CHARGING AHEAD

An **Energy Storage** Guide for Policymakers

IREC
Interstate Renewable Energy Council, Inc.

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CHARGING AHEAD:
AN ENERGY STORAGE GUIDE FOR STATE POLICYMAKERS

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ACRONYMS AND ABBREVIATIONS

ACC	Arizona Corporation Commission
AEPS	Alternative Energy Portfolio Standard
ASOT	Advanced Storage Optimization Tool
CPUC	California Public Utilities Commission
DER	Distributed Energy Resource
DOE	United States Department of Energy
DOER	Massachusetts Department of Energy Resources
DR	Demand Response
EIA	United States Energy Information Administration
EPRI	Electric Power Research Institute
ESI	Energy Storage Initiative
ESS	Energy Storage System
ESVT	Energy Storage Valuation Tool
FERC	Federal Energy Regulatory Commission
GHG	Greenhouse Gas
GW	Gigawatt
IREC	Interstate Renewable Energy Council
IRP	Integrated Resource Plan
ISO	Independent System Operator
KW	Kilowatt
KWH	Kilowatt Hour
LCOE	Levelized Cost of Energy
LTPP	Long-term Procurement Plan
MW	Megawatt
NEM	Net Energy Metering
NREL	National Renewable Energy Laboratory
PGE	Portland General Electric
PUC	Public Utility Commission
PV	Photovoltaic
RES	Renewable Energy Standard, aka Renewable Portfolio Standard (RPS)
REST	Renewable Energy Standards and Tariff
REV	Reforming the Energy Vision (New York)
RTO	Regional Transmission Organization
SGIP	Small Generator Interconnection Procedures or Self Generation Incentive Program
TOU	Time of Use
TVR	Time Varying Rate
UTC	Washington State Utilities and Transportation Commission

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EXECUTIVE SUMMARY

Energy storage technologies—capable of capturing usable energy for use at another time, particularly when it is needed most and/or more valuable—provide flexible solutions to serve energy needs and address existing and emerging challenges. Energy storage technologies also provide an array of grid services and can offer multiple services interchangeably. Integrating energy storage strategically across the electricity system can result in more efficient utilization of other grid resources, defer more costly upgrades or investments, and increase the range of operational possibilities for the electric system.

The very characteristics that make energy storage valuable and attractive also make it challenging to address in policy and regulatory contexts. Despite the game-changing potential of energy storage to transform the electricity system, energy storage is vastly underutilized in the United States' electricity sector. Its deployment remains hampered by the current features of regional, state and federal regulatory frameworks, traditional utility planning and decision-making paradigms, electricity markets, and aspects of the technology itself.

The Interstate Renewable Energy Council's (IREC) *Charging Ahead: An Energy Storage Guide for State Policymakers* is intended to provide state policymakers and regulators with systematic, foundational information on advanced energy storage—a new generation of technologies characterized by flexible operating capabilities and diverse applications—as well as more specific guidance on key issues for consideration in the policymaking context. Advanced energy storage technologies have matured rapidly in recent years and installations are quickly gaining momentum in states across the country. While beyond the scope of this guide, there are untapped opportunities to expand the role and function of traditional forms of storage, particularly cost-effective thermal storage for demand management and integration of high penetrations of renewable energy on the grid (see Additional Resources for more information). While differences exist among the available storage forms and technologies, policy and regulatory solutions designed to address energy storage barriers more holistically, with a technology neutral framework, will help set a glide path for all energy storage technologies.

Deploying energy storage at scale and optimizing its benefits will require innovative and forward-thinking policies (and the political and societal will) to integrate it into existing electric system operations and state regulatory frameworks. To date, state policymakers and electric system stakeholders have navigated energy storage issues without the benefit of a roadmap of key regulatory and policy pathways to support the economic deployment of energy storage. With more storage being deployed and leading states gaining more experience, foundational policy actions and informative lessons learned are emerging. The foundational actions and solutions presented at the end of the guide reflect the reality that certain issues have more clearly defined paths to address identified barriers, while others are still under development and/or ripe for further policy innovation.

State leadership and innovation on landmark energy policy issues, including energy storage and its more robust integration on the grid, will help expedite and optimize the electricity sector transformation already underway. By proactively integrating energy storage technologies into today's policy and regulatory decisions, states can lead the charge to enhance the cost-effectiveness, reliability, quality and functionality of the energy sector. The intent with this guide is to provide an array of possible actions and pathways for further exploration, but more work remains to develop a more comprehensive road map for energy storage in the United States. IREC hopes this guide will serve as a valuable navigational tool and can serve all states well on their energy storage journey.

ABOUT THE GUIDE

The guide is organized into six sections, plus supplementary sections for additional resources and appendices. Each section concludes with a summary of key takeaways for state policymakers, which are provided below for quick reference:

- **Section I. Introduction** provides context for the guide and opportunity for policy leadership on energy storage.
- **Section II. The Current State of Advanced Energy Storage** provides a brief overview of advanced energy storage technologies, their performance characteristics, applications and their services.
- **Section III. How States Can Approach Assessing the Cost and Value of Storage** provides an overview of the economics of energy storage, offers a snapshot of existing tools to assess energy storage costs and benefits, and provides additional insights on evaluating the value of storage.
- **Section IV. State Regulatory Approaches to Energy Storage** provides illustrative examples of state policy and regulatory actions occurring in four identified stage(s) of storage actions (Investigate, Clarify, Energize, Plan), as well as key insights from state efforts.

- **Section V. Foundational State Policy Actions to Address Primary Energy Storage Barriers** discusses the state policy and regulatory barriers that limit or impair storage deployment and provides some recommended foundational policy actions to help states begin to overcome those barriers. This discussion of barriers and foundational policies is not exhaustive, but rather, reflects the most commonly identified barriers and thus the actions likely to have the broadest impact on the energy storage market. Similarly, market rules established by ISOs and RTOs are not covered in this guide, although they are equally critical to the successful deployment of energy storage. At a high level, the guide recommends the following foundational actions to advance energy storage:

CLASSIFICATION & OWNERSHIP	**Clarify How Energy Storage Systems are Classified to Enable Shared Ownership and Operation Functions in Restructured Markets.** In restructured markets, state policymakers and regulators may need to reconsider the current limitations on asset ownership that may prevent “wires-only” utilities from cost-effectively owning storage as assets and, thus, from being able to recover costs through rates. Any approaches seeking to address this issue will likely require the implementation of appropriate regulatory safeguards to protect the competitiveness of energy markets, while still ensuring that the grid and ratepayers can benefit from advanced energy storage technologies.
PLANNING	**Require Proactive Consideration of Energy Storage in Utility Planning Efforts.** States should consider requiring utilities to evaluate energy storage side-by-side with those of traditional wires and resource solutions as a part of integrated resource and distribution planning efforts. State policymakers and regulators will need to be specific about how they want energy storage to be evaluated and modeled (including requiring the use of up-to-date, accurate cost and performance data) in these proceedings if they want to see the most useful and effective results. These proceedings can produce new tools that enable grid transparency that can help identify locations where storage can offer the greatest benefits to customers and the grid.
GRID ACCESS	**Ensure Fair, Streamlined, and Cost Effective Grid Access for Energy Storage Systems.** Energy storage customers, like all customers seeking to connect to the grid, need a process that is transparent, non-discriminatory, timely and cost effective just like any other type of generator. While storage systems can be reviewed using the basic framework of traditional state jurisdictional interconnection procedures, certain modifications could be made to more effectively and efficiently review their impacts on the electric system.
VALUE STREAM	**Create Mechanisms to Capture the Full Value Stream of Storage Services.** States can consider adopting or modifying mechanisms to help create markets for energy storage and capture the full value stream of energy storage services, namely through monetizing the benefits.

- **Section VI. The Conclusion** offers some brief insights on outstanding policy issues and opportunities ripe for further investigation.
- **The Additional Resources** section provides a list of other valuable sources for storage information. **Appendix A** provide a deeper dive on energy storage applications and services, and **Appendix B** contains an overview of existing modeling tools for energy storage valuation.

CHARTING A COURSE FOR ENERGY STORAGE

With this navigational tool and resource guide in hand, state policymakers and regulators should begin to chart a course to address energy storage in their respective markets. The starting point for each state will necessarily be different, based on where you are and what your goal is. While a step-by-step action plan is outside the scope of the guide, the key takeaways and insights offered in *Charging Ahead* should help more states establish a robust framework to charge ahead on energy storage.

Beyond taking proactive steps on storage, continued policy leadership will ensure identified challenges are met with innovative, yet practical solutions that set the stage for market growth. Indeed, the policy and regulatory frameworks are the foundation upon which future growth will be built. Peer-to-peer sharing among states and leveraging the wealth of information gleaned to date from pilot projects and active programs will ensure replication of successful approaches can occur more swiftly.

Credit: S&C Electric Company

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I. Introduction

Energy storage technologies—capable of capturing usable energy for use at another time, particularly when it is needed most and/or more valuable—provide flexible solutions to serve energy needs and address existing and emerging challenges. Energy storage technologies also provide an array of grid services and can offer multiple services interchangeably. Integrating energy storage strategically across the electricity system can result in more efficient utilization of other grid resources, defer more costly upgrades or investments, and increase the range of operational possibilities for the electric system. Yet, the very characteristics that make energy storage valuable and attractive also make it challenging to address in policy and regulatory contexts. Despite the game-changing potential of energy storage to transform the electricity system, energy storage is vastly underutilized in the United States' electricity sector. Its deployment remains hampered by the current features of regional, state and federal regulatory frameworks, traditional utility planning and decision-making paradigms, electricity markets, and aspects of the technology itself.

The focus of this guide is on advanced energy storage technologies—a newer generation of electricity storage technologies characterized by flexible operating capabilities and diverse applications—and their application in the electricity sector. Advanced energy storage technologies have matured rapidly in recent years and installations are quickly gaining momentum in states across the country. Traditional forms of storage—namely, pumped hydro-electric and thermal storage[1]—have been deployed for decades and are actively integrated into several state and utility energy portfolios today. There are untapped opportunities to expand the role and function of traditional forms of storage, particularly cost-effective thermal storage for demand management and integration of high penetrations of renewable energy on the grid.[2] However, to avoid duplication on this topic, we refer readers to the Additional Resources section for more information on these forms of storage.

While differences exist among the available storage forms and technologies, policy and regulatory solutions designed to address energy storage barriers more holistically, with a technology neutral framework, will help set a glide path for all energy storage technologies.

Driven by growth in renewable and distributed generation, the increasing role of the customer in energy management, the availability of information technologies on the grid and other factors, advanced energy storage technologies are on the rise and poised to catalyze further transformation throughout the electricity sector in the coming years.[3,4,5,6] There is also a growing recognition that storage can provide cost competitive alternatives to traditional resources and infrastructure, even where renewables penetration is not an issue. As of early 2017, nearly 800 MW of these advanced storage technologies have been deployed on the U.S. grid, 450% more than cumulative installations at the end of 2008.[7] In addition, systems are increasing in size from smaller kilowatt pilot projects to 100+ MW commercial facilities.[8] Meanwhile the installed cost of certain advanced energy storage technologies is decreasing rapidly due to a variety -of factors: technology improvements, economies of scale, expanded battery deployment in the transportation sector (i.e., electric vehicles), lower transaction costs, and increased access to lower-cost financing. Future energy storage costs are expected to continue to decline, which will further advanced enable storage to become a critical asset for the 21st century electric system.[9]

Among their many applications and services, energy storage technologies are notably capable of increasing grid reliability, providing capacity reserves and voltage support, integrating more renewable and distributed energy on the grid, reducing peak demand, providing effective demand management for certain energy customers, and avoiding or mitigating system disruptions. Energy storage technologies can be located behind-the-meter (i.e., customer-sited), on the distribution system, or on the transmission system. The services energy storage provides have the potential to result in more efficient utilization of other grid resources and to increase the range of operational possibilities for those resources. Value streams for storage are determined by, and dependent on, where systems are located, by what entity controls the storage, and to whom and what location the services and benefits flow. While multiple value streams can exist for storage's myriad services, accessing those value streams is challenged by the current features of regional, state and federal regulatory frameworks, electricity markets, and aspects of the technologies.

The electric system was not designed with advanced energy storage in mind, nor were the policies and rules governing the system. Energy storage does not fit easily within the existing policy and regulatory framework for the electric system. Its unique ability to act as supply, demand, and infrastructure, and to switch between these roles, is what makes storage valuable, but also what challenges its integration into the system. Within most existing state policies and market regulations, energy storage is prevented from offering its multiple capabilities and thus is effectively undervalued and underutilized. For example, a recent report commissioned by the state of Massachusetts found that only a third of the estimated benefits of storage can be monetized and compensated under existing regulations and market designs; the report concluded that, even though storage would result in benefits to ratepayers that substantially outweigh the cost of investment, the lack of sufficient market structures meant such storage would not be deployed.[10] Indeed, existing revenue mechanisms that would encourage investment from private storage developers are generally insufficient in most states. At the same time, while utilities are adept at building and procuring transmission and distribution (T&D) and generation assets, most lack incentives, internal or external motivation, direct experience, policy direction, and/or regulatory guidance to consider energy storage alongside or as an alternative to more traditional resources. As such, energy storage is typically not on the menu of options automatically considered to meet electric system affordability, reliability, and sustainability objectives.

Deploying energy storage at scale and optimizing its benefits will require innovative and forward-thinking policies (and the political and societal will) to integrate it into existing electric system operations and state regulatory frameworks. To date, state policymakers and electric system stakeholders have navigated energy storage issues without the benefit of a roadmap of key regulatory and policy pathways to support the economic deployment of energy storage. With more storage being deployed and leading states gaining more experience, foundational policy actions and informative lessons learned are emerging.

This guide is intended to provide state policymakers and regulators with systematic, foundational information on advanced energy storage, as well as more specific guidance on key issues for consideration in the policymaking context. At the end of each section, for easy reference, we provide a summary of key takeaways for state policymakers.

The guide is organized as follows:

State leadership and innovation on landmark energy policy issues, including energy storage and its more robust integration on the grid, will help expedite and optimize the electricity sector transformation already underway. By proactively integrating energy storage technologies into today's policy and regulatory decisions, states can lead the charge to enhance the cost-effectiveness, reliability, quality and functionality of the energy sector. The path will undoubtedly be challenging, and more resources will be needed to support the decision-making process. The Interstate Renewable Energy Council, Inc. (IREC) hopes this guide will serve as a valuable navigational tool and will serve all states well on their energy storage journey.

II. The Current State of Advanced Storage

Characterized by rapid technological advancements, increased demand for its services and declining costs, energy storage is quickly evolving. As energy storage technologies are deployed across diverse markets, state policymakers, regulators, utilities, and grid operators are gaining an improved understanding of the diverse applications and services energy storage provides. This section provides a brief overview of advanced energy storage technologies, their applications and their services. The resources featured in the Additional Resources section provide more in-depth information on these topics.

A. Energy Storage Technologies

Energy storage is any of several technologies that enable an input of energy to be released for use at another time (i.e., when it is needed or most valuable). Traditionally two types of energy storage technologies have been most common on the electric system: pumped hydroelectric and thermal.[11] Pumped hydroelectric storage has typically been used to balance the oversupply from central station power plants during periods of low demand. Thermal storage, such as grid-interactive space and water heaters or ice or chilled water storage, can be used to shift heating or cooling demand to different times of day to reduce and/or control utilities' peak electricity demand, provide load control, and integrate variable renewable energy resources on the grid.

THERMAL STORAGE

The Regulatory Assistance Project highlights the untapped opportunity to deploy grid-interactive water heaters and ice or chilled water storage for commercial air conditioning as cost-effective and readily available storage solutions to address the "duck curve" challenge of integrating, and avoiding curtailment of, renewable energy at higher penetration levels.[12] Their analysis offers case studies, technology examples, and recommended state policy and regulatory actions to seize this untapped opportunity for thermal storage, which states could consider in concert with the advanced energy storage related recommendations in this guide.

