenticeship council to establish standards for apprenticeship programs, including on-the-job training requirements.[217]
- **Washington**'s Clean Energy Fund (CEF) funded the Cascadia CleanTech Accelerator, a business accelerator program powered by the CleanTech Alliance and Oregon BEST. The 12-week program delivers mentorship, curriculum, connections and funding opportunities designed specifically for early-stage clean tech startups.[218]
- **Colorado** has in place the Colorado Center for Renewable Energy Economic Development (CREED), a research partnership among the National Renewable Energy Laboratory and Colorado's premier research universities – the Colorado School of Mines, Colorado State University and the University of Colorado Boulder. CREED works with public agencies, private enterprise, nonprofit institutions and all Colorado's universities and colleges to meet the following state priorities:
  - Increase the production and use of energy from renewable resources like wind, solar and biofuels.
  - Support economic growth in Colorado and the nation through renewable energy industries.
  - Build a renewable energy economy in rural Colorado and rural America.
  - Establish Colorado as America's leading center for renewable energy research and production.
  - Educate the nation's finest energy researchers, technicians and work force.[219]
- **Maryland**'s Offshore Wind Workforce Development Grant Program supports new or existing training facilities to provide technical and safety training for those working in offshore wind. Notably, it also requires that facilities be dual-use to prevent stranded assets and skills. For example, a site could teach advanced marine welding, a skill needed for offshore wind turbine fabrication but also for ship repair.[220]
- **Nevada** supports the Panasonic Preferred Pathway program to create an accelerated track for workers without manufacturing experience to gain the certifications needed for employment at the Tesla Gigafactory being developed outside Reno, which will need thousands of workers.[221] The program offers a flexible training format that includes Saturday and evening hours so that students can train while still working at their current jobs. The state provided scholarship funding to support students at Truckee Meadows Community College.

- ***Identify underserved and high-unemployment groups and geographies to maximize benefits to communities in greatest need:*** Workers and companies that have recently entered or seek to enter the clean energy marketplace face financial and logistical barriers to accessing and participating in training programs. Clean energy workforce training can be prohibitively expensive, with the certifications that state programs require costing hundreds or even thousands of dollars. In addition to the training costs, employed workers pursuing a career in the clean energy sector can find it difficult to commit significant time to participate in job training programs or attend programs with inflexible hours or limited training sites. In response, states are pursuing strategies to make clean energy workforce training accessible, including providing financial support to workers who want to pursue clean energy-related technical and professional training or retraining, and offering courses at a variety of times and locations and in a variety of formats so that training is convenient and accessible to all targeted populations.

Understanding where such communities are calls for robust communication across government agencies, including social services at the state and local level, and perhaps commissioning additional studies to identify such groups and how they can best be brought into the opportunities of a new energy economy:

Clean Energy Jobs

Clean energy jobs include a variety of new and existing skills across multiple sectors. The following list shows some of the occupations in three leading clean energy sectors, with additional jobs including those in policy, regulatory, legal and analytical fields in support of clean energy:

- ***Energy efficiency:*** **Construction laborers; sheet metal workers; installation workers (floor, ceiling, wall); concrete masons and finishers; heating, ventilation and air conditioning and refrigeration mechanics and installers; hazardous materials removal workers; carpenters; plumbers; pipefitters and steamfitters; electricians; boilermakers; energy field auditors; home energy rating specialists; building analysts; building performance contractors; building envelope specialists; and weatherization auditors.**
- ***Renewable energy:*** **Team assemblers; solar and wind electrical engineers, solar PV installers, solar thermal technicians, solar installation managers, project foreman, solar designers, solar engineers, electricians, technicians, plant operators, pipefitters, line workers, ironworkers, boilermakers, millwrights, riggers, welders, stock and material movers, computer-controlled machine tool operators, machine setters, customer service representatives, production, planning and expediting clerks, machinists and maintenance and repair workers.**
- ***Smart grid:*** **Utility management positions of smart grid programs (project office leadership, program support, quality assurance, planning, functional support, implementation operations and support, functional specialists, cybersecurity experts), meter installers and service providers, intelligent transmission and distribution automation device producers, communications system products and services providers and software system providers and integrators.**

- In **Virginia** Governor Ralph Northam announced the Clean Energy Virginia Initiative in his 2018 state address. Clean Energy Virginia is intended to help the state create clean energy jobs in rural communities, help families lower their electrical bills and solidify Virginia's position as a global leader in renewable energy.
- In **Colorado** Governor Hickenlooper's July 2017 executive order supporting the state's clean energy transition directed the Colorado Office of Economic Development and International Trade, Colorado Department of Local Affairs and the Colorado Department of Labor and Employment to "formalize and expand upon cross-agency efforts to provide economic development strategies and other supportive services to communities impacted by our nation's changing energy landscape by preparing a written annual update to the Governor."[222]
- **Wyoming** has simplified access to training by using mobile labs to provide weatherization and energy efficiency training to individuals living in remote or rural areas. The mobile training labs are equipped with computers, software, diagnostic equipment and tool kits to facilitate comprehensive training.

Update communications and data systems

OPPORTUNITIES FOR ACTION

- ✓ **Meet broadband needs in underserved communities.**
- ✓ **Develop policies and programs to facilitate the state's transition to a "smart state."**
- ✓ **Encourage state agencies or utilities to assess infrastructure efficiencies.**

To realize all the benefits grid modernization can offer, a critical piece of enabling infrastructure is required: a robust communications network. Energy systems and the built environment will need to transmit and receive substantial quantities of data, necessitating a high-speed network to facilitate communication. Large segments of the country lack the high-speed broadband internet access that could provide the necessary connections, and those who do have access to broadband technology may find the network too restricted to transmit the amount of data that will be produced. In addition to broadband deployment, private sector telecommunications companies are beginning to roll out 5G wireless technology. These "small cell" networks, which operate in a high-frequency band of the wireless spectrum, may also offer the rapid and stable connection required for advanced grid technologies, but deployment efforts will have to focus on underserved communities, particularly in rural areas.

- ***Meet broadband needs in underserved communities:*** Where commercial providers have not proactively built out high-speed data connections for consumers, state programs can move to ensure that their citizens' data access needs are met.
  - KentuckyWired is a statewide, open-access fiber-optic network initiative to deliver the internet to communities across **Kentucky** through high-speed broadband technology. Created with a $324 million budget financed by the issuance of bonds, KentuckyWired's goal is to connect all 120 Kentucky counties with broadband. Recognizing the expertise of the private sector, the state entered into agreements with Cincinnati Bell Telephone Company and East Kentucky Network LLC to partner on broadband network construction. When complete, KentuckyWired will consist of 3,000 miles of fiber-optic cable and more than 1,000 sites that will be connectivity points in communities.[223]

Ideas to consider…

- **Articulate a specific, quantifiable broadband goal and designate a single entity to coordinate the states broadband deployment objectives.**
- **Designate a chief data officer to facilitate data sharing and governance across the public sector.**
- **Use other infrastructure development – for instance, with roads and water systems – to support communications network deployment through "dig-once" provisions and other procedures.**
- **Support private sector deployment of new, advanced communications networks.**

  - In Charlotte and Halifax counties in southern **Virginia**, about 50 percent of students lack broadband internet access at home. To address this telecommunications gap, the Virginia Mid-Atlantic Broadband Communities Corporation has partnered with Microsoft to launch a Homework Network to provide high-speed internet access to the homes of thousands of students in rural southern Virginia. Broadband will be deployed wirelessly from schools with unused, low-band spectrum generally referred to as "TV white space" at no cost to the recipients.[224]
  - **Montana**'s vast mountainous terrain and dispersed population are a challenge to deploying broadband infrastructure. Connecting consumers in areas with low population density is often perceived as unattractive because the initial capital investment is high, profit margins are slim and payback periods are long.[225] For example, in Montana, the average cost of fiber construction per rural customer is $10,000, whereas in Seattle, the average cost per customer is $18.[226] However, rural cooperatives in Montana and other states with low population density have found success in connecting remote populations because these cooperatives tend to be owned and operated by the communities they serve. As a result, more than three-quarters of Montana's schools meet the federally mandated bandwidth standard of 100 kilobits per second (Kbps) per student.[227] USDA has assisted the state by providing more than $165 million in low-interest loans to improve rural broadband service through the Rural Utilities Service programs.[228] This model reflects the success of the Rural Electrification Act of 1936, which stimulated rural electricity development by offering low-interest loans and grants to nonprofit, member-owned cooperatives.[229]
  - **Nebraska** passed L.B. 994 in April 2018 to create a Rural Broadband Task Force to develop enhanced broadband service in underserved and unserved rural areas of Nebraska. The task force will have government-appointed members as well as members from the Nebraska Public Power District, state Department of Economic Development and the state Department of Agriculture. This taskforce will provide insight into affordability, suggest feasible implementation scales and timelines and recommend to the governor and state legislators the most efficient use of the federal broadband total infrastructure funds. The reporting and process for implementation should take place no later than December 2019.[230]
- ***Develop policies and programs to facilitate the state's transition to a "smart state":*** A smart state relies on data and digital connectivity to improve its services and operations and to enhance quality of life and economic development. For example:
  - In **Illinois**, Governor Bruce Rauner tasked the state's chief information officer with facilitating the state's progress toward being a "smart state." As part of this effort, the state has identified the deployment of digitally connected technologies in the energy sector as an opportunity for digital transformation where state government might have a leading policy role. Illinois is working on becoming the first U.S. state to support a coordinated, government-led strategy for smart cities initiatives across the state. Governor Rauner mandated the initiative in an executive order released in January 2016 that created a statewide agency charged with overseeing investments in everything from smart lighting projects to internet of things technologies. One such project under this initiative is the development of a vast network of fiber-optic cables across a 23-county region of southern Illinois to address the lack of adequate broadband access for community institutions in many of the region's rural, economically distressed counties.[231]

- ***Encourage state agencies or utilities to assess infrastructure efficiencies:*** States can use existing infrastructure to expand capabilities at lower cost and encourage such programs through pilot programs or state incentives:
  - The **California** Energy Commission has a water-energy advanced metering infrastructure pilot program in which the electric and gas utilities are using their existing AMI to more efficiently enable smart water metering – for example, transmitting water use data over previously installed electric meter systems and adding water data to existing customer engagement programs that encourage electric and gas conservation based on advanced metering data. These pilot programs test shared infrastructure options to yield greater energy and water savings.[232]

Address cyberthreats[233]

OPPORTUNITIES FOR ACTION

- ✓ **Coordinate efforts and information sharing among stakeholders, with clearly defined roles.**
- ✓ **Incorporate cybersecurity into existing planning, including energy assurance plans.**
- ✓ **Promote practices among utilities that build on standards and guidelines to address unique threats and vulnerabilities.**
- ✓ **Ensure that state agencies, including PUCs, have a thorough understanding of how utilities manage risks.**
- ✓ **Continuously evaluate and upgrade skills, systems and planning in response to emerging threats.**
- ✓ **Develop and use the cyber expertise of the state's National Guard unit.**
- ✓ **Use expertise with the civilian workforce to assist with responses.**

Protecting the nation's energy system and infrastructure from cyberthreats is vital to governors, and the risks appear to be growing alongside long-standing risks from natural disasters and physical attacks. Cyberthreats to the energy sector include intrusions into utility business systems (through information technology or IT) to obtain sensitive information and strikes on control systems (via operational technology or OT) that could damage physical energy infrastructure and disrupt the electric, oil or gas supply. An attack on energy infrastructure is also likely to affect other critical infrastructure sectors, such as water, transportation, emergency services, the financial sector and government operations. Electric utilities and other energy providers have reported more frequent attacks on business and operational control systems, and recent attacks and tests have shown that a cyberattack could damage or disrupt energy infrastructure. Studies estimate that the electric power industry will need to spend more than $7 billion by 2020 to protect the grid against cyberattacks; the oil and natural gas industry will need to spend nearly $2 billion by 2018.[234]

Governors face several challenges to protecting critical energy assets against cyberthreats and adequately responding to disruptions a cyberattack would cause. These challenges include limited state-level experience with cyber-related protection, detection, response and recovery activities in general; limited understanding of the threats and risks associated with cyberattacks on the energy system; and an energy system that is interstate and interdependent with other critical infrastructure networks. In addition, the private sector owns and operates more than 85 percent of the nation's critical infrastructure, which calls for additional coordination of efforts and information sharing.

Governors can confront these challenges and enhance the cybersecurity of the energy infrastructure within their state through the following actions:

- ***Coordinate efforts and information sharing among stakeholders, with clearly defined roles:*** Governors are uniquely positioned to bring together agencies and entities to address the interstate, state-federal and public-private nature of energy sector cybersecurity. Governors can convene state agencies that oversee critical infrastructure sectors to align cybersecurity policies and plans and convene states in their region to address potential multistate solutions and responses. In addition to those working in the energy area, states should include first emergency planners and first responders, including the National Guard, who may have expertise in cyberthreats. Governors can also ensure that state agencies take advantage of existing government and industry opportunities for information sharing and response activities that are a cornerstone of a sound cyber strategy. That work can include creating information sharing and analysis organizations. Critical to effective information sharing is information protection;

states may need to create additional protections for information or consider how to use verbal briefings to exchange sensitive information:

- The Electricity Information Sharing and Analysis Center (E-ISAC) gathers and analyzes security data, shares appropriate data with stakeholders, coordinates incident management and communicates mitigation strategies with stakeholders. The E-ISAC, in collaboration with DOE and the Electricity Subsector Coordinating Council (ESCC), serves as the primary security communications channel for the electric industry and enhances industry's ability to prepare for and respond to cyber as well as physical threats, vulnerabilities and incidents. NGA is a member of the Energy Governmental Coordinating Council, which coordinates through the ESCC.

Ideas to consider...