The term “advanced energy storage” encompasses newer and more flexible forms of energy storage, such as batteries, flywheels, and updated versions of thermal storage and compressed air energy technologies.[13] Advanced energy storage technologies have been commercially available for decades in consumer and industrial applications, but only more recently have they gained prominence in the electricity market. Similarly, a growing number of states, utilities, grid operators, and other stakeholders are now beginning to gain valuable insights and understanding of these technologies, their applications, and their performance characteristics through more direct experiences. Among the advanced energy storage technologies being deployed today, batteries are seeing the quickest uptake, with an increase in both number and size of systems *(see below)*.[14]

BATTERY STORAGE TRENDS

With increasing economies of scale and declining costs, battery energy storage projects are increasing in both size and duration. In 2016, lithium-ion batteries constituted approximately 97% of the U.S. energy storage market, due to the declines in lithium-ion battery prices and increasing implementation in large utility-scale projects.[15] Lead-acid batteries, for comparison, made up 1.6% of the market in 2016.[16]

The following represent some of the largest battery projects in the world at the time of drafting:

- San Diego Gas & Electric contracted with AES to install two storage projects totaling 37.5 Megawatts (MW), 150 MWh. When completed, the larger of the two (the 120 MWh project) is expected to be the world’s biggest lithium ion battery project. The project was built in response to the leak at the Aliso Canyon gas storage facility, which caused an unprecedented shortage of natural gas for electricity generation in Southern California.[17]
- Southern California Edison and Tesla announced a 30 MW, 80 MWh lithium ion project.[18]
- The Alamitos Project in Long Beach, California is a 100 MW capacity, 4-hour duration lithium-ion battery slated for completion in 2018.[19]
- A 200 MW, 4-hour vanadium flow battery is in early development in China.[20]
- A 50 Megawatt (MW), 6-hour sodium-sulfur battery in Japan.[21]

Another recent trend is the aggregation of multiple smaller battery systems, typically distributed systems located at homes and businesses, to function effectively as a single “virtual power plant”. An example is a project announced in 2016 that plans to aggregate 1,000 battery systems into a 5 MW, 1.5-hour project.[22]

While a variety of battery chemistries exist, each with different design and performance characteristics, batteries based on lithium-ion chemistries represent the vast majority of installed projects, due largely to their flexibility to provide a range of services and their improved scale efficiencies resulting from use in both vehicle and consumer applications.[23] Table 1 provides an overview and brief comparison of the two primary battery categories:

TABLE 1. COMPARISON OF BATTERY STORAGE TECHNOLOGIES

	SOLID RECHARGEABLE BATTERIES	FLOW BATTERIES
DESCRIPTION	Chemical energy is stored in solid-metal electrodes separated by an electrolyte; project capacity scales by number of units in array	Chemical energy is stored in flowing liquid electrolytes kept in tanks separate from the actual electrochemical cells; project capacity scales by volume of electrolyte tanks
MOST COMMON CHEMISTRIES	Lithium-ion; advanced lead-acid, sodium-based; and zinc-based	Vanadium-based, zinc-based; and sodium-based chemistries; liquid metal
NOTABLE CHARACTERISTICS	Best for flexibility—frequent and/or partial cycling; used for ancillary services, increasingly used for capacity applications; can be scaled for smaller behind-the-meter projects to larger Megawatt scale front-of-meter projects.	Best for duration—periodic and/or full cycling over longer service lifetimes; used for capacity and arbitrage applications; typically for larger Megawatt scale front-of-meter projects.

Across the spectrum of battery technologies, ongoing battery storage research and development efforts are primarily focused on verifying sustained performance over expected service lifetimes, scaling production processes, and achieving cost reductions.

1. Performance Characteristics

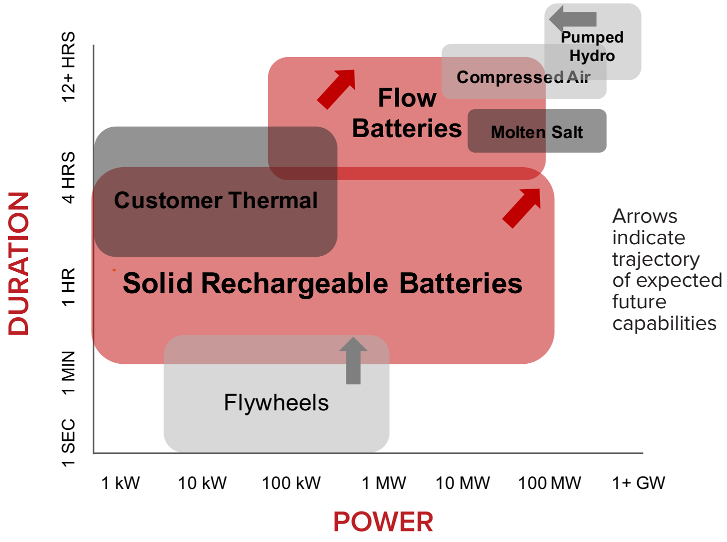
Energy storage technologies feature different performance characteristics, which are relevant for determining (and optimizing) their applications and services to the grid (e.g., moment-to-moment grid stabilization, local system support, bulk system management, etc.). The most important measures of performance are *rated power*—the maximum amount of electric output that the storage can provide—and *duration*—the length of time storage can sustain its electric output.

DETERMINING ENERGY STORAGE DURATION: A QUICK MATH LESSON

The duration—the length of time storage can sustain its electric output—can be determined by knowing how much energy the resource can store. For example, a storage resource described as a 2 MW / 8 MWh unit can sustain its maximum (rated) power of 2 MW for 4 hours (8 MWh of energy divided by 2 MW of power equates to 4 hours of duration).

Figure 1 provides a simplified description of the range of power and duration that different storage technologies currently provide. Appendix A discusses these different applications in greater detail.

FIGURE 1. PERFORMANCE CHARACTERISTICS OF ENERGY STORAGE[24]



Arrows indicate trajectory of expected future capabilities

Other relevant energy storage performance characteristics include:

- round-trip efficiency (a measure of the amount of energy lost in a "round-trip" between the time the energy storage system is charged and then discharged);
- construction time;
- operational costs;
- space requirements;
- cycle life (the number of complete charge-discharge cycles a battery can perform before its nominal capacity falls below 80% of its initial rated capacity);
- the depth of discharge the battery can reach while still retaining its rated cycle life; and
- level of technology maturity.

Table 2 provides a comparison of these different performance characteristics for a sample of energy storage technologies.

TABLE 2. TYPICAL PERFORMANCE CHARACTERISTICS OF SELECTED ENERGY STORAGE SYSTEMS[25]

	Electrochemical Storage				*Mechanical Storage*		
	LEAD ACID	LITHIUM-ION	SODIUM-SULFUR	FLOW BATTERIES	FLYWHEELS	COMPRESSED AIR	PUMPED HYDRO
Round-trip efficiency	70-85%	85-95%	70-80%	60-75%	60-80%	50-65%	70-80%
Typical duration	2-6 hr	0.25-4 hr	6-8 hr	4-12 hr	0.25-4 hr	4-10 hr	6-20 hr
Time to build	6-12 mo	6-12 mo	6-18 mo	6-12 mo	1-2 yr	3-10 yr	5-15 yr
Operating cost	High	Low	Moderate	Moderate	Low	Moderate	Low
Space required	Large	Small	Moderate	Moderate	Small	Moderate	Large
Cycle life	500-2,000	2,000-6,000+	3,000-5,000	5,000-8,000+	100,000	10,000+	10,000+
Technology maturity	Mature	Commercial	Commercial	Early-moderate	Early-moderate	Moderate	Mature

The performance characteristics of energy storage continue to evolve as technologies improve and new technologies achieve commercialization, the figures above are provided for reference purposes based on current information. Given the rapid pace of technological innovation, regulators, policymakers, and other electric sector stakeholders should seek out the most updated information on the state of energy storage technologies to inform policy decision-making and infrastructure investments, and where possible, should avoid establishing policies that are designed with only one technology type or state of technology in mind.

B. Applications and Services

The diversity of energy storage technologies offers an array of applications, services, and benefits. Certain applications, and the corresponding services, are available based on the location of the energy storage system on the grid. Systems directly connected to the transmission and/or distribution systems ("front-of-meter storage") can provide bulk supply services, grid balancing services ("ancillary services"), and transmission and distribution services. Customer-sited distributed storage systems ("behind-the-meter storage") can provide benefits directly to the end-user, such as time-of-use energy cost management, demand charge reductions, and, in some cases, back-up power in the event of a temporary outage or natural disaster. Behind-the-meter storage could also provide most of the applications of front-of-meter storage, such as grid congestion relief, voltage and frequency support, and deferral or avoidance of traditional "wires only" grid upgrades, though it may need to be aggregated and/or controlled to operate under established parameters to meet the necessary market conditions. Figure 2 presents a high-level overview of the various applications and corresponding services of energy storage systems, which are explained in further detail below.

FIGURE 2. ENERGY STORAGE APPLICATIONS & SERVICES

BULK ELECTRIC SYSTEM APPLICATIONS

BULK ENERGY SERVICES
Electric Time Shift
Electric Supply Capacity
Renewables Integration
Firming
Curtailment Avoidance

ANCILLARY SERVICES
Frequency Response & Regulation
Ramping / Load Following
Voltage/VAR Support
Black Start
Spinning and Non-Spinning Reserves
Power Quality

INFRASTRUCTURE APPLICATIONS

TRANSMISSION SERVICES
Network Capacity
Congestion Relief

DISTRIBUTION SERVICES
Network Capacity
Voltage/VAR Support

T&D UPGRADE DEFERRAL

INCREASED HOSTING CAPACITY

AREA REGULATION

BEHIND-THE-METER APPLICATIONS

PEAK DEMAND REDUCTION

ENERGY MANAGEMENT SERVICES
Time-Varying Rate Management
Demand Charge Management

RELIABILITY SERVICES
Back-up Power

Figure 3 was adapted from the DOE/EPRI Electricity Storage Handbook (2015). Please refer to the Additional Resources for the Handbook link and Appendix A for more detailed descriptions of the Applications and Services. Also of note: The Rocky Mountain Institute offers another helpful graphic representation of the various energy storage applications and services in their analysis "The Economics of Battery Storage." This report is featured in the Additional Resources section for reference and comparison.

Energy storage systems are uniquely flexible in their ability to deliver various services interchangeably, switching between services or operation modes based on the highest need or value. In considering the potential value of various storage services, it is helpful to understand how they may be 'stacked' together to optimize the benefits and associated value streams from those services, thus maximizing the overall cost-effectiveness of a storage system. Section III.A.3 provides further insights on the importance of stacking in understanding the economics and value of storage.

There is an extensive and rapidly growing body of research addressing energy storage applications, services and end-use benefits, which this guide will not endeavor to duplicate. Instead, Appendix A provides a digestible high-level summary of the different types of services that energy storage can provide and should be referred to as specific services are discussed elsewhere in this paper. The Additional Resources section also contains references to materials that delve into more detail on the specific services and applications of energy storage.

Credit: RES

C. Key Takeaways for State Policymakers

- Advanced energy storage refers to newer and more flexible forms of energy storage, such as batteries, flywheels, and compressed air energy technologies.

- Batteries are seeing the quickest uptake in today's market, with an increase in both number and size of systems. Lithium-ion batteries constitute the vast majority of the U.S. energy storage market.

- The performance characteristics of energy storage determine their applications and services to the grid. The most common performance metrics are rated power—the maximum electric output that the storage can provide—and duration—the length of time storage can sustain its electric output. Other metrics include: round-trip efficiency; construction time; operational costs; space requirements; cycle life; and level of technology maturity.

- The viability of energy storage technologies is determined by their economic and performance characteristics.

- Given the rapid pace of technological innovation, regulators, policymakers, and other electric sector stakeholders should seek out the most updated information on the state of energy storage technologies to inform policy decision-making and infrastructure investments.

- Energy storage policies and regulations should not target a single technology and should be technology neutral.

- Energy storage systems deployed across the electricity grid, both front-of-meter and behind-the-meter, provide a range of valuable services to the electricity grid and consumers.

- Energy storage systems can be flexible in their ability to deliver multiple services and provide an alternative to traditional infrastructure and investments.

- The myriad applications energy storage can provide to the electricity grid reflect a substantial and untapped value stream of services, which contribute to the value proposition of energy storage.

- Thermal storage, such as grid-interactive space and water heaters and ice or chilled water storage, can be used to shift heating or cooling demand to different times of day to reduce and/or control utilities' peak electricity demand, provide load control, and integrate variable renewable energy resources on the grid.

- For more comprehensive information on energy storage applications and services, refer to Appendix A and Additional Resources.

Credit: AES Energy Storage

III. How States Can Approach Assessing the Cost and Value of Storage

Policymakers and regulators may find that the very flexibility that makes advanced storage attractive also makes it a challenge to incorporate into traditional economic modeling and cost-benefit analysis. The flexibility of applications and multitude of storage services make it difficult to fit energy storage easily into the 'boxes' of supply, demand, or infrastructure. Storage can be co-located with generation, directly connected to the transmission & distribution system, or installed at a customer premise. Storage can also be owned by utilities, customers, or third parties, and it can provide a variety of services to two or more different beneficiaries simultaneously. Each combination of owner, grid location, and use case renders a different economic case and a different set of benefits.

At the same time, some policymakers and regulators are also exploring how the multi-faceted nature of storage is better captured by considering the cost and value of specific services, as opposed to the more traditional focus on the cost and value of specific technologies. Within these discussions, there is an argument that the design of tariffs, procurement processes, rates, and/or incentives should ideally center around the value of the service(s) provided. Doing so allows eligible technologies to respond to those economic signals accordingly.

There is not yet a commonly accepted approach for assessing the value of energy storage, nor is there a single modeling tool or compensation methodology to provide the 'silver bullet' solution. While more work and discussion on this topic is needed, states can take steps to identify ways to integrate storage into existing modeling, planning, and other policy frameworks, which, in turn, will likely further progress to adapt these frameworks to better suit energy storage.

This section provides an overview of the economics of energy storage, offers a snapshot of existing tools to assess energy storage, and provides additional insights on evaluating the value of storage.

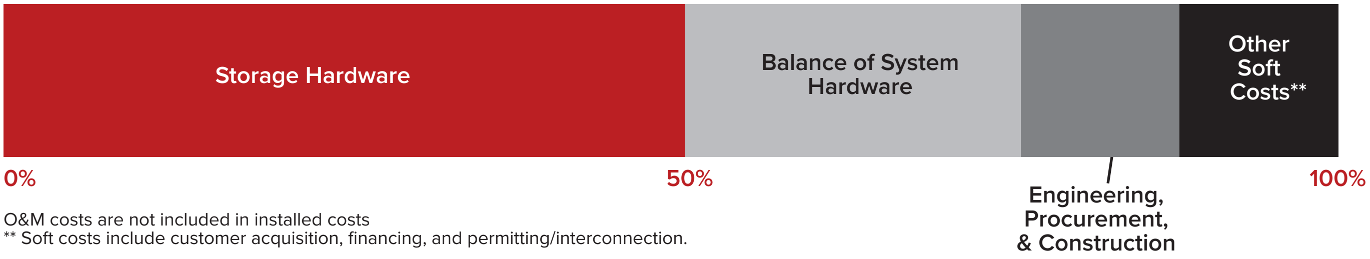
A. Understanding Energy Storage Economics

To evaluate the economics of energy storage, it is important to understand that the attributes that make it such a unique energy technology also make it difficult to conduct an apples-to-apples comparison of costs and benefits alongside other energy technologies. The following provides a breakdown of some of the differentiating elements that can help inform a more comprehensive assessment of the economics of storage.

1. What is the Total Cost of Storage?

An energy storage resource is comprised of the following costs categories, which combine to make up the total installed cost:

FIGURE 3. ILLUSTRATIVE INSTALLED COSTS OF BATTERY STORAGE SYSTEM



O&M costs are not included in installed costs
** Soft costs include customer acquisition, financing, and permitting/interconnection.

Public sources commonly refer only to the storage unit cost, rather than total installed cost. This can be misleading, as the balance of system costs can, in some cases, be more than the storage unit cost. Moreover, the rate of change of each category of costs is different, which can also complicate how the economics of storage is calculated or represented, particularly over time. In addition, because cost data are generally protected by storage developers as proprietary information, accurate and up-to-date cost data for energy storage technologies can be challenging to procure.

2. How is the Cost of Storage Measured?

Energy storage costs can be expressed in two ways, and the units used to communicate vary depending on the source and on which performance characteristic metric the storage cost is based, the two metrics are: rated power or duration.

- A cost metric based on the duration of an energy storage unit is expressed in terms of dollars per kilowatt-hour ($/kWh). For example, a 1 kW, 4-hour unit can hold 4 kWh of energy. At a reported cost of $250/kWh, the cost of the unit is $1,000/kW (4 kWh X $250/kWh=$1,000/kW).

- A cost metric based on the rated power of the energy storage unit is expressed in terms of dollars per kilowatt ($/kW). For example, a 1 kW, 1-hour unit can hold 1 kWh of energy, the cost of the unit at a reported cost of $250/kW, the cost of the unit is $250/kW (1 kW X $250/kW = $250/kW.

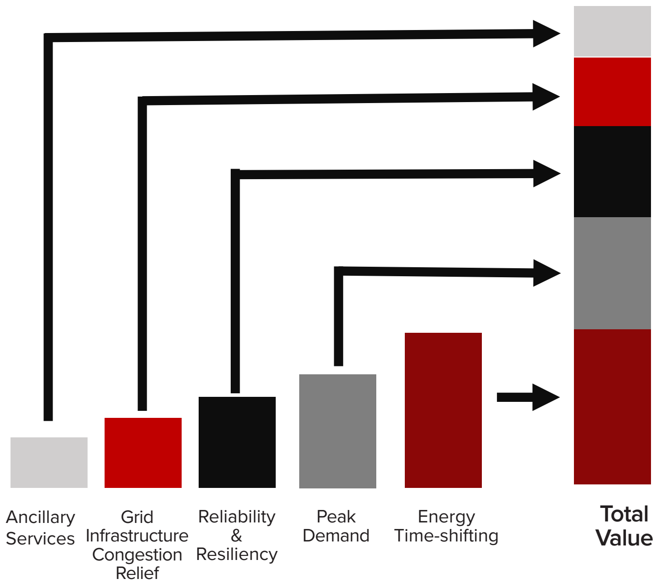
Both the power and duration of a storage unit must be known to understand the full cost picture, relative to its performance characteristics. In addition, it is worth noting that some costs scale with power and some scale with duration, which further confirms the need to understand both for more accurate cost assessments. Furthermore, using standard economic terminology to describe the cost of energy storage may be misleading, especially if compared side-by-side with conventional electricity supply and demand resources, if the performance characteristics and applications of energy storage are not taken accurately into account.

Cost figures for certain energy storage technologies, particularly batteries, are increasingly challenging to pin down due to the continued cost declines and projections for sustained cost declines over the forthcoming years. Guidance from the Electric Power Research Institute (EPRI) on current installed costs of energy storage shows that costs (in $/kW) vary according to project size, duration and technology.[26] The most competitive suppliers are estimated to offer large-scale energy storage for capacity applications (e.g., 50-100 MW, 4-hour) for as low as $1,600/kW. The authors of this guide, however, acknowledge that these figures are likely to be out of date within months of publication. Reports from multiple consultancies suggest that installed costs and/or component costs are expected to fall by 50% over the period 2016-2020.[27]

3. What is "Value Stacking"?

While discussion of energy storage economics tends to focus on cost, the services that the energy storage is intended to provide are an equally important component of this equation. Any thorough or reasonably accurate estimation of storage's value must take these services into account. In other words, determining whether storage is cost-effective requires that one specifically ask, "cost-effective for providing which services?"

FIGURE 4. ILLUSTRATIVE EXAMPLE OF ENERGY STORAGE "VALUE STACKING" CONCEPT



For further explanation and description of the different services storage systems can interchangeably provide, see Appendix A.

Storage can function as generation, load, and grid infrastructure, and even within those categories can operate in multiple different modes not traditionally seen in one resource. In addition, energy storage technologies can interchangeably offer multiple services, many of which are valued independently. Ancillary services, such as frequency regulation and ramping, are valued not for the electrical output so much as the ability to alternately inject or withdraw electricity over very short time intervals that help balance the grid. Capacity services, like spinning reserves, are valued not for electrical output on its own, but rather for the standby nature of the resource and deliveries at only hours of greatest need. Somewhat unique to energy storage is its ability to remain a flexible asset over the course of its life, capable of providing different services as the needs on the grid change over time. For example, an energy storage system could provide reserves for a few years and then shift to provide frequency regulation, or other services, if a higher value service is needed in the future. For further explanation and description of the different services storage systems can interchangeably provide, see Appendix A.

Combining multiple service values into a single system—known as 'value stacking'—ensures a more accurate reflection of the cost of the storage technology relative to the full range of energy storage benefits; in other words, an accurate cost-benefit analysis of energy storage must account for 'value stacking'.

ACCOUNTING FOR STORAGE'S SERVICES

A few recent studies and real-time economic analyses provide a more accurate economic snapshot of the unique nature of energy storage and the benefits resulting from the flexibility of its services:

- The Massachusetts government-commissioned State of Charge (2016) study estimated the potential overall benefits to ratepayers of large-scale energy storage deployment at more than two times the cost, and nearly three times the cost when benefits to resource owners are taken into account.[28] Avoided generation during peak hours of system demand accounted for half of the estimated benefits of storage.[29] Enhanced transmission and distribution capacity, including the ability to integrate more distributed energy resources, such as distributed generation, accounted for a quarter of the estimated benefits of storage.[30]
- A study of the Texas market found that energy storage providing both supply and network services could achieve benefits twice that of costs.[31]
- Several studies from the National Renewable Energy Laboratory (NREL) have concluded that storage provides significant system flexibility benefits, particularly by increasing the efficiency of the generating fleet.[32]
- The mid-Atlantic wholesale market operated by PJM found that it could reduce the reserves required for effective grid frequency regulation by 30% once fast-responding flexible resources like energy storage are deployed.[33]
- Similar findings were echoed in a study of the use of fast-responding flexible resources like energy storage in the Texas wholesale market.[34]

4. How and Where are Energy Storage Grid Services Compensated?

Some of the grid services that storage provides can currently be valued and compensated through rates or market mechanisms, but not all. In states participating in wholesale markets, compensation exists for a range of ancillary services; certain markets also provide compensation for capacity service. In states without wholesale markets, historically only the value for capacity is directly compensated; however, some states are initiating pilot efforts to address this limitation. And in all states, the value of storage to network or distribution services, such as avoiding substation or circuit upgrades, are not currently priced or monetized (see Table 2). Presently, the "value" of such services is typically assumed to be the avoided cost of the alternative, traditional solution, which does not account for other supply or load benefits that storage can provide.

TABLE 3. AVAILABILITY OF DIRECT COMPENSATION FOR STORAGE SERVICES ACROSS MARKETS

SERVICE	STATES IN WHOLESALE MARKETS	STATES NOT IN WHOLESALE MARKETS*
Supply Time-Shift / Arbitrage	Yes	Yes
Capacity / Resource Adequacy	Yes	Yes
Ancillary Services (e.g., frequency regulation, load-following / ramping, spinning reserve)	Yes	No**
Network Services (e.g., upgrade deferral, increased power quality, congestion relief)	No**	No**

* WA, OR, AZ, HI, AK, ID, UT, CO, FL, GA, SC, AL & TN do not presently participate in organized wholesale markets.
NV, MT, WY, NM, MS, NC, KY & MO have a portion of their state territory that participates in organized wholesale markets, but not the entire state.
** While atypical, there are recent emerging examples from a handful of utilities and states (CA, HI, MA & NY) with pilot initiatives underway to procure and offer compensation for these energy storage services. As market rules and polices change and adapt, so too will the opportunity for storage to receive compensation for its services.

Additionally, the flexibility of storage also provides electric system-wide efficiencies that are generally not directly, or even indirectly, valued or compensated. Those system values include but are not limited to:

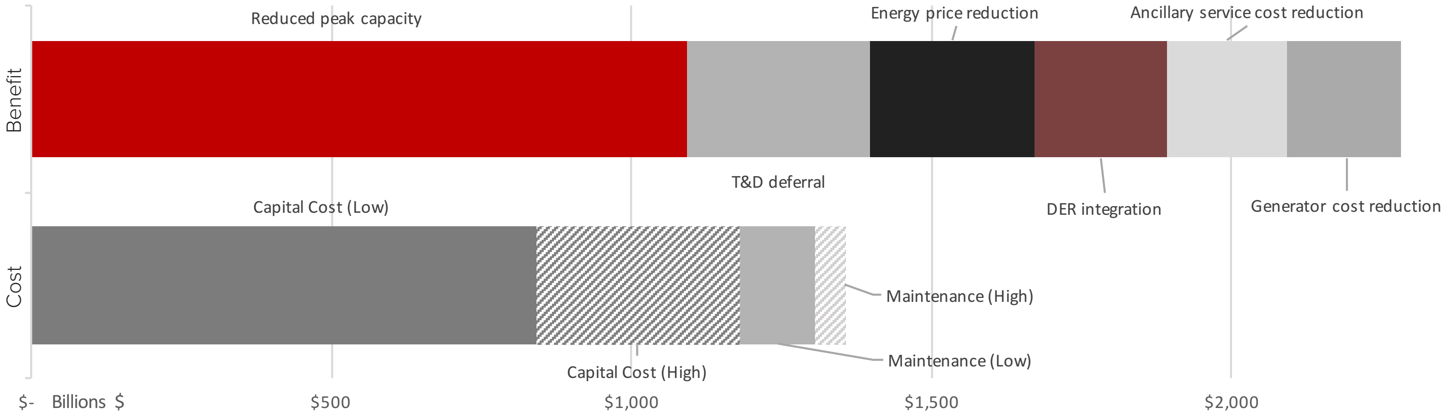
- More efficient use of the generating fleet (i.e., avoided fuel costs, avoided generator start-up/shut-down costs, increased heat rate efficiencies);
- Reduced reserve requirements (i.e., avoided peak capacity, avoided operating reserves);
- Enhanced risk management (i.e., black start/outage mitigation, fuel hedging value, reduced curtailment risk);
- Reduced emissions (i.e., local air quality permitting, greenhouse gas costs);[35]
- Reduced risks and costs to future ratepayers from the avoidance of stranded assets and/or more costly grid infrastructure and capital investments;
- Increased resiliency (i.e., capacity to recover quickly from natural disasters and/or preserve or restore critical emergency response infrastructure).

B. Assessing the Value of Energy Storage in a Policy Context

In addition to the challenges of assessing and compensating energy storage technologies for the full value proposition they can offer, the ‘value’ of energy storage can have different meanings depending on the policy context in which it is being discussed—i.e., the type of commission rulemaking, utility planning process, or other proceeding in which the question of storage’s value arises. In the broadest sense, estimating the value of storage means determining whether its benefit to grid operators, technology developers, end users and ratepayers outweighs the cost of the technology.

In its State of Charge report, Massachusetts took a broad approach to estimating storage’s value and asked under what conditions storage could be cost-effective if widely deployed throughout the state, finding that 1,766 MW of storage would deliver $2.3 billion in benefits to ratepayers (see Figure 5).[36] The report also found that only a third of the estimated benefits of storage can be monetized and compensated under existing regulations and market designs in their region.

FIGURE 5. MASSACHUSETTS “STATE OF CHARGE” ANALYSIS OF BENEFITS & COSTS OF STORAGE



Source: MA DOER State of Charge Report, 2016. Note: Graph recreated from original “State of Charge” report.

The Massachusetts study was the first of its scale directly addressing storage, and not all states will choose to follow its approach. Other states are considering storage's value in different contexts, such as through utility Integrated Resource Plans (IRPs) in Oregon and Washington and through extensive regulatory efforts to incorporate much higher penetrations of DER in New York and California. These and other efforts are discussed further in Section IV.

For state policymakers and utility regulators seeking to determine the 'value of storage,' the best starting point is to understand how the outcome of a valuation effort will be used to guide decision making. If a state is seeking a value for storage to help guide high-level policy decisions, this type of valuation will likely differ from that used to evaluate utility investment decisions, or to set a procurement price or rate. Depending on the type of proceeding, certain tools for measuring storage's value will be more appropriate; likewise, the challenges to valuation in each proceeding are likely to be unique.[37]

Because valuation of storage is still an evolving process that no state, commission nor utility has fully mastered, perhaps the most important takeaway for states, particularly those still early on the energy storage learning 'curve,' is that it is not necessary to wait until each of storage's myriad uses has a defined value before moving forward on the foundational policies and practices recommended in this paper or elsewhere. Indeed, it will be difficult to get to the point of accurately measuring value based on real performance if early adoption steps are not taken in some markets. California, for example, did not resolve the many complex valuation issues related to energy storage before implementing its storage procurement mandate (discussed in Section IV), and the state initially allowed utilities to develop their own proprietary methodologies to evaluate storage, while recognizing that commission review of these methodologies may be needed to ensure they account for storage's full range of benefits.[38] California continues to work closely with utilities and other stakeholders to develop a consistent valuation methodology.

1. Different Modeling Tools for Different Proceedings

Valuing storage is a different proposition depending on whether a state is updating existing regulations to address storage; administrating a generation, distribution or transmission planning effort; or overseeing a rate design case or other proceeding involving pricing storage's services. For each of these types of proceedings, as well as others, there are a variety of modeling tools (some public, most proprietary) that can help evaluate the value of storage (see Appendix B).

Utility commissions undertaking a broad study to determine whether storage can be cost-effective in their state may employ one or more storage-specific tools, such as, but not limited to, the Energy Storage Valuation Tool (ESVT) developed by the Electric Power Research Institute (EPRI), to determine the value of certain use cases based on a hypothetical bundle of services.[39,40] Because ESVT was primarily designed to estimate the value of storage that is directly compensable to a system owner or investor (sometimes called 'direct' value of storage), Massachusetts' State of Charge report expanded its analysis with Alevo Analytics' proprietary tool[41] designed to show how the use cases could achieve the greatest value to ratepayers (sometimes called 'system' value of storage). This analysis resulted in a benefit-to-cost ratio greater than one in most use cases.[42]

Commissions involved in long-range utility planning processes, such as IRPs or transmission planning, to determine where storage assets should be interconnected with the grid, will employ different methodologies for measuring storage's value relative to the supply or infrastructure resources that traditionally comprise such plans. Portland General Electric's 2016 IRP, for example, considers storage as a component in the utility's 'fleet' by asking which use cases would maximize storage's value to the utility's system, and whether the projected operational and capacity value of a battery system in 2021 (relative to cost) warranted including storage in the IRP.[43] This 'net cost of capacity' methodology does not typically consider the value of storage at a specific location on the electric system.[44]

Meanwhile, commissions engaged in more extensive planning efforts to incorporate more significant quantities of DER, including distributed energy storage, into their electric systems, such as in New York and California, are looking at the value of distributed storage and other DER at a more granular level. The Reforming the Energy Vision (REV) proceeding in New York and the Distribution Resource Planning process in California each seek common metrics for evaluating the 'net locational value' of DER.[45] These methodologies aim to address the fact that DERs, including distributed storage, have inherent temporal and locational characteristics that may not be reflected in a straightforward benefit-cost ratio or average value per kWh approach to estimating these resources' value. See Section IV for more details on state efforts.

CASE STUDY

Peña Station NEXT's Storage-Enabled Microgrid

Peña Station NEXT is the result of a partnership between utility Xcel Energy, the City and County of Denver, the Denver International Airport, real estate developer L.C. Fulenwider, energy storage software developer Younicos, and Panasonic Corporation of America. Xcel Energy's customers in Colorado—both on the same feeder circuit as Peña Station NEXT and beyond it—as well as Denver's residents are an additional, implied stakeholder group who also benefit from the microgrid, either directly in the present or indirectly in the future as a result of lessons learned at Peña.

The Peña Station NEXT microgrid project comprises five core elements: a 1.6 MWdc carport solar PV installation located over the Denver International Airport parking lot; a 259 kWdc rooftop solar PV array installed atop Panasonic's corporate office building using Panasonic HIT solar PV modules; a 1 MW / 2 MWh lithium ion battery system located at Panasonic's building; initial anchor load located at Panasonic's Denver operations hub building; and switching and control systems that will operate the battery energy storage system and microgrid functionality. The battery system at Peña Station NEXT will be leveraged for five major use cases whose services and benefits accrue to different combinations of the core stakeholders: solar grid integration, including ramp control for solar smoothing and solar time shifting; grid peak demand reduction; energy arbitrage; frequency regulation; and resilience through backup power.

Once the microgrid is live in early 2017, Xcel Energy, Panasonic, and the other project partners will gather data to review real-world performance and make refinements over time. After completion of the two-year pilot, the project partners will analyze the battery system performance data to determine the optimal settings for the remainder of the battery's estimated 10-year life span, or eight years beyond the initial two-year demonstration pilot.

Source: Energy Storage Association

Yet another context in which valuation of storage arises is in state proceedings involving pricing of storage's services when provided by customers or third-parties, or behind the meter storage, including the design of appropriate rates for customers able to offer those services. Commissions overseeing these proceedings may need to determine whether utilities' costs to procure storage assets can be accurately represented through just and reasonable electricity rates. Pricing to accurately reflect storage's value remains imperfect, however, and according to the New York Department of Public Service staff, may not be "immediately achievable given today's costing methods, available data, current utility tariffing, and the technology infrastructure in place."[46] While no state has defined a specific rate for energy storage, efforts are underway as growing deployment and early policy efforts are spurring greater attention to this issue. Existing competitive procurement processes, such as California's Renewable Market Adjusting Tariff (ReMAT),[47] could be modified and applied to storage as an effective means to let the market set the rate for services. Another example is Consolidated Edison's Brooklyn-Queens Demand Management pilot project, wherein the utility issued a request for proposals for non-wires alternatives, demand-side, and utility-sited resources as an alternative to $1.2 billion in traditional grid upgrades.[48] Ultimately, with continued attention on this front, state efforts to establish more specific storage valuation methods will become easier in coming years.

2. Adaptation of Tools to Accurately Assess the Value of Energy Storage

In general, models used to assess or determine the value of storage may need to incorporate more specific inputs than models used for other energy resources; for example, because load profiles and system needs differ by location, the precise location of storage assets is critical to accurately understanding its value on the grid. In addition, models for storage need to be able to assess activity over shorter (sub-hourly) time intervals to reflect storage's ability to provide ancillary services that involve rapid charging and discharging.[49]

Many of the available storage-specific tools can model with decent accuracy both the 'direct' and 'system' value of storage systems, particularly when combined with one or more other tools to reduce analytical gaps. The table on page 13 shows a few examples of the existing tools and methodologies that measure the value of energy storage, as well as the benefits, use cases and methodological focus included under each tool. In addition, three of these tools evaluate energy storage using optimization models to determine the "optimal" mix of technologies or dispatch of grid services. The Pacific Northwest National Lab's Energy Storage System (ESS) evaluation tool analyzes the economic value of a singular storage system when optimally operated on the grid to meet multiple objectives. Both National Renewable Energy Laboratories' REopt tool and Alevo Analytics' Advanced Storage Optimization Tool (ASOT) model the dispatch of all technologies, including clean energy as well as conventional resources, to optimize the deployment of storage and achieve desired energy performance and cost savings.

A SELECTION OF ENERGY STORAGE-SPECIFIC MODELING TOOLS

The following table summarizes the range of functions of a selection of energy storage–specific modeling tools. As opinions may differ on each tool's capabilities, this information is intended as illustrative and the tools' authors should be contacted for specific information on their respective functions.

TOOL	GRID SERVICES/BENEFITS																			
	Energy Time-Shift (Arbitrage)	Resource Adequacy/Supply Capacity	Load Following	Frequency Regulation	Electric Supply Reserve Capacity	Voltage Regulation	Transmission Upgrade Deferral	Distribution Upgrade Deferral	Transmission Support	Transmission Congestion Relief	Substation On-site Power	TOU Energy Cost Management	Demand Charge Management	Reliability (Backup Power)	Power Quality	Renewable Energy Time Shift	Renewables Capacity Firming	Black Start	Wind Grid Integration	Greenhouse Gas Impacts
EPRI ESVT	✓	✓		✓	✓			✓												
ES-Select™	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓		
NREL REopt	✓			✓			✓	✓				✓	✓	✓						
PNNL ESS Tool	✓	✓						✓						✓						
Navigant ESCT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Alevo ASOT	✓	✓		✓	✓	✓	✓	✓												✓

Note: This is a small sampling of tools used for energy storage valuation.