- **Create a state cyber advisory board, task force or working group with both public and private sector participants.**
- **Enlist the assistance of the state National Guard, including through the creation of a cyber unit.**
- **Promote training and exercising on cyberthreats with state agencies and the energy sector.**
- **Identify the different measures needed to protect operational and informational technologies.**

- The nation's 78 fusion centers, owned and operated at the state and local levels, gather intelligence on threats, including cyberattacks, and serve as conduits for information sharing among federal, state and local governments; private companies; and law enforcement. **New Jersey** co-located its fusion center and emergency operations center to help further that coordination.
- **Vermont** Governor Scott created by executive order a 10-member Governor's Cybersecurity Advisory Team to provide advice on the state's cybersecurity readiness, strategy and planning with members from the public and private sectors.[235] The team is charged with developing a strategic plan and enhancing the relationships and lines of communication across federal, state and local governments and the private sector.
- Nine **Oregon** agencies and various federal and private partners work together on energy assurance planning. Responsibilities are clearly delineated to participating entities, and the lead agency is determined based on the severity of the cyberthreat or attack.[236]
- Since March 2013, **Pennsylvania** has convened utility regulators from neighboring states quarterly to discuss energy-specific cyberthreats and solutions.

- ***Incorporate cybersecurity into existing planning, including energy assurance plans:*** Incorporating comprehensive strategies for potential cyberattacks through utilities; other, private entities; and state agencies is paramount to being prepared for an attack if or when it occurs:
  - In **Arkansas**, the Arkansas Electric Cooperative Corporation evaluated all the critical infrastructure in its network for cybersecurity vulnerabilities and has been working to enhance their system.[237]
  - **Montana** has incorporated planning for cyberthreats into the state energy assurance plan. Responsibility for responding to cyberthreats is placed on the utilities, with oversight and support from state and federal agencies. In addition, the Montana Department of Justice operates the Montana All Threat Intelligence Center to facilitate cybercommunication and threat-response organization.
  - In **Oklahoma**'s state energy assurance plan, cybersecurity responsibilities for the energy sector are also placed on industry. For example, Oklahoma Gas & Electric, the state's largest electric utility, follows the standards and guidelines federally mandated cybersecurity entities have set and created a cyber and physical security team to restore operations in the event of a cyberattack.
  - Other states that incorporate cybersecurity planning, practice and implementation into their energy assurance plans include **California, Colorado, Connecticut** and **Louisiana**.
- ***Promote practices among utilities that build on standards and guidelines to address unique threats and vulnerabilities.*** For example:
  - In 2013, **Connecticut** ratified a comprehensive energy strategy and directed the state's Public Utilities Regulatory Authority (PURA) to conduct a "cyber review" to assess the state's electric, natural gas and water utilities' cyber capabilities and recommend actions to strengthen deterrence.[238] Following the review, PURA held collaborative technical meetings with the state's public utility companies to review the standards and guidelines they follow as part of their cybersecurity risk management programs. Through voluntary standards and guidelines, industry has adopted, among other things, utility-wide cyber updates and procedures for cyberthreat training to identify vulnerabilities.[239]

- ***Ensure that state agencies, including PUCs, have a thorough understanding of how utilities manage risks, and continuously evaluate and upgrade skills, systems and planning in response to emerging threats:*** As cyberthreats evolve and as the deployed technologies and structures of a state's energy systems change, states must continually reassess whether their approaches to cyber defense remain sufficient and appropriate to the risks the sector faces. Rapidly modernizing power sector technologies will present different risks that states must stay abreast of in planning and coordinating; these risks will likely require frequent reassessment:
    - **Indiana**'s Office of Utility Consumer Counselor undertook an assessment of cyberthreats to emerging electrical grid technologies. The assessment focused on microgrids, with the support of one of the state's major utilities.[240]
- ***Develop and use the cyber expertise of the state's National Guard unit:*** National Guard units may have specialized knowledge developed through work in the private sector that can help in the state's response to cyberthreats, including for the energy sector. The National Guard can provide valuable support and expertise in times of an emergency, particularly – as many states are doing – if they have established a dedicated cyber unit. For example:
    - In 2015, the **Washington** National Guard conducted a "red team" operation to expose cyber vulnerabilities at the Snohomish County Public Utility District (SnoPUD). The National Guard, SnoPUD and other government and private-sector members formed the Energy Sector Cybersecurity Working Group and published the Cybersecurity Guide for the Critical Infrastructure of Washington State.[241] The guide is structured based on the National Institute of Standards and Technology (NIST) cybersecurity framework and assists small and medium-sized utilities as well as municipal and cooperative electricity utilities that lack the capacity to invest in expensive cyber defenses.
    - **Delaware, Maryland, Michigan, Missouri, Rhode Island** and **Utah** have units within their National Guard focused on cybersecurity.[242]
- ***Use expertise with the civilian workforce to assist with responses:*** A workforce that understands cyberthreats can mean additional training, often at the state's expense. To cost-effectively bolster capacity, some states have decided to use individuals who already have expertise in cybersecurity – for example:
    - **Michigan** operates a Cyber Civilian Corps that consists of trained experts who volunteer in times of a cyber emergency.[243]

Educate citizens about the benefits and risks of technological innovation

OPPORTUNITIES FOR ACTION

- ✓ **Direct agencies and work with PUCs to explore the customer education and outreach activities needed to support the deployment of innovative energy technologies.**
- ✓ **Direct agencies to support engagement with and education of a range of consumers about the benefits and impacts of innovative energy technologies.**
- ✓ **Promote efforts by state agencies to create educational campaigns focused on kindergarten through grade 12 (K-12) schools.**

Communicating with state residents about changes to the energy systems they use every day can improve the success of programs designed to advance energy innovation. Governors can articulate a broad energy vision to state residents, being clear about why changes to energy systems are occurring and why those changes matter, while state offices can serve as a trusted source of information and outreach for customers likely to be affected by new energy technologies and the changes they may bring to energy use, economic development, infrastructure development, environmental conditions and data privacy.

The flow of information should not be one way: peoples' first-hand experiences and local knowledge may help identify issues related to the deployment of new technologies that can then be accounted for in advance. Programs that engage the public can also help ensure that the public is meaningfully included in providing input that is incorporated into planning processes. For example, studies have shown that those who perceived wind farm planning processes as fairer were less likely later to indicate annoyance with or claim negative impacts from the farms when built.[244] In addition, not all needed engagement will focus on external messaging to the public; governors can ensure that robust internal engagement efforts exist to change minds and get buy-in from state agencies about advancing innovative energy technologies.

Governors can promote education and engagement in several ways:

- ***Direct agencies and work with PUCs to explore the customer education and outreach activities needed to support the deployment of innovative energy technologies:*** Governors can promote efforts to determine what kinds of education and outreach activities would be most beneficial in their states – for example:
  - In **New Hampshire**, the PUC issued an order in 2016 initiating a formal working group to gather input from stakeholders about grid modernization. Among the key topics of inquiry for the working group to explore were the customer education activities needed to support grid-modernization activities and promote customer engagement.[245] The working group's report in March 2017 recommended that utilities take the lead on educating their customers but that state agencies (e.g., the Office of the Consumer Advocate, the PUC) also engage in customer education in complementary and reinforcing ways.[246]

Ideas to consider...

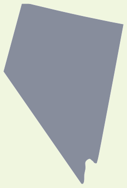
- **Engage with a range of stakeholders well in advance of firm decisions being made or deployment of new programs or equipment.**
- **Assess outreach approaches based on communities (e.g., those with reduced internet access or those mainly oriented toward online media).**
- **Engage with schools to incorporate innovative energy topics in science, technology, engineering and mathematics curricula.**

- ***Direct agencies to support engagement with and education of a range of consumers about the benefits and impacts of innovative energy technologies:*** Outreach and engagement must be tailored to the circumstances of various audiences; rural areas have different needs than urban ones, low-income communities have different needs than wealthy ones and businesses may have different needs than individual residents. There is a need for increased sophistication in customer segmentation to account for these needs and desires. Flexibility is important, as is identifying which channels, messages and messengers can best engage diverse audiences. Governors can ensure that state agencies consider such customer needs. For example:
  - The NextGrid process underway in **Illinois**, which is investigating the benefits and challenges of grid modernization, has a working group of stakeholders devoted solely to issues of customer and community participation. The working group is studying ways to engage, educate and empower customers to help shape and benefit from emerging opportunities in the electricity system and is specifically considering the impact of new technologies on underserved customers and communities. The NextGrid process also offers numerous opportunities for stakeholder engagement and public comment.[247]
  - Similarly, in **Ohio**'s PowerForward initiative, the PUC of Ohio is analyzing innovative energy technologies and pairing that knowledge with broader policy research and education outreach, aiming to educate the public and inform policymakers on best practices to facilitate distribution grid-modernization efforts.[248]
  - In **Vermont**, the Drive Electric Vermont coalition was formed in 2012 by three state agencies (Transportation, Natural Resources and Public Service) and the nonprofit Vermont Energy Investment Corporation to increase adoption of plug-in EVs in the state, with education, marketing and outreach being the cornerstones of the strategy. Among many other activities, Drive Electric Vermont has held ride-and-drive events to expose more people to EVs; used traditional and social media avenues, videos and internet banner advertisements to raise awareness; developed an online information hub; conducted outreach to major Vermont employers about supporting EV infrastructure and employee purchases; and worked with auto dealers to make them aware of the EV options on the market.[249]
  - One goal of the **Michigan** Energy Office (within the Michigan Agency for Energy) is to provide and support education to encourage energy literacy and the development of a vibrant energy workforce. For instance, in 2017-18, the office is providing funding for a range of education and outreach efforts related to renewable energy and energy waste reduction, including offering financial assistance for workshops, conferences or other events that increase awareness of technologies, applications, opportunities and best practices in the state and offering grants to provide education and outreach to Upper Peninsula groups related to an energy waste-reduction plan for the region.[250]
  - As part of the **U.S. Virgin Islands**' efforts to reduce dependence on imported fuels and reduce well-above-average energy costs to consumers, the VIenergize Services Network engages with the public on energy and water efficiency topics and informs islanders about renewable energy goals for the islands. It also helps consumers identify how to pay for efficiency efforts and identify contractors.[251]

- ***Promote efforts by state agencies to create educational campaigns focused on K-12 schools:*** Although U.S. energy systems are evolving rapidly, the transformation will take time, making it important to educate and engage not only current consumers but also future ones. Governors can promote efforts to create educational opportunities in schools related to innovative energy technologies. For example:
  - NYSERDA in **New York** has programs and initiatives to help New York schools lead by example in implementing clean energy projects and provides lessons for K-12 educators on how to explain and demonstrate solar power to their students.[252]
  - The **Tennessee** Department of Environment & Conservation, Office of Energy Programs runs the Tennessee Energy Education Network (TEEN) program, which is designed to engage K12 students in the science of energy conservation and renewable energy. The TEEN program includes free energy education camps and workshops for K12 educators that provide them with the information and resources needed to teach the science of energy and energy conservation in their classrooms.[253]
  - **Florida**'s SunSmart Schools and Emergency Shelters program combines a hurricane resiliency program with educational outreach. The program supports the installation of battery-tied solar energy systems at schools that are also used as emergency shelters for hurricanes. It also includes curricula for the students of those schools to learn about electricity and renewable energy through the solar panels and batteries installed at their sites.[254]

Appendix: State Spotlights

Nevada: Building a new energy economy



Nevada has been active in promoting energy innovation and deployment. Nevada Governor Sandoval has issued executive orders and promoted successful legislation that sends a strong signal for advancing energy innovation in Nevada. His work has spurred action in energy storage and rooftop solar in particular.

In April 2017, Governor Sandoval formed a Committee on Energy Choice tasked with making recommendations and proposals for actions should the Energy Choice Initiative become part of the Nevada Constitution (it passed a ballot referendum in 2016 and, pending a required second vote in 2018, will open the state's electricity markets to retail competition).[255] After vetoing bills raising the state's renewable portfolio standard (RPS) and creating a system for community solar (in light of the state's evolving energy policies), Governor Sandoval pledged to include community solar and an increased RPS in the items for the Committee on Energy Choice to study and discuss.[256] In early 2016, Governor Sandoval issued an executive order that reconvened a New Energy Industry Task Force to provide recommendations on policies to encourage clean energy development, advance grid modernization and resilience and support distributed generation and energy storage.[257] The task force, which included technical advisory committees consisting of utility, environmental, industry, governmental and other stakeholders, delivered a report to the governor recommending a range of actions.[258]

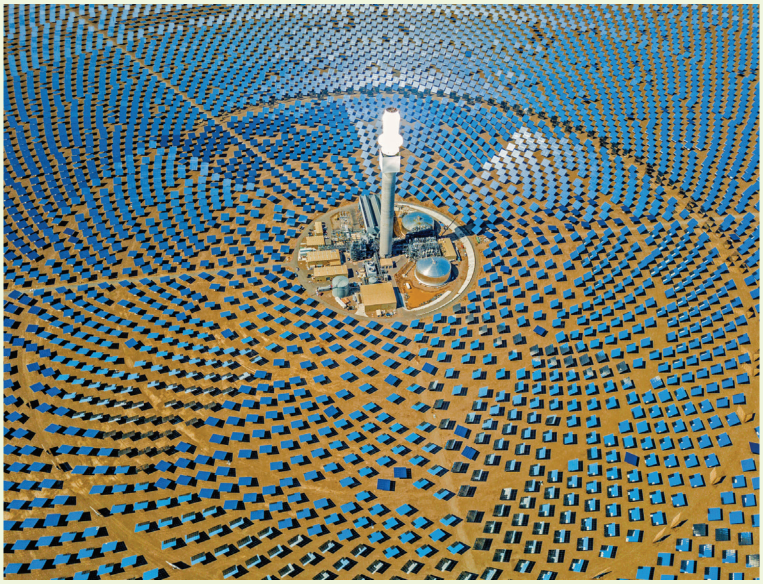
Greater deployment of advanced and connected technologies in the energy system increases the sector's exposure to cyberthreats. Recognizing the heightened vulnerability risk, the Nevada Office of Cyber Defense Coordination was established in 2017 to serve as a single platform to integrate the state's cyber security initiatives, manage strategic policy and planning, and streamline cyber security governance structures.[259]

Energy storage has been a particular focus of action for the governor and the Nevada Legislature. Governor Sandoval signed S.B. 145 in 2017, which created an incentive program for energy storage systems and created an EV infrastructure demonstration program to expand and accelerate the deployment of EVs and supporting infrastructure throughout the state.[260] That same year, S.B. 204 required the PUC to investigate and establish annual targets for certain electric utilities in the state to procure energy storage systems if found to be in the public interest.[261]

Several new laws will help further distributed renewable resources in Nevada. The governor signed S.B. 146 in 2017, which requires utilities to file a distributed resources plan that evaluates the benefits, costs, barriers and needed policies and investments for integration of distributed energy resources.[262] S.B. 65 was passed to enable greater public participation and transparency in the utilities' integrated resource planning process and to ensure that preference is given to resources that provide the greatest economic and environmental benefits and the greatest opportunity for the creation of new jobs in the state, diversify energy portfolios and reduce fuel and carbon price risk.[263] A.B. 405, also enacted in 2017, restored net metering for Nevada customers who have rooftop solar.[264]

S.B. 150 and A.B. 223 created requirements for the PUC to establish annual energy savings goals for each electric utility and required utilities' integrated resource plans to direct not less than 5 percent of energy efficiency expenditures toward programs for low-income customers.[265]

The governor signed S.B. 407 in 2017, creating the Nevada Clean Energy Fund. The fund provides funding for and increases the pace and amount of financing for clean energy projects in the state, joining leading states around the country in forming a green bank to support deployment of clean energy technologies.[266] A.B. 5 was also passed to enable Property Assessed Clean Energy, another financing mechanism that enables low-cost, long-term funding for energy efficiency and renewable energy projects.[267]



New York: Reforming the energy vision

In 2014, New York Governor Cuomo launched REV, a process of transitioning the state's utilities from their traditional role as providers of electricity transmission and distribution services to a new role as distribution system platform providers in the county's first transformation of utilities into smart system integrators. In these new roles, the utilities will become grid managers, coordinating and facilitating the increased use of DER to create a cleaner, more reliable and more resilient grid. Through a combination of regulatory reform, market activation and taking advantage of the state's public energy assets (e.g., the New York Power Authority [NYPA]), REV aims to pursue initiatives that advance renewable energy, energy efficiency, clean energy financing, sustainable and resilient communities, energy infrastructure modernization, clean energy R&D and clean transportation.

The market activation work is led by NYSERDA, which focuses on supporting the growth and deployment of clean technology solutions. The regulatory reform work is led by the state's Public Service Commission, which is developing performance-based metrics tied to earnings mechanisms for achieving smart system integration goals. The commission is also encouraging utilities to be innovative and proactive by allowing them to propose new pilot programs and incentive structures to test ideas.[268] REV has relied on public-private working groups, including one on market design and platform technology, to provide recommendations to regulators.[269]

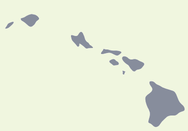
REV is driving New York's six investor-owned utilities to work with energy innovators to lower costs; test advanced technologies; and design new, replicable business models through REV Demonstration Projects, which include a few projects that establish utility-branded clean energy project platforms ("marketplaces") that offer energy efficiency, demand response and DER products and services.[270]

New York has a suite of policies and programs designed to advance clean energy innovation and the achievement of REV goals:

- NY Prize, a NYSERDA-led competition to help communities create microgrids.[271]
- A Clean Energy Standard requiring 50 percent of New York's electricity to come from renewable resources by 2030 as well as a Zero-Emission Credit requirement to support existing nuclear power plants.[272]
- NY-Sun, a NYSERDA program to add more than 3 GW of installed solar capacity in the state by 2023 through incentive programs, assistance for low- to moderate- income residents, support for community solar, a bulk purchasing "Solarize" program and efforts to reduce the "soft costs" of installing solar power systems.[273]

In addition, Governor Cuomo signed a bill in November 2017 directing the Public Service Commission to establish an energy storage target for 2030 for the state and creating an energy storage deployment program to be administered by NYSERDA and the Long Island Power Authority.[274] NYSERDA has already made millions of dollars available for R&D on energy storage and battery innovations.[275]

Hawaii: Advancing a clean and resilient future



Hawaii, in part because of its unique geography and reliance on imported energy, has been pursuing some of the most aggressive policies and programs in the country to advance energy innovation.

Hawaii's Clean Energy Initiative, initially launched in 2008, is a framework of statutes and regulations to advance local, clean, renewable energy sources. Over the years, the goals of the initiative have grown stronger, including achieving the first renewable portfolio standard in the United States to call for achieving 100 percent renewables for energy generation (by 2045) and reducing electricity consumption by 4,300 gigawatt-hours (GWh) by 2030. The initiative fosters collaborative engagement by partnering with a range of stakeholders in focused working groups.[276]

In furtherance of the initiative's goals, the PUC in 2017-18 directed Hawaiian Electric companies to develop and implement a Grid-Modernization Strategy to empower customers' choices, help make DER an essential part of the state's renewable portfolio and use the electric grid to spur economic growth. The Grid-Modernization Strategy will involve investments to spur DER growth and grid modernization, building on investments the companies have made over the past decade in customer- and grid-facing technologies, to create value for customers, enable customers to take greater control over their energy use and generation, increase distribution system efficiency and flexibility, enable two-way communication and power flow on the grid and enhance advanced sensor capabilities. The companies plan to focus on near-term improvements that do not crowd out the potential for future innovative technologies. They will pursue both a layered grid architectural approach, which coordinates across customers, distribution and transmission, and a platform approach that enables the integration of DERs as a system resource.[277]

Hawaii is pursuing other efforts, as well, including the following:

- In 2018, Governor David Ige signed a bill directing the state PUC to establish performance incentive and penalty mechanisms that directly tie electricity utility revenues to the utility's achievement on performance metrics. Member-owned cooperative electric utilities are exempted.[278]
- In 2018, Governor Ige signed two bills related to carbon neutrality:
- Commit to carbon neutrality by 2045 and establishes the Greenhouse Gas Sequestration Task Force (Act 15).[279]
- Establish a statewide carbon offset program (Act 16).[280]
- The State Energy Office is conducting a study on future models for utility ownership and regulation to aid in achieving the state's energy goals.[281]
- Governor Ige in 2017 signed into law an act expressly giving the University of Hawaii legal authority to create, promote and participate in new economic enterprises and expand workforce opportunities based on transforming ideas and concepts arising from basic and applied research conducted at the university into commercially viable and sustainable products and businesses.[282]
- The Hawaii Green Infrastructure Authority was created in 2013 to identify innovative ways to increase access to clean energy financing.[283]
- The State Energy Office created a free mobile app to help drivers locate publicly available EV charging stations statewide.[284]

California: enhancing sustainability and economic development

California has been leading on clean energy innovation for years because of early concerns about air quality. These concerns have extended to broader goals for sustainability and economic development.

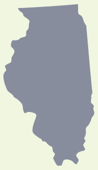
California Governor Jerry Brown, in his 2015 inaugural address, set a goal of increasing the state's renewable electricity standard to 50 percent by 2030, reducing petroleum use in cars and trucks by up to 50 percent, doubling the efficiency of existing buildings and making heating fuels cleaner. In 2015, he signed SB 350 into law, which codified the goals of increasing the state's renewable electricity procurement goal from 33 percent by 2020 to 50 percent by 2030 and doubling statewide energy efficiency savings in electricity and natural gas end uses by 2030. SB 350 also authorized utilities to undertake transportation electrification activities and directed state agencies to evaluate barriers to renewables, energy efficiency and zero-emission transportation options for low-income customers.[285]

Building on decades of work in California to advance zero-emission vehicles, Governor Brown also signed an executive order in January 2018 setting a new target of 5 million zero-emission vehicles (ZEVs) in California by 2030 and directing state entities to work with the private sector and others to spur the construction and installation of 200 hydrogen fueling stations and 250,000 ZEV chargers by 2025.[286]

California's PUC has been pursuing a range of dockets as part of its grid-modernization efforts, including dockets and initiatives on Distribution Resources Plans (which involve siting, valuing and integrating DERs, including figuring out utility roles and business models), ZEVs (including special rates and pilot programs on charging infrastructure and vehicle-grid integration), energy storage, rate reform, demand response, a competitive solicitation framework and utility incentive mechanism pilot for DER deployment.[287] California's PUC also set an energy storage target in 2013 for the state's investor-owned utilities of more than 1.3 GW.[288] Having this energy storage target in place helped accelerate learning about and comfort with storage systems when the Aliso Canyon gas leak in 2015 spurred the commission to fast-track approval of such systems to support the grid.[289]

The California Energy Commission administers several R&D programs to fund innovations related to energy efficiency, renewable energy, transmission and distribution, transportation and more in both the electricity and natural gas systems.[290]

Illinois: Becoming a smarter state



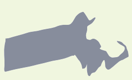
Illinois Governor Rauner and the state's chief information officer launched the Smarter Illinois Initiative to make the state a leader in the digital transformation of government, in part by scaling smart cities technologies to the state level. The state brought together private sector advisors and leaders to help craft a smarter state concept and vision for the state, which was then furthered through even broader stakeholder input from industry, academia, the public sector and research organizations.[291]

The Smarter Illinois Initiative focuses on investing in information and communications technology (ICT), including mobile technologies, big data and analytics and cloud services, as the foundation for "innovation accelerators" such as the internet of things and blockchain, which in turn enable the development of new services and products. In addition to investing in ICT, the initiative invests in other, related needs, such as workforce development and data sharing. The goal of the initiative is to meet explicit social, financial and environmental outcomes, including economic development and civic engagement, sustainable urban planning and administration, data-driven public safety, resilient energy and infrastructure and intelligent transportation. One core line of work involves demonstrating the value of sensors and the internet of things in the built environment (e.g., smart streetlighting, preparing roadways for automated vehicles). For example, the state has used a new procurement platform to enable smaller towns to procure smart streetlighting technologies at state volume discounts. Another core line of work involves collaborating with the private sector to design curricula on analytics, the internet of things and cybersecurity to build a future-ready workforce.[292]

In July 2017, the Illinois Commerce Commission required the state's investor-owned utilities to consider an Open Data Access Framework as they design new data services based on advanced metering infrastructure. The framework includes considerations related to data collection, security and management as well as ways customers (and third parties) can access AMI data so that smart grid functions and markets can be enabled and consumer benefits from advanced meters can be accelerated.[293] More broadly, the commission has launched a grid-modernization/utility of the future study, an 18-month process known as "NextGrid," that is investigating trends in the electricity sector, emerging technologies, the benefits and challenges of grid modernization and potential legal and regulatory revisions that may be needed.[294]

The foundation for some of this progress has been the smart grid law passed in 2011, which reformed utility rate structures, directed significant investments toward upgrading the grid and promoted distributed generation, and the 2016 Future Energy Jobs Act, which will spur investments in energy efficiency, wind, solar and clean energy job training.[295]

Massachusetts: Modernizing the grid



Massachusetts has been pursuing a range of clean energy innovation and grid-modernization initiatives for several years. The Green Communities Act of 2008 and the legislation that followed have spurred the state's Department of Public Utilities (DPU) to require utilities to achieve some of the strongest energy efficiency targets in the country, enable interconnection of distributed generation, pursue smart grid pilot projects, file grid-modernization plans and more. In 2017, the DPU adopted a performance-based ratemaking framework for one of the state's utilities that is designed to incentivize, among other things, investments in advanced clean energy technologies, EV infrastructure and energy storage facilities.[296] In addition, in 2018 the DPU issued a grid-modernization order allowing investments in modern technology to enhance reliability and facilitate the continued adoption of distributed generation while allowing consideration of targeted AMI metering for cost-effective deployment.[297]

In 2017, pursuant to the Energy Diversity Act signed by Governor Charlie Baker in 2016, the Department of Energy Resources (DOER) adopted a 200MWh energy storage target to be achieved by January 1, 2020. This target is part of Governor Baker's broader Energy Storage Initiative, a $20 million commitment to develop policies and explore opportunities to support energy storage in the commonwealth. DOER has taken other actions to support storage deployment, as well, including becoming the first state in the nation to incentivize the pairing of energy storage with solar in a new Solar Massachusetts Renewable Target (SMART) incentive program.[298]

The Energy Storage Initiative is just one of numerous DOER programs and initiatives to support clean energy deployment and innovation, alongside others such as those to advance electric (and other alternative-fuel) vehicles and infrastructure and to promote zero-net-energy buildings. DOER has an Emerging Technology Division focused solely on advancing emerging clean energy and transportation technologies.[299]

The Massachusetts Clean Energy Center (MassCEC), a quasi-public state economic development agency dedicated to accelerating the growth of the clean energy sector, is also a key player in the commonwealth's support for energy innovation. Its DeployMass program, for instance, facilitates the adoption of clean energy innovation technologies at public agencies, public academic institutions and municipalities, thereby creating markets and customers to help innovative clean energy firms in the commonwealth.[300]