BRIEF DESCRIPTIONS:

EPRI ESVT	Electric Power Research Institute's (EPRI) Energy Storage Valuation Tool (ESVT) is a simulation tool used to analyze the cost-effectiveness of energy storage. EPRI now has a new tool, which is the next generation of ESVT, called the Storage Value Estimation Tool (StorageVET) which is not included in the table above.
ES-Select™	is an interactive tool, created by DNC-KEMA in collaboration with Sandia National Laboratories, that helps users identify feasible energy storage technology options. The tool is licensed for public use.
NREL REopt	The National Renewable Energy Laboratory's (NREL) REopt is an optimization model used to determine the cost-optimal combination of renewable energy, conventional generation, and energy storage to meet specific objectives.
PNNL ESS Tool	The Pacific Northwest National Laboratory's (PNNL) Energy Storage Systems (ESS) Evaluation Tool is an input-output model that runs a one-year simulation to estimate the economic value of an energy storage system when optimally operated.
Navigant ESCT	Navigant Research's Energy Storage Computational Tool (ESCT) is a screening tool designed to help users understand the financial benefits of storage deployment.
Alevo ASOT	Alevo Analytics' Advanced Storage Optimization Tool (ASOT) is a model that was used to evaluate the optimal deployment and distribution of storage on the Massachusetts grid. Additionally, this model calculated the amount of greenhouse gas emissions that could be reduced by energy storage.

These tools' ability to estimate and demonstrate the value of energy storage at a detailed level has yet to be carried over into traditional modeling methodologies, i.e., those used for long range generation or transmission planning or electric resource pricing. Typical planning models, for instance, are not granular enough to capture the operations of advanced storage, and models use inaccurate and generally out-of-date cost information. When it comes to their ability to assess storage's value, traditional tools lag behind. However, Hawaii and California are notably working to adapt and/or develop tools to evaluate energy storage more comprehensively in the context of long-term grid planning and grid operations, and states should keep an eye on future developments on this front.

Furthermore, depending on the regulatory structure in place in each state, storage value may not always be transparent. In vertically integrated states, as noted above in Section III.A.4, the absence of wholesale markets for generation or ancillary services makes it difficult to 'see' the value of storage at the state distribution level, as well as at the bulk system level. In restructured states, on the other hand, energy storage's value depends on whether all of storage's services can participate in energy markets. Rules in many regions, for example, may prevent storage from providing ancillary services or transmission services.

C. Key Takeaways for State Policymakers

- The flexibility of applications and multitude of services make it difficult to fit energy storage easily into the 'box' of more traditional economic modeling tools and cost-benefit analyses. Questions surrounding 'who controls' and 'who benefits from' storage further complicate cost-effectiveness assessments.

- There is not yet a commonly accepted approach for assessing the value of energy storage, nor is there a single modeling tool or compensation methodology to provide the 'silver bullet solution'. However, because valuation of storage is still an evolving process, states should not wait until each of storage's myriad uses has a defined value before developing the storage policies recommended here or elsewhere

- While more work and discussion on this topic is needed, states can move forward with steps to identify ways to integrate storage into existing modeling, planning, and other policy frameworks, which, in turn, will likely further progress to adapt these frameworks to better suit energy storage.

- The cost of energy storage only has meaning relative to the expected services and performance it will provide. Any thorough or reasonably accurate estimation of storage's value must take its services into account. Determining whether storage is cost-effective requires that one specifically ask, "cost-effective for providing which services?"

- The question of whether the cost of energy storage is economically justified can be answered more accurately by accounting for system-wide benefits, in addition to direct service values.

- Energy storage faces barriers to market participation and compensation for these direct services in many places. Overcoming barriers to market participation and compensation is critical to ensure the full value of storage can be realized.

- The lack of market structures to value and compensate the benefits of energy storage is a significant barrier to large-scale deployment. The cost-competiveness of storage hinges on a regulatory framework that enables accurate compensation of energy storage services.

- Somewhat unique to energy storage is its ability to remain a flexible asset over the course of its life, capable of providing different services as the needs on the grid change over time. For example, an energy storage system could provide reserves for a few years and then shift to provide frequency regulation, or other services, if a higher value service is needed in the future.

- Determining the value of energy storage requires context and there is not yet one accepted tool or method available that accurately captures the full range of its benefits. For regulators seeking to determine this value, the best starting point is to understand how the outcome will be used to guide decision making.

- The location of storage assets is critical to accurately understanding its value on the grid. In addition, models for storage need to be able to assess activity over shorter (sub-hourly) time intervals to reflect storage's ability to provide ancillary services that involve rapid charging and discharging of batteries.

- Estimating and demonstrating the value of energy storage at a detailed level has yet to be carried over into traditional modeling methodologies by regulated system owners and operators, i.e., those used for long-range generation or transmission planning or electric resource pricing. Typical planning models, for instance, are not granular enough to capture the operations of advanced storage, and models use inaccurate and out-of-date cost information. When it comes to their ability to assess storage's value, traditional tools lag behind.

Credit: S&C Electric Company

IV. State Regulatory Approaches to Energy Storage

When IREC first published Deploying Distributed Energy Storage in February 2015, states were beginning to take legislative and regulatory steps to proactively address the role that energy storage would play in the future electric system. Since that time, activity has begun to pick up significantly, though most states are still in the early phases of their energy storage integration activities. As might be expected, the states where energy storage is being deployed the fastest are also the states taking the most significant policy and regulatory actions related to energy storage.

To date, California, Oregon and Massachusetts are the only states to affirmatively require the regulated utilities to procure energy storage, but other states, including New York, Arizona, Hawaii, and others have begun to consider a variety of other regulatory changes that will help facilitate the use of energy storage going forward.

The nature of these policy and regulatory actions varies depending on market type (restructured versus vertically integrated), mechanisms used by policymakers to spur development, and actions adopted. It is nonetheless worth noting that California is the state most heavily discussed herein, due to its broad range of progressive action on energy storage issues.

Building on Deploying Energy Storage, state policy actions on storage can be grouped in the following core categories (See Figure 6):

FIGURE 6. CATEGORIES OF STATE POLICY ACTIONS ON DISTRIBUTED STORAGE

Energize

States that are encouraging storage market growth through procurement targets, pilot/demonstration project funding,or other mandates or incentives.

Plan

States that are addressing storage within a broader context when planning for the energy future through long-term resource planning, resource valuation efforts, grid modernization or distribution system planning.

Clarify

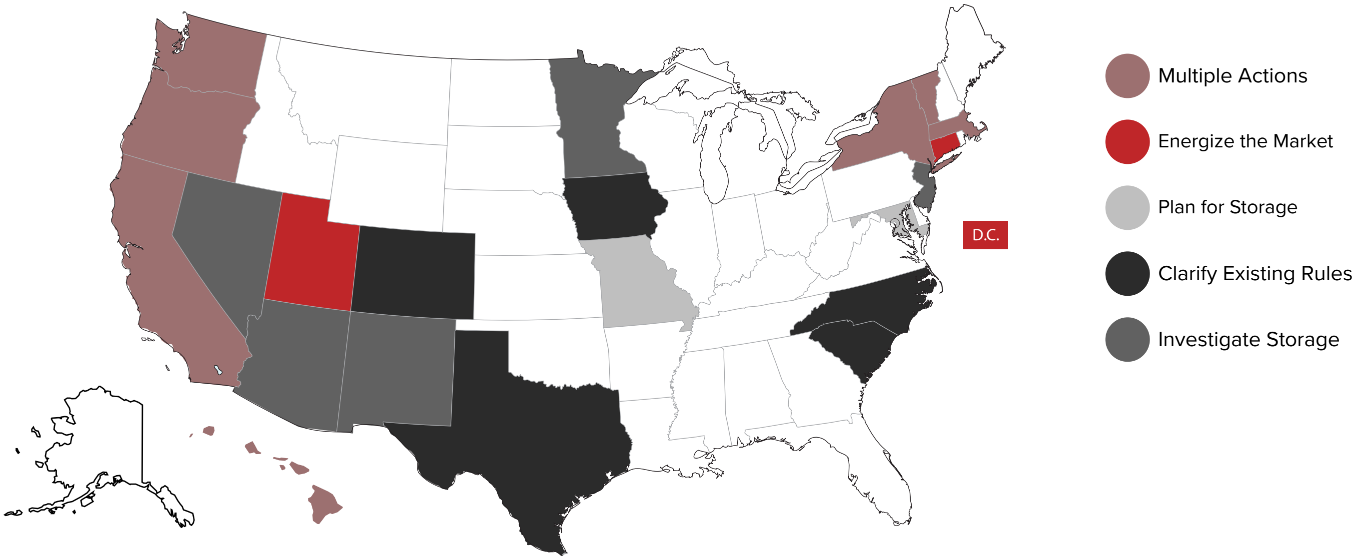
States that are clarifying existing rules as they apply to storage, through revising interconnection, net metering, fire and building codes, and others as applicable.

Investigate

States that have demonstrated an interest in storage through general investigations, workshops, or briefings.

The examples from each of these categories, provided below, are not intended to be exhaustive or to describe in detail all aspects or outcomes of each proceeding, but rather to provide illustrative examples of the types of steps states are, and possibly should, be taking to advance energy storage. In addition, states may choose to pursue actions in multiple categories simultaneously, and as energy storage markets continue to grow and as more experience is gained across the country, not all states may want or need to pursue more time-intensive investigative efforts. Indeed, states leveraging others' experience and the growing body of information on storage will help scale storage more swiftly, avoid reinventing wheels, and support continued cost reductions and increased benefits over time.

FIGURE 7: MAP OF STATE POLICY ACTIONS ON ENERGY STORAGE



Note: Map is not reflective of all state activities on energy storage. Certain early stage policy/regulatory efforts, grant programs and/or pilot projects may not be reflected herein.

A. Investigate Storage

Several states have demonstrated a specific interest in energy storage and have taken exploratory steps to evaluate the potential costs, benefits, functions and regulatory needs of energy storage. In general, regulators at this stage have yet to enact concrete policy or take specific regulatory actions required to enable energy storage, but are instead demonstrating interest with studies, working groups, workshops, and/or pilot programs. However, others have turned these initial exploratory actions into more concrete steps. For example:

- Oregon Following an energy storage workshop hosted by the Oregon Department of Energy (Department) and the Oregon Public Utility Commission in March 2014, the Department subsequently sought comments on the design of a potential program to support demonstration projects.[50] In June 2015, the state legislature passed the nation's second energy storage mandate (after California's) for utilities to procure a minimum of 5 MWh and up to 1% 2014 peak load of advanced energy storage by 2020 (discussed further below).

- Massachusetts In 2015, the Massachusetts Department of Public Utilities held a Stakeholder Conference to discuss issues relating to energy storage deployment.[51] In September 2016, under the Department of Energy Resources' (DOER) Energy Storage Initiative (ESI), Massachusetts released the State of Charge report, concluding that deploying 1,766 MW of storage would be cost-effective. The report also provided recommendations for growing the state's energy storage market, including amending the state's renewable portfolio standard, requiring that storage be considered in future procurements, and streamlining existing interconnection requirements. In December 2016, following authorizing legislation, DOER decided to adopt a storage procurement mandate for the state, which must be adopted by July 2017 (discussed further below).

- Nevada In early 2016, Nevada's Public Utilities Commission opened an Investigation Regarding Energy Storage Technologies to investigate battery storage technologies.[52] The ongoing investigation involves a series of stakeholder meetings and workshops to discuss such storage-related issues as interconnection, valuation, and integration into utility planning. Workshops are ongoing, so it remains to be seen what additional steps (if any) result, particularly in light of Nevada voters' passage in November 2016 of an initiative to open the state's electricity market to competition.

Credit: AES Energy Storage

- **Washington** In 2013, the legislature approved funding for energy storage demonstration projects. In May 2015, the state's Utilities and Transportation Commission ("UTC") staff released a white paper recommending that UTC develop a policy requiring utilities to reflect the value of energy storage's benefits in their IRP processes.[53] In August 2015, UTC hosted a stakeholder workshop. The investigation, and other issues relevant to modeling storage, have since been rolled into another docket studying utilities' IRPs more broadly.[54]

- **Arizona** In 2014 the Arizona Corporation Commission ("ACC") held investigations into distributed and centralized energy storage, as part of a broader proceeding focusing on potential impacts on current utility business models from innovation and developments in the generation and delivery of energy.[55] In August 2016, the ACC opened the first review of the state's Renewable Energy Standards and Tariff (REST) in almost 11 years. Among the Commission's proposals was including new technologies, such as energy storage, in the REST.[56]

- **New Mexico** A series of meetings of the New Mexico Renewable Energy Storage Task Force in 2013, to review, discuss and study energy storage, resulted in a list of recommendations to the legislature for future activities and actions.[57] In 2015, the state released a new, comprehensive energy plan, whose recommendations include to "promote New Mexico as 'the' place to develop and test energy storage technologies" and to "pursue energy storage technology development and demonstration projects such as advanced batteries and flywheel/hydraulic energy storage systems."[58] In February 2017, on its own motion the New Mexico Public Regulation Commission initiated a rulemaking on including energy storage in IRPs.[2]

1. Key Insights

While the foregoing examples have resulted either in concrete policy outcomes, or are on a possible path to doing so, other examples highlighted in Deploying Energy Storage do not appear to have had measurable results yet. These include a white paper on energy storage published by the Minnesota Department of Commerce in early 2014,[59] and a funding opportunity for energy storage in New Jersey,[60] among other investigations.

Based on the examples above, we can draw some general conclusions about the effectiveness of early-stage investigations and workshops. While some proceedings, such as those in Massachusetts and Oregon, appear to have resulted in more robust policy actions—and others, like New Mexico and Washington, may be on their way to doing so—for the most part these investigations' direct effect on energy storage policymaking is small unless they are an early step on a clear "path" from workshops to eventual action.

A goal of Massachusetts' Energy Storage Initiative beyond initial workshops, for example, was funding pilot projects and producing the State of Charge report. In addition to providing a wealth of information for out-of-state policymakers and stakeholders interested in energy storage, including chapters covering modeling the grid benefits of storage, and use cases of specific storage applications, the report lays out concrete policy proposals.

> There is now a greater body of evidence available to regulators, from these earlier state investigations and other reliable sources, about the uses, economics, and role of energy storage.

The intended outcomes of Nevada's investigation, on the other hand, are less clear. While the workshop participants may be on the way to consensus on basic revisions to the state's interconnection requirements to address storage, "bigger picture" items such as the role of storage in utility resource planning could get mired in complexity without clearer guidance from the Commission.

In sum, without some sense of where the state wants to "end up," investigations risk bearing little fruit for commissions and workshop participants alike. States in the beginning stages of considering integration of energy storage can benefit from investigative proceedings and workshops so long as these processes include clear goals and next steps, such as the eventual consideration and adoption of meaningful policies such as those discussed in the following sections. In addition, there is now a greater body of evidence available to regulators, from these earlier state investigations and other reliable sources, about the uses, economics, and role of energy storage. Regulators may be able to rely on these outside sources to plan for more immediate regulatory actions rather than needing to take as many exploratory steps up front in their own state.

B. Clarify Existing Rules as They Apply to Storage

Several states, particularly ones with higher penetrations of distributed generation and increased customer demand for "paired" storage resources (e.g., storage combined with solar PV) are working to clarify and amend interconnection, electricity rates, net metering, and a range of other existing regulations to address energy storage. Allowing energy storage systems to operate effectively under existing regulations is an important first step to stimulating the market, without requiring the creation of entirely new programs.

1. Interconnection Standards

The ability to interconnect systems to the transmission and distribution grid in a fair and efficient manner is fundamental to allowing energy storage to provide the services discussed in the previous sections.

> The ability to interconnect systems to the transmission and distribution grid in a fair and efficient manner is fundamental to allowing energy storage to provide services.

- California has been a leader in revising and clarifying its existing interconnection and net metering rules to address storage resources. In mid-2016, as part of its "Rulemaking to Improve Distribution Level Interconnection Rules and Regulations for Certain Classes of Electric Generators and Electric Storage Resources," the CPUC set forth a revised process for analyzing requests for interconnection of behind-the-meter, non-energy exporting energy storage devices.[61] In particular, this decision clarified how the rules for interconnecting new load (California's Rules 2, 15, & 16) would interact with the rules for interconnecting new generation (Rule 21) when it comes to energy storage. The decision also set forth further steps to define an expedited interconnection process for non-energy exporting storage, a special review process for certain "converter" technologies and to address rules regarding how non-export will be defined. California's interconnection rules already included energy storage in the definition of generator and generating facility, unlike many states. The 2016 decision demonstrates the range of unique issues that the interconnection of energy storage presents, but it is only a modest first step and it is likely that the state will need to address questions regarding how to interconnect exporting energy storage systems in coming years, among other questions.

Outside of California's more comprehensive effort, most states have only begun to take modest steps to address how applications to interconnect energy storage systems will be reviewed. Principally, states have clarified that the existing rules apply to energy storage systems (usually by including storage within the definition of a "generator") and, in some cases, they have clarified how the "net output" of energy storage facilities will be defined. These were the initial steps recommended by FERC in its 2013 update of the Small Generator Interconnection Procedures (SGIP), which acts as a model for many state procedures.