Additional Resources

- Rackley, J., & Silliman, B. (2017). *Powering up: State trends for advancing use of energy storage.* Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2017/2017_Energy Storage_FINAL.pdf
- Gander, S., Lauf, D., & Kambour, A. (2017). *Grid smarts: State considerations for adopting grid modernization technology.* Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2017/Grid Tech_Paper_Final.pdf
- Rackley, J. (2016). *State strategies for advancing the use of energy storage.* Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2016/1610StateStrategiesEnergyStorage.pdf
- Wasserman, A., & Cramer, S. (2016). *Opportunities for governors to align electricity markets with state energy goals.* Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2016/1611GovernorsElectricityMarkets.pdf
- U.S. Department of Energy, National Renewable Energy Laboratory. (2017). *Voices of experience: Integrating intermittent resources. What utilities are learning.* Retrieved from https://www.smartgrid.gov/files/VOE_FINAL_revised_8.9.2017.pdf
- U.S. Department of Energy, National Renewable Energy Laboratory. (2013). *Voices of experience: Insights on smart grid customer engagement.* Retrieved from https://www.energy.gov/sites/prod/files/2013/07/f2/VoicesofExperience.pdf
- Fine, S., & Robison, M. (2015). *On the grid's bleeding edge: The California, New York, and Hawaii power market revolution.* Retrieved from ICF International website: https://www.icf.com/resources/white-papers/2017/on-the-grids-bleeding-edge
- Simchak, T. (2014). *The role of demand management in the utility of the future.* Retrieved from https://www.21stcenturypower.org/assets/pdfs/demand_management_utility_future.pdf
- Kambour, A. (2014, August). *State roles in enhancing the cybersecurity of energy systems and infrastructure* (Issue Brief). Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2014/1408EnhancingCybersecurityEnergySystems.pdf
- MacLellan, T. (2013, September). *Act and adjust: A call to action for governors for cybersecurity* (Issue Brief). Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2013/1309_Act_and_Adjust_Paper.pdf
- Keogh, M., & Thomas, S. (2017). *Cybersecurity: A primer for state utility regulators.* Retrieved from https://pubs.naruc.org/pub/66D17AE4-A46F-B543-58EF-68B04E8B180F
- Cyber Mutual Assistance. *The ESCC's Cyber Mutual Assistance Program: The electric power and natural gas industries share expertise to counter cyber attacks.* Retrieved from http://www.eei.org/issuesandpolicy/cybersecurity/Documents/Cyber%20Mutual%20Assistance%20Program.pdf
- National Institute of Standards and Technology. (2014). *Framework for improving critical infrastructure cybersecurity.* Retrieved from https://www.nist.gov/sites/default/files/documents/cyberframework/cybersecurity-framework-021214.pdf

ENDNOTES

1 Jell, S. (2015, July 31). Electricity from natural gas surpasses coal for first time, but just for one month. Retrieved from the U.S. energy information administration https://www.eia.gov/todayinenergy/detail.php?id=22312#

2 What is U.S. electricity generation by energy source? (2018, March 7). Retrieved from https://www.eia.gov/tools/faqs/faq.php?id=427&t=3

3 Marcy, C. (2018, January 10). Nearly half of utility-scale capacity installed in 2017 came from renewables. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=34472

4 Comstock, O. (2017, June 14). Wind and solar in March accounted for 10% of U.S. electricity generation for first time. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=31632

5 Fu, R., Feldman, D., Margolis, R., Woodhouse, M., & Ardani, K. (2017). U.S. solar photovoltaic system cost benchmark: Q1 2017. Retrieved from the National energy renewable laboratory https://www.nrel.gov/docs/fy17osti/68925.pdf

6 U.S. Department of Energy. (2017). *Staff report to the secretary on electricity markets and reliability.* Retrieved from https://www.energy.gov/sites/prod/files/2017/08/f36/Staff%20Report%20on%20Electricity%20Markets%20and%20Reliability_0.pdf

7 Metelitsa, C. (2017, November). U.S. microgrids 2017: Market drivers, analysis and forecast. Retrieved from https://www.greentechmedia.com/research/report/us-microgrids-2017#gs.O64p4e8

8 Norton, G., & Pitts, B. (n.d.). 4 emerging trends in U.S. offshore wind technologies. Retrieved from https://energy.gov/eere/articles/4-emerging-trends-us-offshore-wind-technologies

9 U.S. Energy Information Administration. (2018). Electric power monthly with data for March 2018. Retrieved from https://www.eia.gov/electricity/monthly/current_month/epm.pdf

10 Parks Associates. (2017, May 3). *Parks Associates: More than 100 million U.S. households do not have a smart home device* [Press release]. Retrieved from https://www.prnewswire.com/news-releases/parks-associates-more-than-100-million-us-households-do-not-have-a-smart-home-device-300450441.html

11 How many smart meters are installed in the United States, and who has them? (2017, December 8). Retrieved from https://www.eia.gov/tools/faqs/faq.php?id=108&t=3

12 Cooper, A. (2107). Electric company smart meter deployments: Foundations for a smart grid. Retrieved from http://www.edisonfoundation.net/iei/publications/Documents/IEI_Smart%20Meter%20Report%202017_FINAL.pdf

13 *2018 Sustainable energy in America factbook.* (2018). Retrieved from The Business Council for Sustainable Energy website: http://www.bcse.org/sustainableenergyfactbook/#

14 SAAR data. Retrieved from Motor Intelligence website: http://www.motorintelligence.com/m_frameset.html

15 Desjardins, J. (2018, February 16). A brief history of technology. Retrieved from https://www.weforum.org/agenda/2018/02/the-rising-speed-of-technological-adoption

16 Broekaert, K., & Espinel, V. A. (2018, February 13). How can policy keep pace with the fourth industrial revolution? Retrieved from https://www.weforum.org/agenda/2018/02/can-policy-keep-pace-with-fourth-industrial-revolution

17 Desjardins, J. (2018). A brief history of technology. Retrieved from https://www.weforum.org/agenda/2018/02/the-rising-speed-of-technological-adoption

18 Schwab, K. (2016, January 14). The fourth industrial revolution: What it means, how to respond. Retrieved from https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond

19 Marcy, C. (2018, January 10). Nearly half of utility-scale capacity installed in 2017 came from renewables. Retrieved from the U.S. energy information administration https://www.eia.gov/todayinenergy/detail.php?id=34472

20 Comstock, O. (2017, June 14). Wind and solar in March accounted for 10% of U.S. electricity generation for first time. Retrieved from the U.S. energy information administration https://www.eia.gov/todayinenergy/detail.php?id=31632

21 Norton, G., & Pitts, B. (n.d.). 4 emerging trends in U.S. offshore wind technologies. Retrieved from https://energy.gov/eere/articles/4-emerging-trends-us-offshore-wind-technologies

22 *U.S. distributed renewables deployment forecast: Solar PV, distributed wind, and biogas to electricity capacity and revenue forecasts: 2016–2025.* Retrieved from https://www.navigantresearch.com/research/u-s-distributed-renewables-deployment-forecast

23 Fu, R., Feldman, D., Margolis, R., Woodhouse, M., & Ardani, K. (2017). U.S. solar photovoltaic system cost benchmark: Q1 2017. Retrieved from https://www.nrel.gov/docs/fy17osti/68925.pdf

24 Berdner, J. (n.d.). The impact of smart inverters: How rule and regulation will transform DG into smart systems. Retrieved from https://www.nrel.gov/pv/assets/pdfs/2015_pvmrw_130_berdner.pdf

25 U.S. Energy Information Administration. (2017). *Modeling distributed generation in the buildings sectors.* Retrieved from https://www.eia.gov/outlooks/aeo/nems/2017/buildings/pdf/moddistribg.pdf

26 Freed, J., Brinton, S., Burns, E., & Robson, A. (2015). *Advanced nuclear 101.* Retrieved from Third Way website: http://www.thirdway.org/report/advanced-nuclear-101

27 U.S. Department of Energy. (2018, May 8). Department of Energy seeks information on small-scale modular coal-based power plants of the future. Retrieved from U.S. DOE https://www.energy.gov/articles/department-energy-seeks-information-small-scale-modular-coal-based-power-plants-future

28 Lazard. (2014). Lazard's Levelized Cost of Energy Analysis – Version 8.0. Retrieved from https://www.lazard.com/media/1777/levelized_cost_of_energy_-_version_80.pdf.

29 Lazard. (2017). Lazard's Levelized Cost of Energy Analysis – Version 11.0. Retrieved from https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf.

30 Stanfield, S., Petta, J., & Auck, S. B.. (2017). *Charging ahead: An energy storage guide for state policymakers.* Retrieved from http://www.irecusa.org/wp-content/uploads/2017/04/IREC_Charging-Ahead_Energy-Storage-Guide_FINALApril2017.pdf

31 Rackley, J., & Silliman, B. (2017, November). *Powering up: State trends for advancing use of energy storage* (Issue Brief). Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2017/2017_EnergyStorage_FINAL.pdf; DOE global energy storage database. (n.d.). Retrieved from http://www.energystorageexchange.org/projects

32 Wood Mackenzie. (2017). *U.S. energy storage monitor: 2016 year-in-review.* Retrieved from https://www.greentechmedia.com/research/report/us-energy-storage-monitor-q1-2017#gs.Q_4Eo0Y

33 Lazard's Levelized Cost of Storage (Version 11) [Computer software]. New York, NY: Lazard.

34 Nadel, S. (2017, February 9). Demand response programs can reduce utilities' peak demand an average of 10%, complementing savings from energy efficiency programs [Web lob post]. Retrieved from http://aceee.org/blog/2017/02/demand-response-programs-can-reduce

35 Woodward, M., & McNary, B. (2017, May 8). American households use a variety of lightbulbs as CFL and LED adoption increases. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=31112

36 Kooroshy, J., Ibbotson, A., Lee, B., Bingham, D. R., & Simons, W. (2015). *The low carbon economy: GS SUSTAIN equity investor's guide to a low carbon world, 2015-25.* Retrieved from http://www.goldmansachs.com/our-thinking/pages/new-energy-landscape-folder/report-the-low-carbon-economy/report.pdf

37 Feldman, B. (2016, October 13). With new control technology, demand response set to become operational tool for utilities. Retrieved from https://www.utilitydive.com/news/with-new-control-technology-demand-response-set-to-become-operational-tool/428247/

38 Parks Associates. (2017, May 3). *Parks Associates: More than 100 million U.S. households do not have a smart home device* [Press release]. Retrieved from https://www.prnewswire.com/news-releases/parks-associates-more-than-100-million-us-households-do-not-have-a-smart-home-device-300450441.html

39 Monthly plug-in sales scorecard. (n.d.). Retrieved from https://insideevs.com/monthly-plug-in-sales-scorecard/

40 *2018 Sustainable energy in America factbook.* (2018). Retrieved from http://www.bcse.org/sustainableenergyfactbook/#

41 Bloomberg New Energy Finance. (2017, July 6). *Electric vehicles to accelerate to 54% of new car sales by 2040* [Press release]. Retrieved from https://about.bnef.com/blog/electric-vehicles-accelerate-54-new-car-sales-2040/

42 U.S. Department of Energy. (2014). *Evaluating electric vehicle charging impacts and customer charging behaviors–experiences from six smart grid investment grant projects.* Retrieved from https://www.smartgrid.gov/files/B3_revised_master-12-17-2014_report.pdf

43 Monthly plug-in sales scorecard. (n.d.). Retrieved from https://insideevs.com/monthly-plug-in-sales-scorecard/

44 International Energy Agency. (2017). *Global EV outlook 2017: Two million and counting.* Retrieved from https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf

45 Memorandum of understanding between Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah and Wyoming regional electric vehicle plan for the west. (2017, October 12). Retrieved from https://www.colorado.gov/governor/sites/default/files/rev_west_plan_mou_10_12_17_all_states_final_1.pdf

46 National Association of City Transportation Officials. (2017). *Bike share in the U.S.: 2017.* Retrieved from https://nacto.org/wp-content/uploads/2018/05/NACTO-Bike-Share-2017.pdf

47 Elliott Bay Design Group. (2018). *Jumbo Mark II class hybrid system integration study* (Ref: 17102-070-0). Retrieved from http://www.wsdot.wa.gov/NR/rdonlyres/6C78A08B-19A1-4919-B6E6-E9EF83E6376D/123052/HybridSystemIntegrationStudy.pdf

48 U.S. Department of Energy. (n.d.). The role of microgrids in helping to advance the nation's energy system. Retrieved from https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid/role-microgrids-helping

49 Roberts, D., & Chang, A. (2017, December 29). Meet the microgrid, the technology poised to transform electricity. Retrieved from https://www.vox.com/energy-and-environment/2017/12/15/16714146/greener-more-reliable-more-resilient-grid-microgrids

50 Metelitsa, C. (2017, November). U.S. microgrids 2017: Market drivers, analysis and forecast. Retrieved from https://www.greentechmedia.com/research/report/us-microgrids-2017#gs.u=1bDl4

51 Gander, S., Lauf, D., & Kambour, A. (2017). *Grid smarts: State considerations for adopting grid modernization technology.* Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2017/Grid Tech_Paper_Final.pdf

52 How many smart meters are installed in the United States, and who has them? (2017, December 8). Retrieved from https://www.eia.gov/tools/faqs/faq.php?id=108&t=3

53 Cooper, A. (2107). Electric company smart meter deployments: Foundations for a smart grid. Retrieved from http://www.edisonfoundation.net/iei/publications/Documents/IEI_Smart%20Meter%20Report%202017_FINAL.pdf

54 U.S. Department of Energy. (2015). Quadrennial technology review 2015. *Chapter 3: Enabling modernization of the electric power system: Technology assessments. Measurements, communications, and controls.* Retrieved from https://energy.gov/sites/prod/files/2015/09/f26/QTR2015-3E-Measurements-Communications-and-Controls.pdf

55 U.S. Department of Energy. (n.d.). Synchrophasor applications in transmission systems. Retrieved from https://www.smartgrid.gov/recovery_act/program_impacts/applications_synchrophasor_technology.html; Southern California Edison. (n.d.). Remote fault indicators. Retrieved from https://www.edison.com/content/dam/eix/documents/innovation/RFIFactSheet-R2.pdf

56 Patel, P. (2017). Looking for methane leaks. *Chemical & Engineering News, 95*(35). Retrieved from https://cen.acs.org/articles/95/i35/Looking-methane-leaks.html

57 National Energy Technology Laboratory. (2018). *Crosscutting research program: Sensors and controls project portfolio.* Retrieved from https://www.netl.doe.gov/File%20Library/Research/Coal/cross-cutting%20research/2018-CCR-Sensors-and-Controls.pdf

58 Austin Energy's 500,000 smart meter program required 100 terabytes of data storage. Case study: Austin Energy smart meter program. Retrieved from http://www.c40.org/case_studies/austin-energy-smart-grid-program

59 How many smart meters are installed in the United States, and who has them? (2017, December 8). Retrieved from https://www.eia.gov/tools/faqs/faq.php?id=108&t=3

60 McKenna, B. (2013, March). What does a petabyte look like? *ComputerWeekly.* Retrieved from https://www.computerweekly.com/feature/What-does-a-petabyte-look-like

61 *Utility analytics. Use cases, platforms, and services: Global market analysis and forecasts.* (2016). Retrieved from Navigant Research website: https://www.navigantresearch.com/research/utility-analytics

62 For further discussion of this topic, see Gander, S., Lauf, D., & Kambour, A. (2017). *Grid smarts: State considerations for adopting grid modernization technology.* Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2017/Grid Tech_Paper_Final.pdf

63 Communications Act of 1934, 41 U.S.C. § 57 (1934). Retrieved from https://transition.fcc.gov/Reports/1934new.pdf

64 Federal Communications Commission. (2018, February 2). *2018 Broadband deployment report* (GN Docket No. 17-199). Retrieved from https://apps.fcc.gov/edocs_public/attachmatch/FCC-18-10A1.pdf

65 HIS Markit. (2017, June). *The urban unconnected.* Retrieved from http://worldwifiday.com/wp-content/uploads/2017/06/The-Urban-Unconnected_White-Paper_FINAL-1.pdf

66 Deloitte. (2017). *Wireless connectivity fuels industry growth and innovation in energy, health, public safety, and transportation.* Retrieved from https://api.ctia.org/docs/default-source/default-document-library/deloitte_2017011987f8479664c467a6bc70ff0000ed09a9.pdf

67 Fixed broadband deployment data from FCC Form 477. (2016, December). Retrieved from Federal Communications Commission website: https://www.fcc.gov/general/broadband-deployment-data-fcc-form-477

68 Federal Communications Commission. (2018, January 2). *Ex parte comments of the National Telecommunications and Information Administration* (WC Docket No. 11–10). Retrieved from https://www.ntia.doc.gov/files/ntia/publications/ntia_comments_on_modernizing_the_fcc_form_477_data_program.pdf

69 Valkenberg, P. (2017, April 25). So what is "blockchain" Anyway? Retrieved from https://coincenter.org/entry/what-is-blockchain-anyway

70 Morgan Stanley. (2018 January 27). Power play: What impact will cryptocurrencies have on global utilities? Retrieved from https://www.morganstanley.com/ideas/cryptocurrencies-global-utilities

71 Applications for blockchain grow in energy, transport. (2017, December 11). Retrieved from https://about.bnef.com/blog/applications-blockchain-grow-energy-transport/

72 For further discussion of this topic, see Gander, S., Lauf, D., & Kambour, A. (2017). *Grid smarts: State considerations for adopting grid modernization technology.* Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2017/Grid Tech_Paper_Final.pdf

73 Energy Futures Initiative & National Association of State Energy Officials. (2018). *U.S. energy and employment report.* Retrieved from https://www.usenergyjobs.org/

74 NOAA National Centers for Environmental Information (NCEI) Retrieved from U.S. Billion-Dollar Weather and Climate Disasters (2018). https://www.ncdc.noaa.gov/billions/

75 NOAA National Centers for Environmental Information (NCEI) Retrieved from U.S. Billion-Dollar Weather and Climate Disasters (2018). https://www.ncdc.noaa.gov/billions/

76 Traffic-related air pollution: A critical review of the literature on emissions, exposure, and health effects. (2010, January 17). Retrieved from https://www.healtheffects.org/publication/traffic-related-air-pollution-critical-review-literature-emissions-exposure-and-health

77 Khan, S., & Vaidyanathan, S. (2018, February 13). *Strategies for integrating electric vehicles into the grid.* Retrieved from http://aceee.org/research-report/t1801

78 Dennis, K., Colburn, K., & Lazar, J. (2016). Environmentally beneficial electrification: The dawn of "emissions efficiency." *The Electricity Journal, 29*(6), 52–58. doi:10.1016/j.tej.2016.07.007

79 Norsworthy, M., Craft, E., & Wolfe, C. (2015). *Clean air guide for ports & terminals.* Retrieved from https://www.edf.org/sites/default/files/content/edf_clean_air_guide_for_ports_terminals_0.pdf?_ga=2.256209807.503400405.1520977198-164943172.1520977198

80 Witte, D. (2017, September 27). The enduring effects of shale on petrochemical manufacturing. Retrieved from https://ihsmarkit.com/research-analysis/the-enduring-effects-of-shale-on-petrochemical-manufacturing.html

81 American Chemistry Council. (2018, April). New manufacturing projects are growing our economy & creating jobs. Retrieved from https://www.americanchemistry.com/Policy/Energy/Shale-Gas/Infographic-Shale-Gas-and-New-US-Chemical-Industry-Investment.pdf

82 Witte, D. (2017). The enduring effects of shale on petrochemical manufacturing. Retrieved from https://ihsmarkit.com/research-analysis/the-enduring-effects-of-shale-on-petrochemical-manufacturing.html

83 National Renewable Energy Laboratory. (2017). *Voices of experience: Integrating intermittent resources. What utilities are learning.* Retrieved from https://www.smartgrid.gov/files/VOE_FINAL_revised_8.9.2017.pdf; Phares, R. (2015, March 11).

84 Renewable energy intermittency explained: Challenges, solutions, and opportunities [Web log post]. Retrieved from https://blogs.scientificamerican.com/plugged-in/renewable-energy-intermittency-explained-challenges-solutions-and-opportunities/

85 California Independent System Operator. (2016). What the duck curve tells us about managing a green grid. Retrieved from https://www.caiso.com/documents/flexibleresourceshelprenewables_fastfacts.pdf

86 California Independent System Operator. (2016). What the duck curve tells us about managing a green grid. Retrieved from https://www.caiso.com/documents/flexibleresourceshelprenewables_fastfacts.pdf

87 Denholm, P., O'Connell, M., Brinkman, G., & Jorgenson, J. (2015). *Overgeneration from solar energy in California: A field guide to the duck chart* (Technical Report No. NREL/TP-6A20-65023). Retrieved from https://www.nrel.gov/docs/fy16osti/65023.pdf

88 Berdner, J. (n.d.). The impact of smart inverters: How rule and regulation will transform DG into smart systems. Retrieved from https://www.nrel.gov/pv/assets/pdfs/2015_pvmrw_130_berdner.pdf

89 Lee, R. M., Assante, M. J., & Conway, T. (2016). *Analysis of the cyber attack on the Ukrainian power grid: Defense use case.* Retrieved from https://www.nerc.com/pa/CI/ESISAC/Documents/E-ISAC_SANS_Ukraine_DUC_18Mar2016.pdf

90 Siciliano, J. (2017, August 22). Nation's largest grid operator suffers 4,000 attempted cyberattacks per month, former chief says. *Washington Examiner.* Retrieved from http://www.washingtonexaminer.com/nations-largest-grid-operator-suffers-4000-attempted-cyberattacks-per-month-former-chief-says/article/2632256

91 Lang, M. (2016, October 23). How smart home devices are being hijacked to attack internet. *San Francisco Chronicle.* Retrieved from https://www.sfchronicle.com/business/article/How-your-baby-monitors-are-being-used-to-attack-10152723.php

92 Douris, C. (2018). *Balancing smart grid data and consumer privacy.* Retrieved from http://www.lexingtoninstitute.org/wp-content/uploads/2017/07/Lexington_Smart_Grid_Data_Privacy-2017.pdf

93 DataGuard energy data privacy program. (n.d.). Retrieved from SmartGrid.gov website: https://www.smartgrid.gov/data_guard.html

94 Responsible conduct in data management. (n.d.). Retrieved from https://ori.hhs.gov/education/products/n_illinois_u/datamanagement/dotopic.html

95 U.S. Department of Energy. (2017). *U.S. energy and employment report.* Retrieved from https://www.energy.gov/downloads/2017-us-energy-and-employment-report

96 Popovich, N. (2017, April 25). Today's energy jobs are in solar, not coal. *The New York Times.* Retrieved from https://www.nytimes.com/interactive/2017/04/25/climate/todays-energy-jobs-are-in-solar-not-coal.html

97 Barbose, G., & Darghouth, N. (2017). Tracking the sun 10: *The installed price of residential and non-residential photovoltaic systems in the United States.* Retrieved from http://eta-publications.lbl.gov/sites/default/files/tracking_the_sun_10_report.pdf

98 Gloria, G. G. (2017, September). *Household income: 2016* (American Community Survey Briefs). Retrieved from https://www.census.gov/content/dam/Census/library/publications/2017/acs/acsbr16-02.pdf

99 Barbose, G., Darghouth, N., Hoen, B., & Wiser, R. (2018). *Income trends of residential PV adopters: An analysis of household-level income estimates.* Retrieved from http://eta-publications.lbl.gov/sites/default/files/income_trends_of_residential_pv_adopters_final_0.pdf

100 Wood, L. V. (2016, June 13). Why net energy metering results in a subsidy: The elephant in the room. Retrieved from https://www.brookings.edu/opinions/why-net-energy-metering-results-in-a-subsidy-the-elephant-in-the-room/

101 Knupfer, S. M., Hensley, R., Hertzke, P., Schaufuss, P., Laverty, N., & Kramer, N. (2017). *Electrifying insights: How automakers can drive electrified vehicle sales and profitability.* Retrieved from https://www.mckinsey.com/~/media/mckinsey/industries/automotive and assembly/our insights/electrifying insights how automakers can drive electrified vehicle sales and profitability/how automakers can drive electrified vehicle sales and profitabilitymck.ashx

102 Community and shared solar. (n.d.). Retrieved from https://www.energy.gov/eere/solar/community-and-shared-solar

103 U.S. economy and electricity demand growth are linked, but relationship is changing. (2013, March 22). Retrieved from https://www.eia.gov/todayinenergy/detail.cfm?id=10491

104 Wasserman, A., & Cramer, S. (2016). *Opportunities for governors to align electricity markets with state energy goals.* Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2016/1611GovernorsElectricityMarkets.pdf

105 *State of the electric utility.* (2016). Retrieved from http://app.assetdl.com/landingpage/state-of-the-utility-survey-2016

106 Larsen, J., & Herndon, W. (2017). What is it worth: The state of the art in valuing distributed energy resources. Retrieved from https://energy.gov/sites/prod/files/2017/01/f34/What Is It Worth--The State of the Art in Valuing Distributed Energy Resources.pdf

107 U.S. Department of Energy. (2017). *Quadrennial energy review. Transforming the nation's electricity system: The second installment of the QER.* Retrieved from https://www.energy.gov/sites/prod/files/2017/02/f34/Quadrennial Energy Review--Second Installment (Full Report).pdf

108 Wood, E., Rames, C., Muratori, M., Raghavan, S., & Melaina, M. (2017). *National plug-in electric vehicle infrastructure analysis.* Retrieved from https://www.nrel.gov/docs/fy17osti/69031.pdf

109 Khan, S., & Vaidyanathan, S. (2018). *Strategies for integrating electric vehicles into the grid, American Council for an Energy-Efficient Economy.* Retrieved from http://aceee.org/research-report/t1801

110 Ibid.

111 Widergren, S. E., Knight, M. R., Melton, R. B., & Narang, D. (2017). *Interoperability strategic vision: Enabling an interactive grid.* Retrieved from https://gridmod.labworks.org/sites/default/files/resources/InteropStrategicVision2017-04-11.pdf

112 *2018 Broadband deployment report.* (2018). Retrieved from https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2018-broadband-deployment-report

113 Stenner, K., Frederiks, E. R., Hobman, E. V., & Cook, S. (2017). Willingness to participate in direct load control: The role of consumer distrust. *Applied Energy, 189,* 76–88. doi:10.1016/j.apenergy.2016.10.099; Recommendations on consumer acceptance of smart grid (Memorandum to the Honorable Patricia Hoffman, Assistant Secretary for Electricity Delivery and Energy Reliability, U.S. Department of Energy). (2013, June 6). Retrieved from https://www.energy.gov/sites/prod/files/2013/06/f1/EAC_SGConsumerRecs.pdf

114 U.S. Department of Energy. (2017). *U.S. energy and employment report.* Retrieved from https://energy.gov/sites/prod/files/2017/01/f34/2017 US Energy and Jobs Report_0.pdf

115 Desjardins, J. (2018, February 16). A brief history of technology. Retrieved from https://www.weforum.org/agenda/2018/02/the-rising-speed-of-technological-adoption

116 Desjardins, J. (2018, February 16). A brief history of technology. Retrieved from https://www.weforum.org/agenda/2018/02/the-rising-speed-of-technological-adoption

117 Broekaert, K., & Espinel, V. A. (2018, February 13). How can policy keep pace with the fourth industrial revolution? Retrieved from https://www.weforum.org/agenda/2018/02/can-policy-keep-pace-with-fourth-industrial-revolution

118 Desjardins, J. (2018). A brief history of technology. Retrieved from https://www.weforum.org/agenda/2018/02/the-rising-speed-of-technological-adoption

119 Vermont Department of Public Service. (2017). *Act 53 report: A report to the Vermont General Assembly on the issue of deploying storage on the Vermont electric transmission and distribution system.* Retrieved from http://publicservice.vermont.gov/sites/dps/files/documents/Pubs_Plans_Reports/Energy_Storage_Report/Storage_Report_Final.pdf

120 State of Colorado, Office of the Governor. (2017, July 11). Executive Order D 2017-015, Supporting Colorado's clean energy transition. Retrieved from https://www.colorado.gov/governor/sites/default/files/executive_orders/climate_eo.pdf

121 *Colorado electric vehicle plan in support of the executive order, "supporting Colorado's clean energy transition."* (2018). Retrieved from https://www.colorado.gov/governor/sites/default/files/colorado_electric_vehicle_plan_-_january_2018.pdf