- In May 2015, North Carolina, a state with significant solar penetration, adopted new procedures based partly on FERC's newly updated SGIP. North Carolina took FERC's suggestion and clarified that battery storage may be connected to the grid through the same procedures as other "small generating facilities."[62] The state did not, however, follow FERC's lead regarding how to define how the net output of a storage facility will be reviewed. South Carolina soon followed North Carolina's lead and adopted similar changes.[63]

- In spring 2016, Minnesota reopened a proceeding to update its interconnection standards to clarify technical screens, timelines and other transparency measures; stakeholders have encouraged the commission to adopt FERC's model SGIP interconnection rules for Minnesota's distribution system and, therein, have included suggested changes to accommodate energy storage systems.[64]

- In December of 2016, Iowa adopted new interconnection rules for distributed generation. The new rules not only incorporate energy storage into the definition of eligible distributed generation facilities, but they also include storage in various portions of the standards to clarify applicability and some unique operating capabilities. There is more to do to create a truly efficient energy storage review process, but these changes are a positive start for the Midwest.[65]

- Additionally, as noted above, Nevada is considering changing its interconnection standard ("Rule 15") to include storage in the definition of generation resources for purposes of interconnecting to the distribution grid, among other changes.[66]

- In 2017, as a part of larger grid modernization efforts, the District of Columbia recommended rulemakings to develop definitions of energy storage and to update interconnection procedures for storage.[67]

2. Net Energy Metering

Clarification of the application of rules regarding net energy metering (NEM) to storage systems (alone or paired with other NEM eligible generators) impacts the behind-the-meter storage market. While some states are evaluating storage in the context of existing NEM policies, others are discussing how storage fits into NEM successor and/or other tariffs.

- As part of a proceeding begun in 2012,[68] California clarified its existing NEM policy, to ensure that when NEM eligible renewable energy devices are coupled with energy storage systems, customers' NEM credits can only be generated by energy produced by those eligible facilities and not from energy pulled from the grid. These clarifications were important to enable co-located storage systems, but also to maintain the integrity of the NEM program, which is designed to promote only renewable self-generation. The new rules included size limits and metering requirements for solar-plus-storage systems larger than 10 kW,[69] and a new NEM estimation methodology for smaller paired systems, which places a cap on the allowable number of kWh exported to the grid instead of a costlier metering requirement. The new estimation methodology only applies to customers paying "time-of-use" (TOU) rates, since there is only a financial incentive where systems can consume grid energy more cheaply during one time period and then receive bill credits for discharging to the grid at a higher rate at other times.[70]

- Hawaii, which has the highest penetration of customer-sited solar PV in the country, and the most aggressive renewable portfolio standard (100% by 2045) in the US, capped its NEM program in fall 2015. The state has yet to decide on a permanent replacement program. Under the interim rules, customers with on-site solar PV had two options: the first option allows for a limited amount of energy exportation to the grid (presumably managed through the adoption of on-site energy storage), while setting a fixed minimum bill of $25 for residential customers; the second option allowed for continued exportation to the grid, with excess generation credited at a lower-than-retail, fixed rate depending on customers' location. Until recently, the second option proved more popular; however, in December 2016 the cap on this option was reached and solar PV customers are for now left with the first option (solar paired with storage), which was one of the aims of the interim program.[71]

- Massachusetts is in the process of designing a new solar incentive to replace NEM, which would, among other things, employ incentive adders to encourage co-location of solar PV and storage assets behind the customer meter, and to encourage siting of energy storage with standalone generators.[72]

- Colorado's main retail electricity provider, Xcel, is adopting alternative rate structures following a recent settlement. The new structures recently approved by the Commission are designed to recover a larger portion of the utility's costs than is possible under the current NEM tariff. Under the proposed structures, NEM customers will need to decide between a rate schedule where they would pay TOU rates, versus another schedule where they would pay demand charges.[73,74] The adoption of a new rate structure may impact market uptake of NEM systems paired with energy storage.

Credit: S&C Electric Company

CASE STUDY

Village of Minster, Ohio

In 2016, the Village of Minster, located in western Ohio, became the first municipal utility to combine solar power and energy storage. By purchasing power from the system, the city is expanding its renewable energy use while reducing electricity costs for ratepayers and increasing the reliability of the grid. To achieve greater savings and increase the project owner's return on investment, the 7 MW/3 MWh lithium ion energy storage system was designed to capture multiple revenue streams through frequency-regulation, power quality, and demand response services.

As the primary service, the storage facility provides fast-responding frequency regulation in the wholesale market through frequent charging and discharging cycles. As a secondary but congruent service to frequency regulation, the storage facility provides reactive power compensation ("var support") to combat an occasional low power factor on the system, eliminating the need to install approximately $350,000 of var-compensation equipment. As a third service, the storage facility provides demand response capability for peak load periods, which reduces the peak-load contribution charge.

Source: Energy Storage Association

RATE DESIGN TOOLS FOR ENERGY STORAGE

Under Time-Varying Rate (TVR) electricity pricing, the price per kWh of electricity is higher during peak periods and lower during off-peak periods. TVR pricing is a form of "demand management" – in other words, providing for greater control of electricity demand rather than increasing supply – and can incentivize uptake of energy storage technologies which in turn can give customers more control over their energy bills. TVR rates and other variable pricing structures also reduce demand on generation facilities, including high-emitting "peaker" plants, and allow transmission and distribution owners to defer expensive upgrades.

One type of TVR, time-of-use (TOU) pricing, is not a recent development: for example, California has allowed utilities to use TOU rates for mid- to large-size customers since 2008. In December 2015, the CPUC began a rulemaking to develop a framework for designing, implementing, and modifying time periods for use in future residential TOU rates.[75] Through the rulemaking, the CPUC aims to adopt TOU rates that provide incentives for energy storage, including paired solar and storage, to respond to rate-based price signals and optimize behind-the-meter output. Numerous other states are also considering, or expanding, their use of TVR.[76] Energy storage providers are particularly interested in the development of TVR structures as they are a key tool to enabling customers to utilize storage systems to capture savings from shifting demand periods, while also responding to broader system needs. It is likely, however, that the differential between the normal and peak pricing periods will need to be relatively significant to result in a meaningful monetization opportunity for energy storage.

Another kind of rate structure that is designed to shift how and when customers manage their energy is a demand charge, which sets an electricity price based on a measure of the customers' maximum instantaneous demand, or peak demand, for electricity rather than (or in addition to) the customers' total monthly consumption. Customers with demand charges tend to have greater incentive to adopt demand side management (DSM) measures and may be more inclined to invest in energy storage to reduce their peak demand, thus reducing their customer charge. Demand charge management is one of the principle revenue streams for many customer-sited storage systems. While demand charges have been in place for commercial and industrial customers for several years, demand charges for residential customers have not been widely adopted, and are considered by many to be problematic because of concerns about their complexity and the potential risk of price-gouging, especially for customers who cannot easily adopt DSM, energy storage or otherwise easily control their demand.

3. Key Insights

California has shown both how important, and how helpful, it can be to move ahead quickly with clarifying and/or modifying existing policies to more explicitly address energy storage. Even in a state with assertive policies like California's, including an incentive program and procurement mandate, we have seen that the market can stall if these foundations are not yet in place. Failing to clarify existing policies can lead to backlogs and potentially costly delays. As an example, California had to issue extensions to parties with incentive reservations under SGIP while it worked out how to meter and allocate interconnection costs for storage systems co-located with NEM eligible renewable generators.[77] As has commonly been the case for newly launched solar programs,[78] it is also highly likely that interconnection issues could emerge as a significant blockade to the success of storage programs if they are not addressed prior to the launch of any incentive, procurement mandate, or other storage-centric program.

> California has shown both how important, and how helpful, it can be to move ahead quickly with clarifying and/or modifying existing policies to more explicitly address energy storage.

The experience in Hawaii with the NEM program, on the other hand, has shown how storage can be used to help enable transition to a different compensation policy for renewable generators. A similar circumstance may emerge in the case of interconnection policy where storage may become a solution to allow for additional DER penetration while avoiding significant upgrade costs.

Beyond NEM and interconnection, every state will have other policies that require further clarification as they relate to energy storage, such as local permitting and code requirements for behind-the-meter projects, requirements surrounding certificates of public convenience for front-of-meter projects, and other statutory definitions that may need clarification to ensure consistency throughout other energy-related statutes or rules, and others not covered herein.

Ultimately, states should identify which policies are already in place in their state that new energy storage project will interact with, assess whether they may need modifying in order to clarify storage's role under those policies, and move ahead with those revisions as a first-priority effort.

C. Energize the Storage Market

Certain states have moved beyond early exploration of energy storage and have elected to provide direct stimulus to help facilitate the growth of the market, either through the adoption of storage procurement requirements, the use of financial incentives, or through funding for pilot or demonstration projects. A procurement requirement sets out a clear target: typically, a MW amount of grid-interconnected storage, which alone does not require direct financial incentives or an outlay of initial funding. Other approaches encourage energy storage adoption through financial incentives or direct funding, which require an initial allocation, or reallocation, of funds (ratepayer dollars or taxpayer dollars, or both). Other states, namely Hawaii, have found that ambitious renewable portfolio standards have also acted as an important indirect measure to drive the energy storage market because achievement of goals like 50% or more of renewable energy creates a greater demand for storage's grid balancing services.

1. Procurement Requirements

- California's storage procurement requirement (AB 2514) remains the most visible and ambitious policy aimed at stimulating the storage market to date in the United States, and has proven to be a significant driver for the quickly growing energy storage market in California. Established by legislation in 2010 and still undergoing phased implementation by the CPUC,79 California's storage requirement requires investor-owned utilities to meet an overall energy storage procurement target of 1.325 gigawatts (GW) by 2020. AB 2868 (Gatto, 2016) ordered the utilities to explore the feasibility of increasing the procurement target by an additional 500 MW. The procurement targets for each utility are further specified and subtargets for transmission-connected, distribution-connected, and customer-side storage were established. In 2014 the CPUC approved the utilities' storage procurement plans and the utilities are continuing to issue solicitations, with the most recent solicitations issued in December 2016.

- Oregon adopted a storage procurement requirement for its investor owned utilities through legislation in 2015 (HB 2193) and is undergoing implementation by the state PUC;80 the Commission has circulateddraft procurement guidelines for stakeholder comment. By January 2018 the Commission must begin considering storage project proposals, and implement the final procurement program by January 2020.

- In December 2016, pursuant to legislation (H. 4568), the Massachusetts Department of Energy Resources determined it will adopt a storage requirement by July 2017.[81]

- In March of 2017, the New York Public Service Commission ordered the utilities to each have at least two energy storage projects deployed and operating at two distribution substations or feeders by the end of 2018.[82]

- More modestly, in January 2016, the Connecticut Department of Energy and Environmental Protection has directed its electric distribution utilities to propose energy storage projects as grid enhancements pursuant to Public Act 15-5.[83]

Whether or not other states choose to follow a similar policy path, California's, Oregon's and Massachusetts' actions will likely have impacts on energy storage markets in other states, by spurring development of model regulatory frameworks (including the revisions to existing regulations, standards and rate structures discussed above) which could serve as examples elsewhere; providing "case studies" demonstrating to energy storage stakeholders what results when states implement storage solutions at a large scale, thereby helping ease regulators and utilities' concerns; helping bring down the installation costs and soft costs of advanced energy storage technology deployments; and generating additional research and information on energy storage deployment as the procurement mandates are implemented and mature.

2. Storage as part of Renewable Energy Standard and Clean Energy Procurements

As noted above, strong renewable energy standards ("RES") can help drive storage deployment indirectly by increasing the need for the grid and energy balancing services storage can offer. Another way some states are more directly stimulating their energy storage markets is by including storage as part of an existing RES or alternative energy portfolio standard ("APS"). Vermont's RES, H. 40 (Act 56), was amended in 2015 to require that two percent of each retail electricity provider's annual sales come from "energy transformation projects," or projects (expressly including energy storage systems) that provide energy-related services other than the generation of electricity and that result in a net reduction in GHG emissions attributable to retail electricity customers.[84] Massachusetts' APS currently applies to fly-wheels, combined heat and power, and gasification.[85] The State of Charge report makes note that "amending [Massachusetts' APS] would help close the revenue gap for storage project developers by creating an additional revenue stream to monetize the system benefits not readily captured by storage developers, but which ultimately flow to all ratepayers in the form of lower electricity prices."[86] The result of such an amendment, which is still in the early stages of consideration, remains to be seen. Another method for achieving similar goals is to include storage in clean energy procurements. Pursuant to Public Act 15-107, Connecticut included energy storage as a discrete resource category in a 2016 small-scale clean energy solicitation, seeking competitive bids that could be compared with renewables and energy efficiency.[87]

3. Incentives and Direct Funding for Pilots or Projects

At this time, only a handful of states provide direct financial incentives for energy storage as part of an established program. With the exception of California's Self Generation Incentive Program (SGIP), which has provided incentives for advanced energy storage systems since 2008 and was updated in 2016 with new storage eligibility requirements (including a 15% carve-out from the existing energy storage budget category for storage projects installed at residential sites, and a higher incentive level for such projects relative to larger storage projects),[88] these programs are still emerging. The SGIP has had a very significant effect on the growth of the storage market in California.[89] It remains to be seen whether similar incentives in other states, particularly if acting without the foundational policies discussed above, could have similar effects.

Many states offer other forms of financial support for pilot and demonstration energy storage projects, such as clean energy grants or funds. In January 2016, New York's public utility commission approved a 10-year, $5.322 billion Clean Energy Fund, which includes funding for energy storage projects.[90] Washington State operates a more modest clean energy fund, with $14.3 million available in matching grants for utilities to further their storage capacity, particularly to allow greater integration of renewables into the grid. The Fund in 2013 supported four storage projects, and changes in 2016 expanded the scope to support grid integration projects more broadly.[91] Utah's SB 0115 includes funding for pilot projects including new, utility-scale battery storage,[92] and other storage demonstrations are being funded through similar authorized programs.[93]

In addition, there are numerous utility-led energy storage pilot projects proposed and in place, which are not captured here. Depending on the circumstances, states do not necessarily need a separate funding source for utility energy storage projects if utilities are granted regulatory permission to execute well-developed pilot programs (with clearly articulated objectives and regulatory oversight), which will allow the utility to gain more experience with the technologies, thus enabling them to integrate storage in their portfolios for the long-term benefit of ratepayers. However, funding directed specifically towards energy storage projects may be more effective at incentivizing utilities to take advantage of the learning opportunity when it comes to these new technologies.

4. Key Insights

While direct funding efforts act to stimulate the storage market, they are often part of early-stage investigations into storage technologies, and thus not on par with broader-scale policy approaches, such as storage procurement requirements or addressing storage in an RES or APS. As such, they may have limited value without a concrete plan for further supportive policies and market opportunities. One-off funding for pilot projects may demonstrate to a utility or commission that a particular example of storage is feasible or cost-effective, but this is not the type of robust policy foundation necessary to ensure a state's storage market is self-sustaining. To the extent policymakers and regulators have oversight or review of the pilots, projects should have clearly defined objectives in mind and a transparent means to track, measure and evaluate the information gleaned from the pilot effort, thus ensuring any ratepayer or taxpayer dollars spent to pilot energy storage translates into meaningful next steps to move the market forward.

> Any state policy effort to stimulate its storage market should incorporate a clear picture of where the state wants its market to "end up."

While alternatives to storage procurement requirements exist and are an important part of the portfolio of available approaches to deploying storage, the primary advantage of a storage requirement is that it sets out a clear target: typically, a MW amount of grid-interconnected storage. As abovementioned, any state policy effort to stimulate its storage market should incorporate a clear picture of where the state wants its market to "end up." This has been shown to spur action in the other foundational areas, discussed in Section V, that are necessary for the development of a robust and self-sustaining market for energy storage services.

D. Plan for Storage: Addressing Storage Within Broader, Long-Term Energy Planning Efforts

As more states look to energy storage as a tool to ease integration of significantly higher penetrations of renewable resources on the grid and to enhance overall grid operations and system efficiency, it follows that considerations of energy storage would occur in the context of other efforts aimed at creating a more integrated, resilient, and modern grid. The two most prevalent and relevant proceedings are so-called Grid Modernization and IRPs[94] and related transmission planning proceedings. The tools and approaches within each provide important pathways to integrate and optimize storage deployment on the grid. Within these proceedings are other concurrent efforts to modify existing policies to enable greater penetrations of all DERs, including energy storage.

1. Grid Modernization

Numerous states, including New York, California, Hawaii, among others, are engaged in complex proceedings aimed to modernize the grid and shape the future of the electricity sector. Others, including Minnesota, Maryland, New Hampshire, Rhode Island, and the District of Columbia, are just getting underway. While each of the states that have begun to tackle the topic of distribution "grid modernization" are approaching the effort in slightly different ways, a consistent set of tools and regulatory approaches are beginning to emerge as key to unlocking the grid modernization puzzle. Below are some of these elements that most relate to energy storage.

- **Distribution Plans:** While states have historically reviewed utility plans for development of the transmission system and for the procurement of large-scale generation assets through IRPs or other similar proceedings, regulators generally have exercised little direct oversight over distribution system planning. However, since the role of the distribution system is changing dramatically due to the increase in DERs, states are starting to take a closer look at how this critical system is designed and planned for. Thus, the four states that are farthest along in their grid modernization proceedings have all required the utilities to prepare distribution plans,[95] with a particular focus on how the utilities will integrate the growth of DERs on the distribution systems. These include considering what additional tools and investments may be required to accommodate DERs, but also how DERs may help to defer or avoid traditional investments. Energy storage gets consideration in these plans as a load modifying resource, a tool to help defer or avoid upgrades, and to help address technical issues on the grid (such as voltage control) as the amount of distributed generation grows. A transparent distribution planning effort is more likely to incorporate energy storage by compelling utilities to demonstrate that they are proactively planning for how to integrate DERs on to the distribution grid.