122 *Energy snapshot: Commonwealth of the Northern Mariana Islands.* (2015, June). Retrieved from National Renewable Energy Laboratory website: https://www.nrel.gov/docs/fy15osti/64293.pdf

123 *Report of the Market Design and Platform Technology Working Group.* (2015). Retrieved from http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/5e74ed080a95647085257e7000425e60/$FILE/MDPT-Report_150817_Final.pdf

124 Rocky Mountain Institute. (2016). *Minnesota's 2025 energy action plan: Stakeholder-driven strategies for success.* Retrieved from https://www.lec.leg.mn/projects/2025/MN_E2025_final.pdf

125 State of Nevada, Executive Department. (2016, February 23). Executive Order 2016-04, Order directing the governor's office of energy to reconvene the new energy industry task force. Retrieved from http://energy.nv.gov/uploadedFiles/energynvgov/content/Programs/New Energy Industry Task Force 2016 Reconvene Order.pdf

126 Nevada Department of Energy, New Energy Industry Task Force. (2016). *Final recommendations.* Retrieved from http://energy.nv.gov/uploadedFiles/energynvgov/content/Programs/NEITF Final Recommendations(1).pdf

127 South Carolina Office of Regulatory Staff: Energy Office. (2016). *South Carolina state energy plan.* Retrieved from http://www.energy.sc.gov/files/view/SC%20Energy%20Plan__20160729.pdf

128 Maryland Electric Vehicle Infrastructure Council. (n.d.). Retrieved from http://msa.maryland.gov/msa/mdmanual/26excom/html/13electricv.html

129 Maryland hosts workplace charging workshops. (2018). Retrieved from Maryland Electric Vehicle Infrastructure Council website: http://www.mdot.maryland.gov/newMDOT/Planning/Electric_Vehicle/About_the_Council.html

130 S.B. 176, Maryland Legis. (2011). Retrieved from http://mgaleg.maryland.gov/2011rs/chapters_noln/ch_400_sb0176e.pdf

131 S.B. 714, Maryland Legis. (2015). Retrieved from http://mgaleg.maryland.gov/2015RS/chapters_noln/Ch_378_sb0714T.pdf

132 State of Washington, Office of the Governor. (2014, April 29). Executive Order 14-04, Washington carbon pollution reduction and clean energy action. Retrieved from https://www.governor.wa.gov/sites/default/files/exe_order/eo_14-04.pdf

133 Washington State Utilities and Transportation Commission. (2017, October 11). *Report and policy statement on treatment of energy storage technologies in integrated resource planning and resource acquisition* (Dockets UE151069 and U161024). Retrieved from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwiSn5PWiL3ZAhWEnFkKHTRfC6QQFggsMAE&url=https%3A%2F%2Fwww.utc.wa.gov%2F_layouts%2F15%2FCasesPublicWebsite%2FGetDocument.ashx%3FdocID%3D237%26year%3D2016%26docketNumber%3D161024&usg=AOvVaw2vTR7IO1gYVP8jJsNAy8Iw

134 New Mexico Public Regulation Commission. (2017, August 2). Final order amending integrated resource planning rules 17.7.3 NMAC to include energy storage resources (Case No. 17-00022UT). Retrieved from http://www.nmprc.state.nm.us/general-counsel/docs/17-00022-UT%20Final%20Order%20Amending%20Intergrated%20Resource%20Planning%20Rule17%207%203%20NMAC%20to%20Include%20Energy%20Storage%20Resources.pdf

135 Minnesota Public Utilities Commission. (2018, May 24). Docket E999/CI-16-521.

136 Office of the Governor, State of Colorado. (2005, July 15). Executive Order D 005 05, Greening state government. Retrieved from https://www.colorado.gov/pacific/sites/default/files/d00505.pdf

137 Office of the Governor, State of Colorado. (2015, October 28). Executive Order D 2015-013, Greening of state government. Retrieved from https://www.colorado.gov/pacific/sites/default/files/Greening%20Govt.%20E.O.%20-%20signed_1.pdf

138 Commonwealth of Pennsylvania Governor's Office. (2004, December 15). Executive Order 2004-12, Energy management and conservation in commonwealth facilities. Retrieved from http://www.oa.pa.gov/Policies/eo/Documents/2004_12.pdf

139 Losinio, L. (2017, August 13). GPA to phase out fuel-powered vehicles. *The Guam Daily Post.* Retrieved from https://www.postguam.com/news/local/gpa-to-phase-out-fuel-powered-vehicles/article_7838e2b8-7be5-11e7-93c9-4709b00d5e30.html

140 Energy efficient state vehicles, Tenn. Code Ann. § 4-3-1109 (2011). Retrieved from http://www.ngvpolicy.com/TN_4-3-1109_Text.pdf

141 Spector, J. (2017, December 1). New York governor approves energy storage target, months after the bill passed. Retrieved from Greentech Media website: https://www.greentechmedia.com/articles/read/new-york-approves-energy-storage-target#gs.rqKeVag

142 California Public Utilities Commission. (2013, October 17). *CPUC sets energy storage goals for utilities* [Press release]. Retrieved from http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M079/K171/79171502.PDF

143 H.B. 2193, 78th Oregon Legis. Ass. (2015) (enacted). Retrieved from https://olis.leg.state.or.us/liz/2015R1/Downloads/MeasureDocument/HB2193

144 S.B. 204, 79th Nevada Ass. (2017) (enacted). Retrieved from https://www.leg.state.nv.us/Session/79th2017/Bills/SB/SB204.pdf

145 Barbose, G. (2017). *U.S. renewables portfolio standards: 2017 annual status report.* Retrieved from http://eta-publications.lbl.gov/sites/default/files/2017-annual-rps-summary-report.pdf

146 Act 097 (15), 28th Hawaii Legis. (2015) (enacted). Retrieved from https://www.capitol.hawaii.gov/session2015/bills/GM1197_.pdf

147 2016 American Samoa energy action plan. (2016, September 22). Retrieved from http://www.asrec.net/2016/09/22/2016-american-samoa-energy-action-plan/

148 Inova Energy Group. (2016). *Iowa energy plan.* Retrieved from http://www.iowaenergyplan.org/docs/IowaEnergyPlan.pdf

149 Michigan Public Service Commission. (2018, February 5). *MPSC announces agenda for Feb. 20 EV pilot program discussion* [Press release]. Retrieved from http://www.michigan.gov/mpsc/0,4639,7-159-16400_17280-459619--,00.html

150 New York State Energy Research and Development Authority (NYSERDA). (2017, April 19). *NYSERDA announces $15.5 million available for energy storage projects to support the electric grid* [Press release]. Retrieved from https://www.nyserda.ny.gov/About/Newsroom/2017-Announcements/2017-04-19-NYSERDA-Announces-Millions-Available-for-Energy-Storage-Projects; NYSERDA. (2017, June 21). *NYSERDA announces $6.3 million available for emerging energy storage products and technology to support the electric grid* [Press release]. Retrieved from https://www.nyserda.ny.gov/About/Newsroom/2017-Announcements/2017-06-21-NYSERDA-Announces-Millions-Available-for-Emerging-Energy-Storage; New York battery and Energy Storage Technology (NY-BEST) Consortium. (n.d.). Retrieved from NYSERDA website: https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Storage/NY-BEST

151 Clean energy fund–Washington Department of Commerce. (n.d.). Retrieved from http://www.commerce.wa.gov/growing-the-economy/energy/clean-energy-fund/

152 West Virginia Strategic Research and Development Tax Credit Act, Ch. 11, Art. 13R, 83d Legis. (2017). Retrieved from http://www.wvlegislature.gov/wvcode/Code.cfm?chap=11&art=13R

153 State of Oregon, Office of the Governor. (2017, November 6). Executive Order 17-20, Accelerating efficiency in Oregon's built environment to reduce greenhouse gas emissions and address climate change. Retrieved from http://www.oregon.gov/gov/Documents/executive_orders/eo_17-20.pdf

154 California Energy Commission. (2018). *Initial study and proposed negative declaration for the 2019 energy code* (Docket No. 18-BSTD-01). Retrieved from http://docketpublic.energy.ca.gov/PublicDocuments/18-BSTD-01/TN222679_20180222T142828_Initial_Study_and_Proposed_Negative_Declaration_for_the_2019_En.pdf

155 P.L., Ch. 518, Maine Legis. (2010). Retrieved from http://www.mainelegislature.org/legis/bills/bills_124th/chapters/PUBLIC518.asp

156 Frequently asked questions. (2018). Retrieved from https://www.naruc.org/servingthepublicinterest/how-commissions-work/faqs/

157 Standard interconnection agreements & procedures for small generators (2017, February 13). Retrieved from https://www.ferc.gov/industries/electric/indus-act/gi/small-gen.asp

158 Rhode Island Division of Public Utilities & Carriers, Office of Energy Resources, and Public Utilities Commission. (2017). *Rhode Island power sector transformation: Phase one report to Governor Gina M. Raimondo.* Retrieved from http://www.ripuc.org/utilityinfo/electric/PST Report_Nov_8.pdf

159 Transforming Maryland's electric grid (PC44). (n.d.). Retrieved from http://www.psc.state.md.us/transforming-marylands-electric-grid-pc44/

160 Puerto Rico Energy Resiliency Working Group. (2017). *Build back better: Reimagining and strengthening the power grid of Puerto Rico.* Retrieved from https://www.governor.ny.gov/sites/governor.ny.gov/files/atoms/files/PRERWG_Report_PR_Grid_Resiliency_Report.pdf

161 Ibid.

162 CEPR-MI-2018-0001 in Re: Reglamento sobre el desarrollo de microredes [partially Spanish]. (2018). Retrieved from Comisión de Energía de Puerto Rico website: http://energia.pr.gov/numero_orden/cepr-mi-2018-0001/

163 Wasserman, A., & Cramer, S. (2016). *Opportunities for governors to align electricity markets with state energy goals.* Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2016/1611GovernorsElectricityMarkets.pdf

164 Hawaii Public Utilities Commission, Establishing a performance incentive mechanism for procurement in phase 1 of the Hawaiian Electric Companies' final variable requests for proposals (Docket No. 2017-0352, Order No. 35405).

165 Hawaii Public Utilities Commission. (2018, April 18). *PUC opens proceeding to investigate performance-based regulation for the Hawaiian Electric Companies* [Press release]. Retrieved from http://puc.hawaii.gov/main/puc-opens-pbr-investigation/

166 E21 Initiative. (n.d.). Retrieved from http://www.betterenergy.org/projects/e21-initiative

167 Recovery of Actual Cost of Certified Demand-Side Capacity Option, 2010 Georgia Code, § 46-3A-9 (2010). Retrieved from https://law.justia.com/codes/georgia/2010/title-46/chapter-3a/46-3a-9/

168 Wasserman, A., & Cramer, S. (2016). *Opportunities for governors to align electricity markets with state energy goals.* Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2016/1611GovernorsElectricityMarkets.pdf

169 National Association of Regulated Utility Commissioners Staff Subcommittee on Rate Design. (2016). *NARUC manual on distributed energy resources rate design and compensation.* Retrieved from http://pubs.naruc.org/pub/19FDF48B-AA57-5160-DBA1-BE2E9C2F7EA0

170 An Act Relating to Renewable Energy, Ass. Bill 405, 79th Nevada Legis. (2017) (enacted). Retrieved from https://www.leg.state.nv.us/App/NELIS/REL/79th2017/Bill/5487/Overview

171 Electric vehicle price plan. (n.d.). Retrieved from http://www.srpnet.com/prices/home/electricvehicle.aspx

172 Kwoka, J. E., Jr.. (2002). Twenty-five years of deregulation: Lessons for electric power. *Loyola University of Chicago Law Journal, 33,* 885. Retrieved from http://lawecommons.luc.edu/luclj/vol33/iss4/11

173 Commonwealth Edison. (2017, February 13). *ComEd launches new, industry-leading energy data product* [Press release]. Retrieved from https://www.comed.com/News/Pages/NewsReleases/2017_02_13.aspx

174 Environmental Defense Fund and Illinois Citizens Utility Board. (2014, August 14). Open data access framework [Web log post]. Retrieved from http://blogs.edf.org/energyexchange/files/2014/08/14-_____-CUB-EDF-Exhibit-1-1-Open-Data-Access-Framework-FINAL.pdf

175 Pennsylvania Public Utilities Commission. (2016, June 30). *PUC approves standards for secure access to smart meter data; safeguarding privacy while facilitating beneficial information flow* [Press release]. Retrieved from http://www.puc.state.pa.us/about_puc/press_releases.aspx?ShowPR=3720

176 Renewable Energy and Energy Efficiency Portfolio Standard (REPS), North Carolina Gen. Statutes, § 62-133.8 (n.d.). Retrieved from https://www.ncga.state.nc.us/EnactedLegislation/Statutes/HTML/BySection/Chapter_62/GS_62-133.8.html

177 Allen, P, Van Horn, G., Goetz, M., Bradbury, J., & Zyla, K. (2017). *Utility investment in electric vehicle charging infrastructure: Key regulatory considerations.* Retrieved from http://www.georgetownclimate.org/files/report/GCC-MJBA_Utility-Investment-in-EV-Charging-Infrastructure.pdf

178 Dennis, J. S., Kelly, S. G., Nordhaus, R. R. & Smith, D, W. (2016). *Federal/state jurisdictional split: Implications for emerging electricity technologies.* Retrieved from http://eta-publications.lbl.gov/sites/default/files/lbnl-1006675.pdf

179 FERC v. Electric Power Supply Association, 136 S. Ct. 760 (2016). Retrieved from https://www.courtlistener.com/opinion/3177219/ferc-v-electric-power-supply-assn/; Hughes v. Talen Energy Marketing, 136 S. Ct. 1288 (2016). Retrieved from https://www.supremecourt.gov/opinions/15pdf/14-614_k5fm.pdf.