- **Hosting Capacity Analyses:** Separately, or as part of their distribution plans, commissions are requiring utilities to conduct hosting capacity analyses for their distribution systems.[96] These analyses include a detailed technical review of the ability of specific circuits on the distribution grid to host additional distributed generation, as well as other DERs, including energy storage, particularly since storage can function as generation and load depending on its operational state. Hosting capacity analyses require compilation of data about load, generation, and physical assets (wires, substations, etc.) to determine how much additional DER each circuit can accommodate without violating technical limits, including power quality, protection, thermal limits, etc. The results of these analyses can be made available via online maps and downloadable spreadsheets that enable DER

CASE STUDY

Kauai Solar-Plus-Storage Projects

Member-owned electric co-op Kauai Island Utility Cooperative (KIUC) plans to add dispatchable renewable generation while achieving significant cost savings by purchasing power from two solar-plus-storage facilities. The first project, a Tesla facility which came online in early March 2017, stores power produced during the day from the 13-megawatt (MW) solar PV system using a 52 megawatt-hour battery installation and dispatches that power when it is needed. In January 2017, KIUC announced plans to buy power from AES Distributed Energy, which will pair a 28-MW solar PV array with a 100 MWh battery system and charge KIUC 11 cents per kilowatt-hour (a significant reduction from the price of Tesla facility's power at 14.5 cents per kilowatt-hour). These projects are notable in that they will help to integrate even greater amounts of renewable generation at a lower cost than the utility pays for fossil fuel generation, saving both KIUC and its ratepayers money.

Source: Spector, Julian, "AES' New Kauai Solar-Storage 'Peaker' Shows How Fast Battery Costs Are Falling," Greentech Media (Jan. 16, 2017) available at: https://www.greentechmedia.com/articles/read/aes-puts-energy-heavy-battery-behind-new-kauai-solar-peaker providers to identify locations where their technology can offer both system benefits and avoid significant interconnection costs. For example, a developer may be able to identify a location where strategic use of a storage system could help increase the ability of a circuit to host additional distributed solar capacity. The results can be used to aid in utility distribution planning and also to facilitate a faster interconnection process.

- **Locational Value Assessments:** Some states have begun to develop a methodology to assess the specific locational value of DERs on the distribution system.[97] These methodologies aim to address the fact that DERs, including storage, have inherent temporal and locational characteristics that may not be reflected in a straightforward benefit-cost ratio or average value per kWh approach to estimating these resources' value. These tools could be used to help determine the rates for DERs participating in compensation tariffs and could guide pricing under other DER procurement programs.

- **DER Forecasts:** In addition to understanding the current capacity of the system using the hosting capacity analyses, and the potential value of DERs at different points on that system, Commissions are requiring utilities to develop sophisticated forecasts of predicted DER growth on the distribution system that will enable utilities to make proactive planning decisions to help accommodate, and integrate DERs onto the system in the future.[98]

- **Data Access:** Another key component of distribution system transformation involves enabling data access for third-party providers about the distribution system and about customer behavior to better design their systems and identify and reach customers. A complimentary aspect of some of these discussions involves what information the utility needs from DER providers to be able to better integrate and manage high levels of DER on the system. Storage providers have an interest in these discussions as they could significantly impact their ability to identify appropriate grid locations for their projects, as well as customers who may benefit most directly from the services that an energy storage system can provide. An integral aspect of accessing data is having the communication and controls infrastructure deployed on the grid to acquire the data in a usable and understandable format. This infrastructure is a key feature of a more modern grid and will open the door to accessing the full value streams of energy storage. The issues of cyber security and privacy are additional elements of the data access discussion that require careful consideration.

- **Utility Business Model:** A few states have recognized that the current utility cost recovery framework does not align utility incentives with state DER growth objectives and other renewable energy goals, particularly if third-party owned DERs are predominant. New York, in particular, has tackled this issue head-on and is attempting to gradually redesign the structure of the utility incentive framework away from traditional capital investments and more towards market-based activities and performance-based incentives.[99] California is also evaluating a very limited pilot program to test whether utilities will choose to deploy third-party DERs in place of traditional wires solutions if they are provided with an additional incentive to do so (to compensate for the loss of the rate of return they may have traditionally received for a wires-based solution).[100] More states are expected to take this issue on in coming years, adding another important forum to explore energy storage technologies as non-wires solutions.

In addition to these core components, some of these proceedings are also addressing the adoption of smart meters, smart inverter settings, among other topics, most of which could also help further deployment of energy storage into the distribution system. Although individually incremental, each component of these proceedings can help advance the opportunities for energy storage to thrive in a modern electricity system that is more dependent upon distributed and customer-sited resources. Together, the various components work to transition states and utilities to a new way of planning for their distribution system that will make energy storage and other DERs a fundamental part of those systems, rather than a nuisance or an afterthought.

Credit: RES

2. Integrated Resource Plans

Another approach some regulators and utilities appear to be moving toward is incorporating energy storage into utilities' IRPs or other long-range procurement plans. This type of "resource planning" involves the utility's deciding the optimal mix of generation and demand-side resources to meet its future needs, while ensuring cost effectiveness and reliability. While IRP requirements usually arise in vertically integrated states, either through legislation, commission administrative rules, or individual dockets, many restructured states undertake similar planning (California, for example, has done this through its long-term procurement plan ["LTPP"] proceedings, but has now folded that into an IRP process).

Until recently, most utility resource planning has relied on methods that do not adequately model advanced energy storage resources. Yet, a well-managed portfolio of resources includes distribution, generation and demand management capabilities (in order to defer transmission and distribution upgrades and for other valuable, locational services), all of which energy storage is able to provide.

A few utilities and commissions are updating their resource planning processes to accurately model advanced storage. Some examples include, but are not limited to:

- In 2015, Missouri's utility commission required Kansas City Power and Light Company's IRP to "review the impact of foreseeable emerging energy storage technologies throughout the 20-year planning period." The utility's submitted IRP report includes the required discussion of storage potential, including a smart grid demonstration project with a storage component.[101]
- In Oregon, the commission ordered utility Portland General Electric to address storage in its 2016 IRP, partly to meet the utility's requirement to procure 5 MWh of energy storage under Oregon's storage procurement mandate (discussed earlier). The IRP seeks to add an average of 135 MW of energy efficiency, 77 MW of demand response programs, and 175 MW of renewable energy in each of the next four years. The IRP also includes a valuation framework that Portland General Electric can apply to future energy storage procurement decisions, consisting of five key energy storage value streams: (1) energy shifting or arbitrage; (2) ancillary services; (3) avoided renewable curtailment; (4) system peaking or capacity value; and (5) locational value.

Until recently, most utility resource planning has relied on methods that do not adequately model advanced energy storage resources.

- In Hawaii, following input from utility commission workshops, utility Hawaiian Electric Company updated its Power Supply Improvement Plan with recent estimates of energy storage cost and performance data and accounting for ancillary services benefits.[102] As a result, the utility's new plan included more than 150 MW of additional storage projects through 2022.
- As noted earlier, Washington UTC's integrated resource planning proceeding[103] is addressing staff's earlier recommendation of a policy requiring utilities to reflect the value of energy storage's benefits in their IRP processes.[104]

As seen from the above discussion—and the many states that are missing from it—much remains to be done in terms of establishing policy frameworks to support energy storage deployment. Clearly, however, many regulatory methods for tackling barriers to storage already exist and have proven effective, even if the "best practices" are still under development.

E. Key Takeaways for State Policymakers

- States considering approaches to their energy storage markets should assess which stage(s) of storage development they are currently in (Investigate, Clarify, Energize, Plan), which may help guide next steps to advance storage. The stages are not necessarily sequential, and states would be wise to pursue multiple pathways simultaneously to nurture favorable market conditions over the long-term. Any state policy effort should clearly articulate the objectives and intended outcomes.

- States should leverage other states' experience with storage, as well as the growing body of reputable evidence about energy storage, to avoid more time- and resource-intensive exploratory steps, thus enabling more swift state actions to establish foundational pathways for storage.

- For states that have not yet taken any steps toward incorporating storage into their electric system, an investigation could be an appropriate place to begin, with the important caveat that investigations may be a wasted effort for commissions and workshop participants without some sense of where the state wants to "end up." For the most part, investigations' direct effect on energy storage policymaking is small unless they are an early step on a clear "path" from workshops to eventual action.

- Investigative proceedings and workshops should include clear goals and next steps, such as the eventual consideration and adoption of meaningful policies such as those discussed in the following sections.

- Identifying a list of regulatory hurdles present in the state that need to be addressed to allow the energy storage market to flourish could be an important first-step exercise; however, states could consider taking some of the more concrete steps outlined above and in Section V. In other words, states do not need to wait for a full energy storage study to begin or a pilot to conclude before it begins clarifying existing policies and rules.

- For all states, reworking existing regulations to prepare for (and enable) increased penetration of energy storage is critically important to creating a smooth glide path for energy storage. States should identify what policies are already in place in their state, and which may need modification in order to clarify storage's role under those policies and move ahead with those revisions as a first-priority effort.

- Allowing energy storage systems to operate effectively under existing regulations is an important first step to stimulating the market, without requiring the creation of entirely new programs.

- For all states, energy storage can provide significant value to the grid but is unlikely to be strategically deployed to do so in the absence of market signals or regulatory enablers. State actions and clear guidance are imperative to creating robust, sustainable markets for energy storage.

- The ability to interconnect energy storage systems to the grid in a fair and efficient manner is fundamental to allowing energy storage to provide the services discussed in the previous sections. States can consider moving ahead quickly with clarifying and/or modifying the foundational policies of interconnection (see Section III.B for examples).

- Storage procurement requirements are an important part of the portfolio of available approaches to deploying storage; the primary advantage of a storage requirement is that it sets out a clear target: typically, a MW/MWh amount of grid-interconnected storage. This has been shown to spur action in other foundational areas that are necessary for the development of a robust and self-sustaining market for energy storage services.

- For states that are seeking to address storage as part of a more comprehensive planning effort, considerations of energy storage are and should occur in the context of other efforts aimed at creating a more integrated, resilient, and modern grid, namely grid modernization proceedings, IRPs, and related transmission planning efforts.

- A consistent set of tools and regulatory approaches are beginning to emerge as key to unlocking the opportunity to integrate and optimize storage deployment on the grid, namely: Distribution Plans, Hosting Capacity Analyses, Locational Value Assessments, DER Forecasts, Data Access, and the Utility Business Model.

- One-off funding for pilot projects may help demonstrate that a specific energy storage application or technology is feasible or cost-effective, but this is not the type of robust policy foundation necessary for a self-sustaining storage market.

V. Foundational State Policy Actions to Address Primary Energy Storage Barriers

Despite widespread recognition of the game-changing potential of energy storage, its deployment remains hampered by the current features of state and federal regulatory frameworks and electricity markets. This section discusses the state policy and regulatory barriers that limit or impair storage deployment and provides some recommended foundational policy actions to help states begin to overcome them.

The barriers identified were informed, in part, by interviews with utility regulators from across the country, as well as energy storage providers operating across several states and representing a range of technologies and business models. The interviewees represented interests from a spectrum of regulatory frameworks (some with considerable energy storage experience and others with very little), market types (vertically integrated vs. restructured), and states with varying levels of DER penetration.

This discussion of barriers and foundational policies is not exhaustive, but rather, reflects the most commonly identified barriers and thus the actions likely to have the broadest impact on the energy storage market. The focus of the recommendations is state policy, as opposed to local or national policies. For instance, local government regulations and permitting processes, state fire codes, and building codes that can have an impact on the streamlined adoption of energy storage are not discussed.[105] Similarly, market rules established by ISOs and RTOs are not discussed herein although they are equally critical to the successful deployment of energy storage.[106] It is also worth noting the foundational actions and solutions presented range in their level of specificity, due to the fact that certain issues have more clearly defined paths to address barriers, while others are still under development and/or ripe for further policy innovation. The intent with this guide is to provide an array of possible actions and pathways for further exploration, but more work remains to develop a more comprehensive road map for energy storage in the United States.

It is important to note that barriers experienced foremost by developers may be distinct from those experienced by regulators. Moreover, in general, developers confront these barriers directly while regulators often hear about them secondhand (either through disputes before the commission or through testimony in active proceedings). The barriers discussed herein are mostly examined from the perspective of the storage customer or developer, but it is important to recognize that regulators can encounter their own set of informational barriers that affect their ability to swiftly and cost-effectively respond to the growing interest in storage. Regulators may lack the tools to address energy storage comprehensively, and may feel under-resourced in terms of staff and time. In some cases, they may be forced to prioritize other issues over energy storage, which may impair their focus on energy storage. This may be particularly true in states where there is not yet an active storage market or industry players, as well as states that are still in the early-stages of renewables market growth. To address this more overarching barrier, all states, and their legislatures, can and should ensure their regulatory agencies have sufficient resources and staff to grapple with these important issues. Indeed, the regulatory and policy framework on which the energy system of the future rests largely in the hands of state commissions, and the people working daily to oversee the electricity sector have an important and challenging task ahead.

Credit: East Penn Manufacturing

With the following recommendations, this guide offers insights on some initial and important pathways for states as they navigate energy storage matters.

CLASSIFICATION & OWNERSHIP	**Clarify How Energy Storage Systems are Classified to Enable Shared Ownership and Operation Functions in Restructured Markets.** In restructured markets, state policymakers and regulators may need to reconsider the current limitations on asset ownership that may prevent "wires-only" utilities from cost-effectively owning storage as assets and, thus, from being able to recover costs through rates. Any approaches seeking to address this issue will likely require the implementation of appropriate regulatory safeguards to protect the competitiveness of energy markets, while still ensuring that the grid and ratepayers can benefit from advanced energy storage technologies.
PLANNING	**Require Proactive Consideration of Energy Storage in Utility Planning Efforts.** States should consider requiring utilities to evaluate energy storage side-by-side with those of traditional wires and resource solutions as a part of integrated resource and distribution planning efforts. State policymakers and regulators will need to be specific about how they want energy storage to be evaluated and modeled (including requiring the use of up-to-date, accurate cost and performance data) in these proceedings if they want to see the most useful and effective results. These proceedings can produce new tools that enable grid transparency that can help identify locations where storage can offer the greatest benefits to customers and the grid.
GRID ACCESS	**Ensure Fair, Streamlined, and Cost Effective Grid Access for Energy Storage Systems.** Energy storage customers, like all customers seeking to connect to the grid, need a process that is transparent, non-discriminatory, timely and cost effective just like any other type of generator. While storage systems can be reviewed using the basic framework of traditional state jurisdictional interconnection procedures, certain modifications could be made to more effectively and efficiently review their impacts on the electric system.
VALUE STREAM	**Create Mechanisms to Capture the Full Value Stream of Storage Services.** States can consider adopting or modifying mechanisms to help create markets for energy storage and capture the full value stream of energy storage services, namely through monetizing the benefits.

A. Clarify How Energy Storage Systems are Classified to Enable Shared Ownership and Operation Functions in Restructured Markets

Energy storage faces unique barriers to deployment in restructured, or deregulated, states due to existing rules and limitations governing these competitive markets. Specifically, most of these states specifically limit utilities to owning and operating transmission & distribution (T&D) infrastructure, or the "wires" of the grid. Non-utility third parties, on the other hand, can own generation assets and bid generated energy into interstate wholesale markets operated by ISO/RTOs and regulated by FERC. The reasons for this limitation on utility-ownership extend back to the origins of energy deregulation, the purpose of which is to foster competition among electricity providers while ensuring T&D owners are agnostic to the generation resources connecting to the grid, and to prevent any single provider from controlling the entire energy supply chain.[107]

An unanticipated effect of such rules, however, is the prohibition of "wires-only" utilities from owning and operating energy storage systems, or at least the severe limitation on their use, because storage technology combines aspects of generation—i.e., storage can function at times as a supply resource, which must be competitively sourced in restructured markets—with T&D asset capabilities. States may also have regulations preventing utilities from recovering the cost of T&D services provided by energy storage systems through utility rates if the asset in question is also participating in wholesale energy markets.

For example, a "wires-only" utility may be permitted to install an energy storage device on its system to provide a distribution service or services; but if only a portion of the battery's capacity is needed at any given time, the utility may be prevented from using the remaining capacity for other, independent services for which there is a wholesale market (such as ancillary services).[108] In Texas, which is a deregulated state, if an entity intends to use an energy storage asset to sell energy or ancillary services at wholesale, state rules classify it as "generation;" thus it could not be owned by a "wires-only" utility if it would realize any value from these services through the market.[109]

Such restrictions on classification can prevent energy storage from being cost-effective for investors, utilities, and ratepayers. Even in states without explicitly defined limits on ownership, basic uncertainty about how commissions would classify a particular storage service or application can be a barrier to investment in storage projects.[110] The Public Utility Commission of Texas is considering this issue in an active docket, wherein AEP Texas North applied for approval to install lithium-ion batteries in two locations on its system as qualified distribution assets that will be eligible for the company's distribution cost of service.[111] The outcome of this proceeding is likely to set a precedent for other utilities and other restructured markets as they consider energy storage investments.

Energy storage faces unique barriers to deployment in restructured, or deregulated, states due to existing rules and limitations governing these competitive markets.

Today, as changes to the grid and utility business model unfold, and as newer technologies encompass an ever-broadening range of capabilities, the traditional lines are blurring between what constitutes a generator versus T&D. Segregation and constraints on ownership of more dynamic assets, like storage, can prevent advanced technologies from being deployed and/or delivering maximum benefits to the grid, utilities, ratepayers, and states. To address this problem, state policymakers and regulators could consider revising current regulations governing the limitations on asset ownership, which may be preventing many "wires-only" utilities from owning storage as assets and, thus, from being able to recover prudently incurred costs through rates.