180 S.B. 1731, 85th Texas Legis. (2017) (enacted). Retrieved from https://legiscan.com/TX/text/SB1731/id/1625480

181 S.B. 758, Maryland Legis. (2017). Retrieved from http://mgaleg.maryland.gov/2017RS/bills/sb/sb0758E.pdf

182 About us. (n.d.). Retrieved from Connecticut Green Bank website: https://www.ctgreenbank.com/about-us-2017/

183 Product offerings. Retrieved from NY Green Bank website: https://greenbank.ny.gov/Investments/Product-Offerings; NY Green Bank. (2017, February 27). *Quarterly metrics report No. 14 (December 31, 2017)* [Webinar]. Retrieved from https://greenbank.ny.gov/-/media/greenbanknew/files/2017-Q4-Metrics-Webinar.pdf

184 Energy-efficiency lease program. (n.d.). Retrieved from https://www.energy.gov/savings/energy-efficiency-lease-program

185 S.B. 407, 79th Nevada Legis. (2017). Retrieved from http://energy.nv.gov/uploadedFiles/energynvgov/content/Pages/SB407_EN.pdf

186 Property Assessed Clean Energy (PACE). (n.d.). Retrieved from https://energy.mo.gov/assistance-programs/pace

187 PACE programs near you. (n.d.). Retrieved from http://pacenation.us/pace-programs/

188 H.B. 589, Session L. 2017-192, 2017 North Carolina Gen. Ass. (2017). Retrieved from https://www.ncleg.net/Sessions/2017/Bills/House/PDF/H589v6.pdf

189 3rd party solar PV power purchase agreement (PPA). (2015, March). Retrieved from NC Clean Energy Technology Center website: http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2015/01/3rd-Party-PPA_0302015.pdf

190 Kentucky Public Service Commission, Order in Case No. 2010-00089. (2010, December 16). Retrieved from http://energy.ky.gov/Programs/SEE KY/March 2012 Meeting/Residential/PSC Order Approving HowSmart Pilot_Dec 2010.pdf

191 Kentucky Public Service Commission. Order in Case No. 2012-00484, How$martKY.

192 On-bill financing: Cost-free energy efficiency improvements. (2015, April 7). Retrieved from http://www.ncsl.org/research/energy/on-bill-financing-cost-free-energy-efficiency-improvements.aspx

193 Public energy performance contracting. (n.d.). Retrieved from https://www.colorado.gov/pacific/energyoffice/public-energy-performance-contracting

194 State energy savings performance contracting. (2013, November 15). Retrieved from National Conference of State Legislatures website: http://www.ncsl.org/research/energy/state-energy-savings-performance-contracting.aspx

195 Shama, B. (2016). *State of Utah: State building energy efficiency program annual report to the governor and the legislature, FY2016.* Retrieved from https://dfcm.utah.gov/wp-content/uploads/2016_SBEEP_Annual_Report.pdf

196 Revolving loan funds. (n.d.). Retrieved from U.S. Department of Energy website: https://www.energy.gov/eere/slsc/revolving-loan-funds

197 Public facility loan. (n.d.). Retrieved from https://www.ahfc.us/efficiency/non-residential-buildings/energy-efficiency-revolving-loan-fund-aeerlp/

198 Approval of proposed rate rider PEV (plug-in electric vehicle) for Alabama Power Company. (2012, February 21). Retrieved from https://www.pscpublicaccess.alabama.gov/pscpublicaccess/PSC/PSCDocumentDetailsPage.aspx?DocumentId=afc26ceb-7d06-4e3e-a909-c63c19ab5d49&Class=Filing

199 A.B. 5, 79th Nevada Legis. (2017). Retrieved from https://www.leg.state.nv.us/Session/79th2017/Bills/AB/AB5_EN.pdf

200 Volkswagen Clean Air Act civil settlement. (n.d.). Retrieved from https://www.epa.gov/enforcement/volkswagen-clean-air-act-civil-settlement

201 Ibid.

202 Workforce Development Council. Retrieved from http://www.jobsnd.com/workforce-councils/workforce-development-council

203 Washington Department of Commerce, Office of Economic Development & Competitiveness. (2017). *Proposed strategic plan for Washington state clean energy technology sector 2017–2019.* Retrieved from http://www.commerce.wa.gov/wp-content/uploads/2017/01/Sector-Leads-Clean-Tech-Strategy-2016.pdf

204 Alternative energy. (n.d.). Retrieved from http://www.kansascommerce.com/468/Alternative-Energy

205 State of Nevada, Office of the Governor. (2016, March 16). Executive Order 2016-08, Order Regarding Workforce Development. Retrieved from http://gov.nv.gov/News-and-Media/Executive-Orders/2016ADA/2016-08-Order-Regarding-Workforce-Development/

206 Natural Resources Sector Council. Retrieved from http://gov.nv.gov/OWINN/SectorCouncil/Natural-Resources-Sector-Council/

207 What does "Career Pathway" mean in Nevada, and how are pathways part of the Governor's vision for the state? Retrieved from http://gov.nv.gov/OWINN/Career-Pathways/

208 Cook, J. J. (2017). *Clean energy-related economic development policy across the states: Establishing a 2016 baseline* (Technical Report NREL/TP-6A20-67656). Retrieved from https://www.nrel.gov/docs/fy17osti/67656.pdf

209 Ibid.

210 Ibid.

211 Ibid.

212 New York State Governor's Office. (2018, January 2). *Governor Cuomo unveils 20th proposal of 2018 state of the state: New York clean energy jobs and climate agenda* [Press release]. Retrieved from https://www.governor.ny.gov/news/governor-cuomo-unveils-20th-proposal-2018-state-state-new-yorks-clean-energy-jobs-and-climate

213 New York State Energy Research and Development Authority. (2018). *Offshore wind is ready to power New York* [Fact sheet]. Retrieved from https://www.nyserda.ny.gov/-/media/Files/Programs/offshore-wind/OSW-FactSheet.pdf

214 Hardcastle, A., Waterman-Hoey, S., & Kunkle, R. (2009). *Renewable energy industry trends and workforce development in Washington state.* Retrieved from http://cru.cahe.wsu.edu/CEPublications/wsueep09-018/wsueep09-018.pdf

215 Goldman, C. A., Peters, J. S., Albers, N., Stuart, E., & Fuller, M. C. (2010). *Energy efficiency services sector: Workforce education and training needs.* Retrieved from https://emp.lbl.gov/sites/all/files/report-lbnl-3163e.pdf

216 Redman, E. (2010). *2010 Efficiency first workforce survey.* Washington, DC: Home Performance Resource Center.

217 Cook, J. J. (2017). *Clean energy-related economic development policy across the states: Establishing a 2016 baseline* (Technical Report NREL/TP-6A20-67656). Retrieved from https://www.nrel.gov/docs/fy17osti/67656.pdf

218 Energyfutureconf.com. (n.d.). Retrieved from http://www.energyfutureconf.com/wa17/images/Presentations/2017/1D_Young.pdf

219 Colorado Center for Renewable Energy Economic Development. (2018). Retrieved from Colorado School of Mines website: http://inside.mines.edu/RES-Colorado-Center-for-Renewable-Energy-Economic-Development

220 Offshore wind workforce development grant program. (2018). Retrieved from http://energy.maryland.gov/Pages/Info/renewable/offshorewindworkforce.aspx

221 Business recruitment plan. (n.d.). Retrieved from http://www.diversifynevada.com/programs-resources/leap/p3

222 State of Colorado, Office of the Governor. (2017, July 11). Executive Order D 2017-015, Supporting Colorado's clean energy transition. Retrieved from https://www.colorado.gov/governor/sites/default/files/executive_orders/climate_eo.pdf

223 Kentucky's statewide broadband network moves forward with build-out. (2016, September 20). *Government Technology.* Retrieved from http://www.govtech.com/network/Kentucky-Statewide-Broadband-Network-Moves-Forward-Buildout.html

224 Mid-Atlantic broadband communities and Microsoft launch new homework network to bring thousands of students online in rural Virginia. (2017, May 23). Retrieved from https://news.microsoft.com/2017/05/23/mid-atlantic-broadband-communities-and-microsoft-launch-new-homework-network-to-bring-thousands-of-students-online-in-rural-virginia/

225 Trostle, H., & Mitchell, C. (2017). *Cooperatives fiberize rural America: A trusted model for the internet era* (Policy Brief). Retrieved from https://muninetworks.org/sites/www.muninetworks.org/files/Cooperatives-Fiberize-Rural-America.pdf

226 Montana Telecommunications Association. (2016). *Conquering Montana's divide: A report on the state of rural broadband.* Retrieved from http://www.broadbandmt.com/wp-content/uploads/2016/10/MTA_Broadband_Report_2016.pdf

227 Ibid.

228 Lutey, T. (2015, July 20). USDA commits $30 million to rural Montana internet service. *Billings Gazette.* Retrieved from http://billingsgazette.com/news/government-and-politics/usda-commits-million-to-rural-montana-internet-service/article_df16e9a1-d8fa-5455-bb5f-1fe426c79553.html

229 Powering sustainable rural communities. (n.d.). Retrieved from U.S. Department of Agriculture Rural Development website: https://www.rd.usda.gov/programs-services/all-programs/electric-programs

230 L.B. 994, 105th Nebraska Legis. (2018). Retrieved from https://nebraskalegislature.gov/FloorDocs/105/PDF/Intro/LB994.pdf. See also LB 994. (2018, February 5). Retrieved from Nebraska Rural Electric Association website: https://www.nrea.org/sites/default/files/grassroots_storage/tplb_994_2018_broadbandtaskpdf.pdf

231 Clancy, H. (2017, March 13). The first smart state? The quest to link up the land of Lincoln. *GreenBiz.* Retrieved from https://www.greenbiz.com/article/first-smart-state-quest-link-land-lincoln; IBOP–project partners. (n.d.). Retrieved from Illinois Department of Innovation & Technology website: https://www.illinois.gov/icn/projects/ibop-ec/Pages/ibop_partners.aspx

232 California Public Utilities Commission. (2016, June 9). *CPUC approves water energy nexus pilot programs designed to help save water and energy* [Press release]. Retrieved from http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M163/K153/163153993.PDF

233 For further discussion and recommendations on this topic, see Kambour, A. (2014, August). *State roles in enhancing the cybersecurity of energy systems and infrastructure* (Issue Brief). Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2014/1408EnhancingCybersecurityEnergySystems.pdf

234 Bipartisan Policy Center. (2014). *Cybersecurity and the North American electric grid: New policy approaches to address an evolving threat.* Retrieved from http://bipartisanpolicy.org/sites/default/files/Cybersecurity%20Electric%20Grid%20BPC.pdf; ABI Research. (2013). Cyber-attacks against oil & gas infrastructure to drive $1.87 billion in cybersecurity spending by 2018. Retrieved from https://www.abiresearch.com/press/cyber-attacks-against-oil-gas-infrastructure-to-dr/.

235 State of Vermont, Executive Department. (2017, October 10). Governor's Cybersecurity Advisory Team, State of Vermont Executive Order No. 18-17 (October 10, 2017),. Retrieved from http://governor.vermont.gov/sites/scott/files/documents/EO%2018-17%20-%20Governor%27s%20Cybersecurity%20Advisory%20Team.pdf.

236 Kambour, K. (2014, August). *State roles in enhancing the cybersecurity of energy systems and infrastructure* (Issue Brief). Retrieved from https://www.nga.org/files/live/sites/NGA/files/pdf/2014/1408EnhancingCybersecurityEnergySystems.pdf

237 Mantooth, H. A., & Wingfield, A. (2013). *State of Arkansas energy assurance plan.* Retrieved from https://www.adeq.state.ar.us/energy/resources/pdfs/arkansas-energy-assurance-plan.pdf

238 Connecticut Public Utilities Regulatory Authority. (2014). *Cybersecurity and Connecticut's public utilities.* Retrieved from http://www.ct.gov/pura/lib/pura/electric/cyber_report_041414.pdf

239 Ibid.

240 Indiana tackles crucial microgrid cybersecurity head-on. (2016). Retrieved from http://www.in.gov/activecalendar/EventList.aspx?fromdate=11/15/2016&todate=11/15/2016&display=Day&type=public&eventidn=254170&view=EventDetails&information_id=252794

241 Energy Sector Cybersecurity Working Group. (n.d.). *Cybersecurity guide for critical infrastructure for the state of Washington.* Retrieved from https://www.snopud.com/Site/Content/Documents/cyber/Cybersecurity_WA_915.pdf

242 National Association of State Energy Officials. (2015). *NASEO state energy cybersecurity model analysis: Michigan cybersecurity structures and programs profile.* Retrieved from http://www.naseo.org/data/sites/1/documents/publications/Michigan%20Cyber%20Profile%2012-29-15%20final%20draft%20copy.pdf; Maynard, M. (2014, January 28). The National Gard takes on hackers [Web log post]. Retrieved from The Pew Charitable Trusts website: http://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2014/01/28/the-national-guard-takes-on-hackers

243 Michigan cyber civilian corps. (2018). Retrieved from http://www.michigan.gov/som/0,4669,7-192-78403_78404_78419---,00.html

244 Hübner, G., Pohl, J., & Hoen, B. (2108, March 13). *Comparing strongly annoyed individuals with symptoms near U.S. turbines to those in surveyed European communities* [Webinar]. Retrieved from https://emp.lbl.gov/webinar/comparing-strongly-annoyed-individuals

245 The State of New Hampshire Public Utilities Commission. (2016, April 1). *IR 15-296, Electric distribution utilities: Investigation into grid modernization, order on scope and process* (Order No. 25,877). Retrieved from https://www.puc.nh.gov/Regulatory/Docketbk/2015/15-296/ORDERS/15-296_2016-04-01_ORDER_25877.PDF

246 Grid Modernization Working Group. (2017). *Grid modernization in New Hampshire: Report to the New Hampshire Public Utilities Commission.* Retrieved from https://www.puc.nh.gov/Regulatory/Docketbk/2015/15-296/LETTERS-MEMOS-TARIFFS/15-296_2017-03-20_NH_GRID_MOD_GRP_FINAL_RPT.PDF

247 Working group 4: Customer and community participation. (n.d.). Retrieved from NextGrid Illinois website: https://nextgrid.illinois.gov/customer.html; Public participation. (n.d.). Retrieved from NextGrid Illinois website: https://nextgrid.illinois.gov/Comments.html

248 PowerForward. (2018). Retrieved from https://www.puco.ohio.gov/industry-information/industry-topics/powerforward/

249 What drives you? (2018). Retrieved from https://www.driveelectricvt.com/; Wagner, F., Roberts, D., Francfort, J., & White, S. (2016). *Drive Electric Vermont case study.* Retrieved from https://www.energy.gov/sites/prod/files/2016/06/f32/Vermont Case Study.pdf

250 Michigan Energy Office. (2018). Retrieved from https://www.michigan.gov/energy/0,4580,7-230-72052_72054---,00.html; RFP's/loans. (2018). Retrieved from Michigan Agency for Energy website: https://www.michigan.gov/energy/0,4580,7-230-72052_72054_73823---,00.html

251 VIenergize. (n.d.). Retrieved from Virgin Islands Water and Power Authority website: http://www.viwapa.vi/OurEnergyFuture/VIenergize.aspx

252 K-12 schools. (2018). Retrieved from New York State Energy Research and Development Authority website: https://www.nyserda.ny.gov/Communities-and-Governments/K-12-Schools

253 K-12 Tennessee energy education network. (n.d.). Retrieved from https://www.tn.gov/environment/program-areas/energy/state-energy-office--seo-/programs-projects/programs-and-projects/k-12-tennessee-energy-education-network.html

254 Florida's SunSmart program helps provide power to schools when storms strike. (2014, May 30). Retrieved from https://www.energy.gov/eere/articles/floridas-sunsmart-program-helps-provide-power-schools-when-storms-strike

255 Nevada Office of the Governor. (2017, April 3). *Governor Sandoval announces committee on energy choice membership* [Press release]. Retrieved from http://gov.nv.gov/News-and-Media/Press/2017/Governor-Sandoval-Announces-Committee-on-Energy-Choice-Membership/

256 Gonzalez, Y. (2017, June 16). Sandoval vetoes community solar, higher clean-energy standard. *Las Vegas Sun.* Retrieved from https://lasvegassun.com/news/2017/jun/16/sandoval-veto-community-solar-higher-clean-energy/

257 State of Nevada, Executive Department. (2016, February 23). Executive Order 2016-04, Order directing the governor's Office of Energy to reconvene the New Energy Industry Task Force. Retrieved from http://energy.nv.gov/uploadedFiles/energynvgov/content/Programs/New Energy Industry Task Force 2016 Reconvene Order.pdf

258 Nevada Department of Energy, New Energy Industry Task Force. (2016). *Final recommendations.* Retrieved from http://energy.nv.gov/uploadedFiles/energynvgov/content/Programs/NEITF Final Recommendations (1).pdf

259 *Nevada Office of Cyber Defense Coordination: Strategic Plan 2018-2020.* (2017). Retrieved from http://dps.nv.gov/uploadedFiles/dpsnvgov/content/divisions/OCDC/home/Nevada-Office-of-Cyber-Defense-Coordination_Strategic-Plan_2018%202020.pdf

260 S.B. 145, 79th Nevada Legis. (2017) (enacted). Retrieved from https://www.leg.state.nv.us/App/NELIS/REL/79th2017/Bill/4981/Text

261 S.B. 204, 79th Nevada Legis. (2017) (enacted). Retrieved from https://www.leg.state.nv.us/App/NELIS/REL/79th2017/Bill/5078/Text

262 S.B. 146, 79th Nevada Legis. (2017) (enacted). Retrieved from https://www.leg.state.nv.us/App/NELIS/REL/79th2017/Bill/4982/Text

263 S.B. 65, 79th Nevada Legis. (2017). Retrieved from https://www.leg.state.nv.us/Session/79th2017/Reports/history.cfm?ID=123

264 A.B. 405, 79th Nevada Legis. (2017). Retrieved from https://www.leg.state.nv.us/App/NELIS/REL/79th2017/Bill/5487/Overview

265 S.B. 150, 79th Nevada Legis. (2017) (enacted). Retrieved from https://www.leg.state.nv.us/App/NELIS/REL/79th2017/Bill/4986/Text; A.B. 223, 79th Nevada Legis. (2017) (enacted). Retrieved from https://www.leg.state.nv.us/App/NELIS/REL/79th2017/Bill/5053/Text

266 S.B. 407, 79th Nevada Legis. (2017) (enacted). Retrieved from https://www.leg.state.nv.us/App/NELIS/REL/79th2017/Bill/5472/Text

267 A.B. 5, 79th Nevada Legis. (2017). Retrieved from https://www.leg.state.nv.us/Session/79th2017/Reports/history.cfm?ID=21

268 *Reforming the energy vision.* (2016). Retrieved from https://www.ny.gov/sites/ny.gov/files/atoms/files/WhitePaperREVMarch2016.pdf

269 *Report of the Market Design and Platform Technology Working Group.* (2015). Retrieved from http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/5e74ed080a95647085257e7000425e60/$FILE/MDPT-Report_150817_Final.pdf

270 REV demo projects. (n.d.). Retrieved from New York State website: https://rev.ny.gov/rev-demo-projects-1

271 NY Prize. (2018). Retrieved from New York State website: https://www.nyserda.ny.gov/All-Programs/Programs/NY-Prize

272 New York State Public Service Commission. (2016, August 1). *Order adopting a clean energy standard.* Retrieved from http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b44C5D5B8-14C3-4F32-8399-F5487D6D8FE8%7d; Clean energy standard. (2018). Retrieved from New York State Energy Research and Development Authority website: https://www.nyserda.ny.gov/All-Programs/Programs/Clean-Energy-Standard

273 NY-Sun. Retrieved from New York State Energy Research and Development Authority website: https://www.nyserda.ny.gov/All-Programs/Programs/NY-Sun

274 A.B. A6571, 2017–2018 New York Legis. (2017). Retrieved from https://www.nysenate.gov/legislation/bills/2017/a6571/amendment/original

275 New York State Energy Research and Development Authority (NYSERDA). (2017, April 19). *NYSERDA announces $15.5 million available for energy storage projects to support the electric grid* [Press release]. Retrieved from https://www.nyserda.ny.gov/About/Newsroom/2017-Announcements/2017-04-19-NYSERDA-Announces-Millions-Available-for-Energy-Storage-Projects; NYSERDA. (2017, June 21). *NYSERDA announces $6.3 million available for emerging energy storage products and technology to support the electric grid* [Press release]. Retrieved from https://www.nyserda.ny.gov/About/Newsroom/2017-Announcements/2017-06-21-NYSERDA-Announces-Millions-Available-for-Emerging-Energy-Storage; New York battery and Energy Storage Technology (NY-BEST) Consortium. (n.d.). Retrieved from NYSERDA website: https://www.nyserda.ny.gov/Researchers-and-Policymakers/Energy-Storage/NY-BEST

276 Hawaii Clean Energy Initiative. (2017, February). *Transforming power in paradise: The Hawaii Clean Energy Initiative* (HECI Fact Sheet). Retrieved from http://www.hawaiicleanenergyinitiative.org/wp-content/uploads/2015/02/HCEI_FactSheet_Feb2017.pdf

277 Hawaii Public Utilities Commission. (2018, February 7). Instituting a proceeding related to the Hawaiian Electric Companies' grid modernization strategy (Docket No. 2017-0226, Order No. 35268). Retrieved from https://www.hawaiianelectric.com/Documents/about_us/investing_in_the_future/dkt_2017_0226_2018_02_07_PUC_decision_and_order_35268.pdf; Hawaiian Electric Companies. (2017). *Modernizing Hawai'i's grid for our customers.* Retrieved from https://www.hawaiianelectric.com/Documents/about_us/investing_in_the_future/final_august_2017_grid_modernization_strategy.pdf

278 S.B. 2939, 29th Hawaii Legis. (2018). Retrieved from https://www.capitol.hawaii.gov/session2018/bills/SB2939_SD2_.HTM

279 H.B. 2182, 29th Hawaii Legis. (2018). Retrieved from https://www.capitol.hawaii.gov/session2018/bills/HB2182_CD1_.htm

280 H.B. 1986, 29th Hawaii Legis. (2018). Retrieved from https://www.capitol.hawaii.gov/session2018/bills/HB1986_CD1_.htm

281 Utility model study. (2018). Retrieved from Hawaii State Energy Office website: http://energy.hawaii.gov/utility-model

282 Act 039, 29th Hawaii Legis. (2017) (enacted). Retrieved from https://www.capitol.hawaii.gov/session2017/bills/GM1139_.pdf

283 GEMS financing program: About us. (2018). Retrieved from Hawaii Green Infrastructure Authority website: http://gems.hawaii.gov/learn-more/about-us/

284 EV stations Hawaii mobile app. (2018). Retrieved from http://energy.hawaii.gov/testbeds-initiatives/ev-ready-program/ev-stations-hawaii-mobile-app

285 California Energy Commission. (2018). *2017 Integrated energy policy report.* Retrieved from http://docketpublic.energy.ca.gov/PublicDocuments/17-IEPR-01/TN222377_20180126T144311_Proposed_Final_2017_Integrated_Energy_Policy_Report_Clean_Versi.pdf; Clean Energy & Pollution Reduction Act: SB 350 overview. (2018). Retrieved from California Energy Commission website: http://www.energy.ca.gov/sb350/

286 California State Office of Governor Edmund G. Brown Jr. (2018, January 26). *Governor Brown takes action to increase zero-emission vehicles, fund new climate investments* [Press release]. Retrieved from https://www.gov.ca.gov/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/

287 Distribution resources plan (R.14-08-013). (2018). Retrieved from California Public Utilities Commission website: http://www.cpuc.ca.gov/General.aspx?id=5071; Zero-emission vehicles. (2018). Retrieved from California Public Utilities Commission website: http://www.cpuc.ca.gov/zev/; Energy storage. (2018). Retrieved from California Public Utilities Commission website: http://www.cpuc.ca.gov/General.aspx?id=3462; California Public Utilities Commission. (2017). *California smart grid: Annual report to the governor and the legislature in compliance with Public Utilities Code § 913.2.* Retrieved from http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Annual_Reports/Smart_Grid_Annual_Report_2016_Final.pdf; Shallenberger, K. (2017, April 3). The top 5 states for utility grid modernization and business model reform. *Utility Dive.* Retrieved from https://www.utilitydive.com/news/the-top-5-states-for-utility-grid-modernization-and-business-model-reform/439550/

288 California Public Utilities Commission. (2013, October 17). *CPUC sets energy storage goals for utilities* [Press release]. Retrieved from http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M079/K171/79171502.PDF

289 Wagman, D. (2017, May 8). Energy storage rose from California crisis. *IEEE Spectrum.* Retrieved from https://spectrum.ieee.org/energywise/energy/the-smarter-grid/california-crisis-tests-energy-storage-supply-chain

290 Energy research & development. (2018). Retrieved from http://www.energy.ca.gov/research/

291 Smarter Illinois initiative. (2018). Retrieved from https://www2.illinois.gov/sites/doit/Strategy/Pages/SmarterIllinois.aspx

292 Clarke, R. Y. (2017). *Smarter and future-ready Illinois continues to execute on its digital transformation strategy: Update.* Retrieved from https://www2.illinois.gov/sites/doit/Strategy/Documents/IDCWhitePaper-SmarterAndFuture-ReadyIllinois.pdf

293 State of Illinois, Illinois Commerce Commission. (2017, July 26). The Citizens Utility Board and the Environmental Defense Fund: Proceeding to adopt the Illinois open data access framework. Retrieved from http://blogs.edf.org/energyexchange/files/2017/07/odaf_14-0507_final_order.pdf?_ga=2.258154761.2003218344.1501238079-1840594613.1501238079

294 State of Illinois, Illinois Commerce Commission. (2017, April 30). Illinois Commerce Commission on its own motion: Regarding Illinois' consideration of the utility of the future: "NextGrid" grid modernization study. Retrieved from https://nextgrid.illinois.gov/resolution.pdf; NextGrid: Illinois utility of the future study. Retrieved from NextGrid Illinois website: https://nextgrid.illinois.gov/

295 Unger, D. J. (2017, April 27). After five years, Illinois smart grid buildout showing results. *Energy News Network.* Retrieved from http://midwestenergynews.com/2017/04/27/after-five-years-illinois-smart-grid-buildout-showing-results/; S.B. 1652, Illinois Gen. Ass. (2011). Retrieved from http://www.ilga.gov/legislation/97/SB/PDF/09700SB1652lv.pdf; S.B. 2814, Illinois Gen. Ass. (2016). Retrieved from http://www.ilga.gov/legislation/publicacts/99/PDF/099-0906.pdf

296 Massachusetts Department of Public Utilities. (2017). *Department of Public Utilities annual report.* Retrieved from https://www.mass.gov/files/documents/2018/01/26/DPU 2017 AR - Final.pdf

297 The Commonwealth of Massachusetts, Department of Public Utilities. (2018, May 10). *Department of Public Utilities issues order to modernize commonwealth's electric grid* [Press release]. Retrieved from https://www.mass.gov/news/department-of-public-utilities-issues-order-to-modernize-commonwealths-electric-grid

298 Massachusetts Executive Office of Energy and Environmental Affairs & Department of Energy Resources. (2017, June 30). *Baker-Polito administration sets 200 megawatt-hour energy storage target* [Press release]. Retrieved from https://www.mass.gov/news/baker-polito-administration-sets-200-megawatt-hour-energy-storage-target

299 DOER divisions and services. (2018). Retrieved from Commonwealth of Massachusetts website: https://www.mass.gov/guides/doer-divisions-and-services

300 DeployMass. (2018). Retrieved from Massachusetts Clean Energy Center website: http://www.masscec.com/deploymass

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