One approach that has been proposed[112] is to permit "sharing" of storage assets between utilities and third-party generation owners, though this approach has not yet been implemented anywhere. Under this arrangement, regulators could allow "wires-only" distribution utilities to own energy storage assets while "sharing" control with third-parties that would control energy dispatch. Under this framework, a storage system could participate in the market for some services, while the "wires-only" utility could seek cost-recovery for its investment in that asset through rates. Because regulators in restructured states may see this and other approaches that challenge traditional assumptions of deregulation as controversial, they could also consider implementing appropriate regulatory safeguards to ensure the advantages of widely deployed energy storage outweigh any potential risks and avoid unintended consequences on ratepayers. While there may be good reasons to continue to protect the competitiveness of energy markets by preventing direct utility participation, the opportunities created by advanced energy storage technologies may warrant reconsideration of existing limitations on ownership.

FERC recently issued a policy statement providing additional guidance for electric storage resources that seek to concurrently recover their costs through cost-based and market-based rates, which, according to FERC, "helps ensure that these resources can operate at maximum efficiency to benefit the electric system and consumers."[113] In its announcement about the policy statement, FERC notes that "with regard to adverse market impacts, FERC is not convinced there will be a detriment to other market competitors."[114] This FERC guidance is an important step that will provide greater clarity on this issue at the federal level, and states should leverage this opportunity as they develop state-specific guidance and mechanisms for storage. However, more guidance and direction from FERC is needed to further clarify details and parameters on this issue.

B. Require Proactive Consideration of Energy Storage in Utility Planning Efforts

Utilities have an enormous responsibility to provide safe, reliable and low-cost electric service to their customers, and because their investment decisions are closely scrutinized by regulators, ratepayer advocates, and other stakeholders, they tend to be cautious organizations that can be slow to change or respond to new technologies.[115] One of the central ways that utilities make decisions, and get approval for their future investments, are through long-term planning proceedings that assess system needs in the future and evaluate the costs and benefits of the various options available to address those needs. Upon approval by regulators, these proceedings set the path for major investments in coming years. If energy storage is not properly considered in these long-term planning efforts, the opportunity for meaningful deployment diminishes substantially and creates a domino effect of lost opportunities for energy storage to effectively replace other investments. Given extant market barriers and challenges to integrating and utilizing more energy storage on the grid, state actions to set clear policy goals and targets for storage, such as procurement requirements, can help spur investor-owned utilities to integrate storage more proactively in their planning efforts. If procurement requirements are well-designed, energy storage will have an opportunity to compete with more traditional solutions and utilities will begin to more proactively integrate energy storage solutions into their investment, planning, and operational decisions (see Section IV.D for additional details on planning tools and initiatives).

For utilities to recognize the benefits and opportunities associated with wide-scale deployment of energy storage, it is important that they be tasked with considering these technologies in their long-term planning proceedings as potential investment options in each area where storage technologies can provide services (i.e., as a capacity resource, T&D resource, for peak load reduction, etc.). As discussed in Section IV, in many states the primary planning proceeding is the IRP,[116] which is focused on how to meet forecasted energy demand over a long-range (ten or more year) horizon.[117] Some states also have transmission planning proceedings and other resource-specific proceedings as well. By requiring utilities to consider energy storage as a part of these central planning proceedings, states can ensure that the unique services, costs and benefits of energy storage get evaluated side-by-side with those of traditional generation and T&D solutions.

> The optimal end goal should be the integration of energy storage as a fundamental resource for consideration in the planning process, particularly as utilities learn more about the potential uses and benefits of the newly available technologies and get more comfortable building their services into their planning models.

However, state policymakers and regulators will need to be specific about how they want energy storage to be considered and evaluated in these proceedings if they want to see the most useful and effective results. As discussed in Section III, there is a considerable learning curve to overcome regarding how to best assess the value of energy storage, particularly when compared to traditional assets that utilities are already comfortable modeling. Utilities cannot rely on outdated modeling tools to assess energy storage, which may not be granular enough or have accurate or up-to-date cost and performance data for these new technologies, and state regulators may need to guide these efforts to ensure appropriate consideration.[118] In addition to uncertainty around how to model the economic costs and benefits of storage, utilities may lack sufficient information about the potential operating capabilities of storage systems.[119] Regulators can help to resolve these concerns by requiring utilities to demonstrate how and where they considered energy storage and by allowing outside stakeholders to help ensure that the proper cost and performance data is being utilized.

While consideration in IRPs and transmission planning proceedings will help guide utilities toward energy storage investments, those proceedings tend to favor large-scale resources and can be focused on utility-driven energy storage procurement. Since much of energy storage's potential lies in its ability to offer services at customer sites and to help integrate distributed renewables, there are also hurdles at the distribution system that need to be addressed from a planning standpoint.

Regulators may thus consider requiring utilities to demonstrate that they have a robust and not overly constrained process for considering non-wires alternatives (which may include energy storage) for distribution system investments. Developing criteria and processes for consideration of non-wires alternatives is a relatively new frontier for regulators and utilities, and there is not yet an established set of best practices for what this process should entail.[120] This will be a fundamental change to the way that most utilities are used to planning their distribution systems, but it could result in a more meaningful "integration" of energy storage resources and an overall lowering of the costs of maintaining the distribution system.

Alternatively, by requiring utilities to prepare a publicly accessible distribution investment plan on a periodic basis, regulators can similarly require utilities to demonstrate how they are planning for the integration of energy storage on the distribution system. These proceedings allow opportunities for sharing of information about the locations on the distribution system where there may be opportunities for both grid and customer-sited energy storage to provide valuable services. If utilities are required to prepare accurate hosting capacity analyses of their distribution systems and to share the underlying data supporting those assessments in granular and readily accessible formats, then energy storage providers (and other DER providers) will be better equipped to identify optimal grid locations with sufficient interconnection capacity for their deployment. This information is particularly valuable for energy storage developers because it also helps to identify exact locations on the grid where their technology may be able to help "expand" the hosting capacity of a circuit without the need for traditional wires upgrades.

In the long run, the optimal end goal should be the integration of energy storage as a fundamental resource for consideration in the planning process, particularly as utilities learn more about the potential uses and benefits of the newly available technologies and get more comfortable building their services into their planning models. For now, however, it is important for regulators to nudge utilities forward, both by requiring them to consider a full range of technologies, but also by giving them the room to try out these new resources even if they do not fit within the traditional investment paradigms that regulators have established for past planning proceedings.

C. Create Mechanisms to Capture the Full Value of Storage Services

Utility regulators frequently have difficulty identifying how, and through what mechanism, to create the appropriate price signals to help energy storage asset owners and customers "capture" value (see Section III for more on the value of energy storage). The Massachusetts State of Charge study found that the biggest challenge to achieving more storage deployment is the "lack of clear market mechanisms to transfer some portion of the system benefits (e.g., cost savings to ratepayers) created to the storage project developer."[121] This barrier is not limited to Massachusetts. There are only a few markets in the United States where storage applications can capture more than one or two value streams among the many that could potentially be available.

There are existing mechanisms, however, that states can consider adopting or modifying to help create markets for energy storage and capture the full value stream of energy storage services, namely through monetizing the benefits. Chief among them are rate structures that enable users to maximize the customer-sited storage's potential; procurement processes or auctions, where commissions must approve developers' or utilities' compensation for electricity assets and services; incentive programs; and procurement requirements or targets. The merits of each of these mechanisms should be evaluated in the context of a state's market conditions, as well as their appropriateness relative to any identified policy objectives.

For customer-sited energy storage systems, traditional utility rate structures can make it difficult to capture the full value that such storage systems can provide. Setting more accurate price signals for storage services that are more reflective of the varying market prices can ensure that energy storage assets are deployed to optimize their multiple function(s) on the grid, which should, in turn, optimize the economic benefits for the customer and/or storage provider. Time-varying rate structures, such as time-of-use (TOU) rates (see Rate Design Tools for Energy Storage) provide an example of a rate structure that may be effective at optimizing the services and economics of energy storage on the grid, thus making it a more enticing value proposition for owners, investors, and/or customers. For example, with sufficient differentials between on-peak and off-peak hours, TOU rates could encourage the adoption of behind-the-meter energy storage, including paired solar and storage, to respond to rate-based price signals and optimize behind-the-meter output.[122] Peak-coincident demand charges, based on customers' maximum instantaneous load during periods of peak system demand, could provide similar economic motivations for customer adoption of behind-the-meter energy storage. See section IV for additional information on rate design.

Credit: S&C Electric Company

States with existing NEM rates may consider storage specific NEM rate structures to help facilitate better use of energy storage systems when paired with a distributed solar system, as well as optimize the integration of solar on the grid. Alternative structures could be designed specifically to encourage customer behavior that benefits the grid overall, thus minimizing any potential for cost-shifting to other ratepayers.[123,124] As noted above, California offers an example of a state that has taken steps to clarify that for NEM-eligible renewable energy devices coupled with energy storage systems, customers' NEM credits can only be generated by energy produced by those eligible facilities and not from energy pulled from the grid.[125]

Additionally, demand response (DR) programs may offer an effective means to further incentivize deployment of energy storage as an alternative to new generation by utilities (see below). Through a DR auction or similar program, under which each bid into the auction names a price per kW for the DR services it offers, states could create opportunity for storage systems and other DERs to bid against each other. Such programs, however, need to be structured to allow for aggregation of small participants and may need to be examined to ensure they do not rely on assumptions based upon outdated technologies or customer capabilities.

> There are existing mechanisms, however, that states can consider adopting or modifying to help create markets for energy storage and capture the full value stream of energy storage services, namely through monetizing the benefits.

DEMAND RESPONSE AND ENERGY STORAGE

Demand response (DR) gives energy users tools and signals to reduce their energy demand, or load, during times of peak demand, thus freeing up capacity on the electric system. Most DR programs have historically been run by utilities; however, regulators are now frequently turning to DR programs as an alternative to new generation. Not surprisingly, energy storage is particularly well situated to participate in DR programs. In California, the CPUC has imposed a new DR requirement on utilities, calling for at least 22 MW of third-party demand response, and set up a Demand Response Auction Mechanism, or "DRAM", program. The DRAM is the first time that distributed energy resources, including storage, have been bid against each other in a standardized way in California.[126] Each bid into the DRAM will name its price per kW for the DR services it offers.[127] Energy storage is expected to play a significant role in bids, and net-metered customers and California SGIP recipients can participate.[128]

For front-of-meter energy storage, determining appropriate compensation or cost-recovery may be difficult for various reasons, including but not limited to those discussed in Section III on the valuation of storage. Regulators in vertically integrated states may be challenged by the absence of wholesale markets, which otherwise could indicate a price for storage at the distribution level to help inform an adequate rate of recovery by investors.[129] In these states, furthermore, utilities generally have far greater access to data that could inform regulators or developers of appropriate pricing of storage assets and services, based on specific services at particular points on the grid.[130] To address this informational barrier, regulators in vertically integrated states could look to examples of neighboring, restructured markets to estimate the value of providing different storage services, require utilities to pursue competitive bids for identified grid services, and/or work more closely with utilities and other stakeholders to evaluate system economics.[131] While perhaps challenging, regulators can play an important role in setting forth the necessary frameworks and methodologies that support the creation of more explicit and accurate price signals, rates, and/or compensation mechanisms for energy storage.

D. Ensure Fair, Streamlined, and Cost Effective Grid Access for Energy Storage Systems

Energy storage projects designed to send power back onto the electric grid, or to operate in parallel with it, need an interconnection agreement to be allowed to safely, and legally, operate. Indeed, just as it is for other types of generators,[132] the process of obtaining an interconnection agreement is one of the most critical paths in the storage development process and storage developers consistently identify it as a key barrier to storage growth. Interconnection barriers for energy storage are multifaceted, and thus there are several considerations states should consider when approaching solutions. See Section IV.B for additional discussion on interconnection.

Energy storage customers, like all customers seeking to connect to the grid, need a process that is transparent, non-discriminatory, timely and cost effective. IREC has published model interconnection procedures, along with other resources,[134] that provide regulators with adoptable examples of the best practices that can be implemented to ensure a fair and efficient interconnection process for all projects. Additionally, like other inverter-based generators, advanced energy storage systems will benefit from the adoption of smart inverter settings, which may lower interconnection costs and enable storage systems to offer services that benefit the grid and assist with renewables integration.[135]

Beyond these fundamental practices that benefit all interconnection applicants, there are several storage-specific issues that need to be explicitly addressed in interconnection rules. These issues range from relatively simple and straightforward, to complex and rapidly evolving. The suggestions below are focused on policies in state jurisdictional interconnection standards. It is important to note that some wholesale projects may have to interconnect under FERC jurisdictional tariffs (depending their point of interconnection and the nature of the sale). While some considerations apply to both types of tariffs, there may be additional changes needed to FERC jurisdictional tariffs that are not discussed herein.

First, as a starting point, a state should identify whether it has adopted statewide interconnection standards, and, if so, determine if these standards expressly apply to energy storage projects. State interconnection procedures that were drafted with only traditional generators in mind may contain language making them technically applicable only to "generators." While energy storage technologies behave like a generator, they do not actually "generate" electricity; however, when storage is functioning as a generator, the same or similar technical standards applicable to other generators should generally be a sufficient starting point for storage projects. In other words, a state does not need to adopt a separate set of technical review standards to evaluate the 'generator' functions of energy storage before an interconnection application can be reviewed and considered. Instead, a state can revise or clarify the existing definition of eligible generator in the state interconnection standards to ensure that it explicitly includes energy storage.[136] Without this simple clarification, energy storage systems may be unintentionally prohibited from interconnecting to the grid (and/or they will be subject to ambiguous standards and processes that will result in costlier, time-intensive processes to interconnect). While a simple definitional change is the right starting point, it is also true that there may need to be further refinements to the technical standards in order to better take into account the operating characteristics of storage and to enable storage to be deployed in a manner that captures its greatest value.

Second, for energy storage systems of all types, but particularly those paired with other generators, it is important that utilities not assume that energy storage systems would operate at full capacity 24 hours a day the way they would normally assume for a conventional generator. Since energy storage systems must charge in order to discharge that assumes technically impossible behavior. In addition, it assumes behavior that is unlikely to be economical for a storage operators who are more likely to choose to charge when there is a surplus of energy (and correspondingly low rates) and to discharge when there is a greater demand for generation (and thus higher energy rates). The consequences of assuming storage systems are constantly operating at full output is that the utility is more likely to identify upgrades that could be necessary to interconnect a project, which would raise the cost of storage projects overall. In addition, this could result in an overbuilt system that assumes the need for "wires" capacity that is never actually utilized. To safeguard against such worst case scenarios from occurring, while also removing this key barrier to storage, regulators can adopt interconnection procedures that allow applicants to define how and when they will operate their energy storage systems, and these operating constraints can be incorporated into the binding interconnection agreement.[137] Storage systems should also have the option of being reviewed in the traditional manner (i.e., with no operational constraints) if they do not want to accept any limitations on their operating behavior.[138] This approach can help balance system safety and reliability concerns, while also keeping costs for ratepayers low and encouraging efficient use of energy storage systems.

Credit: RES

Third, since energy storage systems can function as load (i.e., some storage systems charge from the grid) as well as generation, there are separate issues to consider through the interconnection process. In most, if not all, state rules governing the interconnection of new load are separate from the interconnection procedures for new generation. The technical review process that utilities undergo for other new load sources can similarly be applied to energy storage, though some modifications might need to be made to recognize the controllable nature of energy storage's charging functions. The technical review utilities do to assess the grid impacts of new generation is similar to the technical review it has to do for new load, and thus it makes sense for utilities to be able to review the charging and discharging functions together for efficiency sake.

However, the rules regarding the allocation of costs are often different; in most cases, some costs associated with interconnecting new load are covered by the rate base (i.e., all ratepayers), while most or all costs associated with interconnecting new generation are the responsibility of the customer-generator seeking to interconnect. Thus, to provide greater clarity on this issue, regulators should identify and specify how these different cost allocation rules apply to energy storage systems, particularly where it is determined that a grid-related upgrade would be required for both the charging (load) and discharging (generator) functions. Ideally energy storage customers should be treated in a non-discriminatory manner and have access to the benefit of any applicable cost-allocation measures (i.e., spread among the rate base) that would apply to other new sources of load; but, like other

CASE STUDY

Alamitos Energy Storage Project

In the Los Angeles basin, increasing renewables penetration and the unexpected shutdown of the San Onofre Nuclear Generating Station in 2012 created the need for replacement capacity flexible enough to meet the demands of California's grid. Through a request for proposals for replacement peaking capacity that elicited more than one thousand responses, the utility Southern California Edison (SCE) selected the AES Alamitos 100 MW, 4-hour lithium-ion storage project as a viable solution to meet its peak load needs. The project is currently under development, with a target operating date of 2020 and planned operations until at least 2040.

SCE's selection of the project in such a competitive environment is an affirmation of the long-run cost-efficiency of battery-based energy storage and its ability to ensure least cost to ratepayers. The Alamitos energy storage project will provide two main services to the grid: peaking capacity and grid balancing services. For the former, the storage will be an official source for Resource Adequacy, a requirement set by the California Public Utilities Commission (CPUC) to ensure California has enough generation to reliably meet peak demands. For the latter, the storage will bid into wholesale frequency regulation markets and other ancillary services markets maintained by the California Independent System Operator (ISO).

The Alamitos storage project will substitute for traditional gas-fired peaking plants and improve the availability of renewable resources. Moreover, the instantaneous starting capability of the Alamitos storage project can reduce out-of-merit generation, start-up costs for other gas-fired peaking plants on the California grid, reducing overall peak energy costs. And by being deployed close to LA basin customers, the storage project also reduces transmission losses.

Source: Energy Storage Association.

generators, energy storage should bear the responsibility for reasonable and prudent upgrade costs that may result from their generator function and deemed necessary through the generator review processes. In addition, streamlining the review of the load and generating functions is more efficient for the utility and the energy storage applicant.

Fourth, there are additional preliminary interconnection review issues for "non-exporting" energy storage systems (i.e., those designed to not export electricity onto the grid). Depending on the design of the storage system, there may be little to no need for a formal interconnection review process at all. Clarifying when energy storage systems need to submit an interconnection application, and what level of review each type of system will need to undergo, can help minimize disputes and maintain an efficient process for all parties.

Finally, for energy storage systems that wish to interconnect to the distribution grid, but participate in wholesale energy markets (either for ancillary services, demand response, energy, or capacity), questions have arisen about whether these projects require a federal or state jurisdictional interconnection agreement, or both.[140] While this question is not solely up to state regulators to resolve, states should work with FERC to ensure a clear answer emerges such that energy storage projects are able to offer their full range of services without encountering unnecessary jurisdictional hurdles. This issue will be an important one to address in the near-term, and may need more dedicated attention by FERC, especially as energy storage markets grow across the country.

The above issues reflect the most commonly identified interconnection barriers in state jurisdictional interconnection procedures, but it is likely that as advanced storage technologies evolve, and as the market place expands to allow a greater diversity of applications for these technologies, that new interconnection challenges, as well as solutions, will emerge. States wishing to prevent delays in the interconnection process can create an ongoing technical working group that meets periodically to help address interconnection issues, whether they be storage specific, or related to issues encountered by all types of interconnection applicants.[141]

E. Key Takeaways for State Policymakers

- **Clarify How Energy Storage Systems are Classified to Enable Shared Ownership and Operation Functions in Restructured Markets.** In restructured markets, state policymakers and regulators could reconsider the current limitations on asset ownership that may prevent "wires-only" utilities from owning storage as assets and, thus, from being able to recover costs through rates. Any approaches seeking to address this issue will likely require the implementation of appropriate regulatory safeguards to protect the competitiveness of energy markets, while still ensuring that the grid and ratepayers can benefit from advanced energy storage technologies.

- **Require Proactive Consideration of Energy Storage in Utility Planning Efforts.** States should consider requiring utilities to evaluate energy storage side-by-side with those of traditional wires and resource solutions as a part of integrated resource and distribution planning efforts. State policymakers and regulators will need to be specific about how they want energy storage to be evaluated and modeled (including requiring the use of up-to-date, accurate cost and performance data) in these proceedings if they want to see the most useful and effective results.

  - Regulators can require utilities to prepare a publicly available distribution investment plan on a periodic basis and demonstrate how they are planning for the integration of energy storage on the distribution system.

  - Requiring utilities to prepare accurate hosting capacity analyses of their distribution systems, using robust methodologies, and to share the underlying data supporting those assessments in granular and readily accessible formats can help identify optimal grid locations for energy storage.

- **Create Mechanisms to Capture the Full Value Stream of Storage Services.** States can consider adopting or modifying mechanisms to help create markets for energy storage and capture the full value stream of energy storage services, namely through monetizing the benefits.

  - Time-varying rate structures, such as time-of-use (TOU) rates, provide an example of a rate structure that may be effective at optimizing the services and economics of energy storage on the grid, thus making it a more enticing value proposition for owners, investors, and/or customers.

  - Demand response (DR) programs may offer an effective means to further incentivize deployment of energy storage as an alternative to new generation by utilities. Such programs, however, need to be structured to allow for aggregation of small participants and may need to be examined to ensure they do not rely on assumptions based upon outdated technologies or customer capabilities.

  - Regulators in vertically integrated states could look to examples of neighboring, restructured markets to estimate the value of providing different storage services, and work more closely with utilities to evaluate system economics

- **Ensure Fair, Streamlined, and Cost Effective Grid Access for Energy Storage Systems.** Energy storage customers, like all customers seeking to connect to the grid, need a process that is transparent, non-discriminatory, timely and cost effective just like any other type of generator. The adoption of statewide interconnection standards for all generators, which also include specific components to address energy storage, is foundational for an energy storage market.

> Requiring utilities to prepare accurate hosting capacity analyses of their distribution systems, using robust methodologies, and to share the underlying data supporting those assessments in granular and readily accessible formats can help identify optimal grid locations for energy storage.

  - States should consider adopting statewide interconnection standards (that apply to all utilities that fall under the jurisdiction of the state utility commission).

  - Within those standards, states can revise or clarify the existing definition of eligible generator in the state interconnection standards to ensure that it explicitly includes energy storage.

  - The technical review process that utilities undergo for conventional “generation” and “load” sources seeking to interconnect is similar and can be consolidated for efficiency sake.

  - Regulators can adopt interconnection procedures that allow applicants to define how and when they will operate their energy storage systems, and these operating constraints can be incorporated into the binding interconnection agreement.

  - Regulators should identify and specify how cost allocation rules apply to energy storage systems, particularly where it is determined that a grid-related upgrade would be required for both the charging (load) and discharging (generator) functions of storage. Ideally energy storage customers should be treated in a non-discriminatory manner and have access to the benefit of any applicable cost-allocation measures that would apply to other new sources of load, while also sharing the responsibility for reasonable and prudent upgrade costs that may result from their generator function and deemed necessary through the generator review processes.

  - Regulators should clarify when energy storage systems need to submit an interconnection application, and what level of review each type of system will need to undergo, to help minimize disputes and maintain an efficient process for all parties. This is especially important for “non-exporting” energy storage systems (i.e., systems designed to not export electricity onto the grid), which may require little to no review.

  - States wishing to prevent delays in the interconnection process can create an ongoing technical working group that meets periodically to help address interconnection issues, whether they be storage specific, or related to issues encountered by all types of interconnection applicants.

  - States should work with FERC to ensure clear answers emerge about which interconnection rules apply such that energy storage projects can offer their full range of services without encountering unnecessary jurisdictional hurdles.

Credit: S&C Electric Company

VI. Conclusions

With this navigational tool and resource guide in hand, state policymakers and regulators should begin to chart a course to address energy storage in their respective markets. The starting point for each state will necessarily be different, based on where you are and what your goal is. While a step-by-step action plan is outside the scope of this guide, the key takeaways and insights offered in this guide should help more states establish a robust framework to charge ahead on energy storage.

Absent a more in-depth deployment plan or goal for energy storage, immediate actions can be taken within the context of utility planning efforts, procurement requirement programs, grid modernization proceedings, and/or through clarification of existing state policies and regulatory rules.

In addition, beyond taking proactive steps on storage, continued policy leadership will ensure identified challenges are met with innovative, yet practical solutions that set the stage for markets to grow. Indeed, the policy and regulatory frameworks are the foundation upon which future growth will be built. Peer-to-peer sharing among states and leveraging the wealth of information gleaned to date from pilot projects and active programs will ensure replication of successful approaches can occur more swiftly.

In the process of research and drafting this guide, several issues outside the scope of this guide emerged, but their exclusion does not imply that they are not worthy of further investigation and deeper thinking. On the contrary, we hope this guide will inspire additional research and evaluation to help resolve outstanding questions and help inform policy decision-making on energy storage. Examples include, but are not limited to, the following:

- How can utility performance-based incentives be designed to encourage greater deployment of both front-of-meter and behind-the-meter energy storage?
- As policymakers seek to tackle the challenge of comparing storage costs and benefits with traditional resources, what frameworks and/or tools can assist with the transition from the more 'traditional' cost-benefit analysis to a more holistic, 'system-wide' analysis?
- What is the opportunity cost of not deploying energy storage, due to the lack of compensation mechanisms for valuable services, and how should states account for this in policy analyses or modeling efforts?
- How should states approach the development of pricing and market structures that encourage customers investing in behind-the-meter energy storage to operate them for the benefit of the grid, versus solely for their own benefit?
- In vertically integrated states, how should regulators approach determining transparent values for ancillary services and ensure they are appropriately valued?
- Can grid reliability responsibilities be shared between utilities and third-party providers of energy storage?
- How should states evaluate the value of storage as a part of transmission or distribution infrastructure, as opposed to a supply resource?

> Continued poilcy leadership will ensure identified challenges are met with innovative, yet practical solutions that set the stage for markets to grow.

Certainly, other issues and questions will continue to arise as investigations of energy storage continue and expand into more states. The process of unpacking the challenges to better understand the barriers is a necessary part of the journey to arrive at policy actions. While the tendency is to hone in on the unknown and the most immediate obstacles, it is important to identify that which is well-known and verifiable and to approach the process with a shared commitment to arrive at workable solutions.

To that end, we urge state policymakers and other stakeholders to venture forth with confidence that the energy storage journey ahead will be worthwhile and truly empowering.

VII. Additional Resources

The following sample of resources provide additional information on energy storage:

- **Deploying Distributed Energy Storage: Near-Term Regulatory Considerations to Maximize Benefits** – This report by IREC identifies key regulatory policy considerations to guide regulators and other stakeholders as they seek to evaluate and unlock the benefits of energy storage. http://www.irecusa.org/publications/deploying-distributed-energy-storage/

- **DOE/EPRI Electricity Storage Handbook** – A how-to guide for utility and rural cooperative engineers, planners, and decision makers to plan and implement energy storage projects, sponsored by the U.S. Department of Energy and the Electric Power Research Institute in collaboration with the National Rural Electric Cooperative Association. http://www.sandia.gov/ess/publications/SAND2015-1002.pdf

- **Energy Storage Association** - A national energy storage trade association that works to educate policymakers and the public about the importance of energy storage technologies. http://energystorage.org/energy-storage

- **Energy Storage Valuation in California:** Policy, Planning, and Market Information Relevant to the StorageVET Model – As part of documentation by the Electric Power Research Institute (EPRI) of their Storage Valuation Estimation Tool (StorageVET) model, this report includes descriptions and technical details related to the valuation of energy storage operated in the California electric power system, and it reviews policies, programs, and markets relevant to the use and treatment of energy storage implemented by the California Public Utility Commission (CPUC), California Independent System Operator (CAISO), electric utilities, and others—important for understanding lessons from the first state to make significant progress on energy storage. http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002008901

- **Including Advanced Energy Storage in Integrated Resource Planning: Cost Inputs and Modeling Approaches** – This report by the Energy Storage Association provides an overview of how to incorporate advanced energy storage in long-term utility integrated resource planning processes. http://energystorage.org/IRP.

- **Market and Policy Barriers to Energy Storage Deployment** – This report by Sandia National Laboratories identifies regulatory and market-based hindrances to deploying energy storage and discusses possible solutions to address the current challenges. http://www.sandia.gov/ess/publications/SAND2013-7606.pdf

- **State of Charge: Massachusetts Energy Storage Initiative Study** – As part of the Massachusetts Energy Storage Initiative to evaluate and demonstrate the benefits of deploying energy storage technologies, the Department of Energy Resources (DOER) and the Massachusetts Clean Energy Center (MassCEC) partnered to conduct a study to analyze the economic benefits and market opportunities for energy storage in the state. http://www.mass.gov/eea/docs/doer/state-of-charge-report.pdf

- **Survey of Modeling Capabilities and Needs for Stationary Energy Storage Industry** – This Navigant report describes each of the models currently used in the industry to evaluate energy storage technologies. This study does not evaluate the quality or performance of the specific models and tools but rather describes their current capabilities and future development plans, as expressed by the software developers surveyed and other industry experts. http://energystorage.org/system/files/resources/survey_of_modeling_capabilities_and_needs_for_the_stationary_energy_storage_industry_-_final_may_2014.pdf

- **Teaching the "Duck" to Fly (Second Edition)** – This report by The Regulatory Assistance Project seeks to address the challenging ramping issues faced by utility operators due to the increased penetration of wind and solar energy resources by proposing ten strategies, including controlling electric water heaters, using ice storage for commercial air conditioning, and deploying targeted electric storage, among others. http://www.raponline.org/wp-content/uploads/2016/05/rap-lazar-teachingtheduck2-2016-feb-2.pdf

- **Technology Roadmap: Energy Storage** – This report by the International Energy Agency provides a roadmap to understand and communicate the value of energy storage to energy system stakeholders. https://www.iea.org/publications/freepublications/publication/technology-roadmap-energy-storage-.html

- **The Economics of Battery Energy Storage** – Produced by the Rocky Mountain Institute, this report discusses the impact of storage location on the range of potential services it can provide and delves into examples of value-stacking, with a focus on customer-sited energy storage. http://www.rmi.org/Content/Files/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf

- **U.S. Department of Energy Global Energy Storage Database** – An open-access resource that provides detailed information on energy storage projects and policies in the U.S. and around the world. http://www.energystorageexchange.org/projects/data_visualization

- **U.S. Energy Storage Monitor** – A quarterly report of U.S. energy storage market trends, including analysis of market growth, technology maturation, industry supply chains, and policy and regulatory developments—executive summaries are free to the public. https://www.greentechmedia.com/research/subscription/u.s.-energy-storage-monitor
- **Utility Scale Energy Storage Systems: Benefits, Applications, and Technologies** – This report by the State Utility Forecasting Group explores the role that utility scale energy storage can play on the grid by providing a review of six potential benefits and the various storage applications as well as a comparison and description of available energy storage technologies. https://www.purdue.edu/discoverypark/sufg/docs/publications/SUFG%20Energy%20Storage%20Report.pdf
- **SMARTGRID.GOV** – This website provides useful information on a variety of smart grid topics and contains reports and lessons learned from the 16 American Recovery and Reinvestment Act of 2009 (ARRA) energy storage demonstration projects. This includes contact information for each project. https://www.smartgrid.gov/recovery_act/program_impacts/energy_storage_technology_performance_reports.html

Credit: RES

Appendix A. Energy Storage Applications and Services

Energy Time-Shifting

A fundamental application of energy storage systems is to move energy across time, and create flexible reserves that are available on demand. When energy is low-cost or plentiful, it can be stored and returned to the system when it is more valuable or in high demand. The following are the most common energy time-shifting applications.

Electric time-shift means capturing energy when the market value or need for that energy is lower ('off-peak'), and then expelling that energy when market value or need is higher. The same service can be applied to absorb excess renewable energy (sometimes called 'spillage') to avoid renewable system curtailment. This front-of-meter application can help lower overall system costs and enable greater integration of variable renewable energy sources.

Time-varying rate management refers to a behind-the-meter storage system that is used to capture energy during off-peak time periods, when rates are lower, and then discharge that energy to serve onsite loads during on-peak times, when rates are higher. This application is particularly relevant in markets with dynamic pricing, critical-peak pricing, time-varying rates, and/or demand charges.

Peak Demand Management

A critical factor in electric system planning is determining when the peak demand for electricity will occur and ensuring there are adequate generating resources and capacity to deliver instantaneous energy to meet that peak demand. Energy storage systems can be deployed in both front-of-meter and behind-the-meter applications to provide **peak demand reduction** and other forms of load modulation to ensure energy supply and demand are most cost-effectively matched.

For customers impacted by rate structures that include demand charges, which are based on the highest demand for capacity during the given billing period, typically a 15-minute interval during that billing cycle, behind-the-meter storage systems can provide a valuable **demand charge management** service—in other words, a means to reduce customers' peak demand and thus avoid or reduce the demand charge and provide energy bill savings. These charges are designed to reflect the cost of serving the demand, so customer efforts to reduce demand charges can also result in system savings.

Electric Supply and Reserve Capacity

Energy storage systems that deliver stored energy to the grid function like a traditional generation asset by providing electric supply or reserve capacity. This application is primarily offered by larger front-of-meter storage systems, but under the right circumstances could be performed by aggregating capacity of smaller front-of-meter and/or behind-the-meter distributed storage systems.

To the extent energy storage is used to provide **electric supply capacity**, it may defer and/or delay investments in other generation capacity and/or purchases on the wholesale electricity market. Energy storage systems co-located with renewable energy installations can serve to increase the capacity value of those systems, by reducing variability and increasing output of the renewable energy facility. Utilizing energy storage for capacity and reserve services may also prevent costly generator starts and stops, reducing the need to idle power plants waiting to be called upon. To this end, energy storage can help reduce system operation costs, wasted fuel, and emissions.

Ancillary Services

When electricity supply and demand are perfectly matched, the grid operates at a specific frequency (60 hertz). Any significant deviations (i.e., when supply exceeds demand or vice versa) from this frequency can result in damage to power system equipment. Energy storage systems are capable of providing critically important **ancillary services**, the most important of which are described below.

Frequency response and regulation are high-value grid services that ensure system reliability and performance. Energy storage systems that provide these services follow a grid signal that tells them to either inject more or less energy for a short period of time, or alternatively charge more or less quickly, to manage deviations of the grid frequency. The ability to modify both supply and demand is unique to energy storage, as assets traditionally used to provide these services can only modify one or the other.
Ramping or load following are other critical ancillary services. Energy storage systems applied to provide these services are used to 'follow' system load, steadily increasing or decreasing output to match system demand in real time. This is especially important in instances of high ramping when demand is growing rapidly.

Equally important to grid stability is maintaining proper voltage and current, which controls power flows and enables both active and reactive power to reach loads on the grid. Certain energy storage systems can provide valuable **voltage/VAR support** to the grid by modulating charging and discharging behavior dynamically

Energy storage systems can also provide both **spinning and non-spinning reserve capacity**, which is capacity that is available almost instantaneously for un-forecasted and immediate system capacity needs, potentially in lieu of other on-demand solutions. To the extent storage is used for this purpose, it may allow other generation assets to operate with improved efficiencies instead of being used in part or in whole to meet reserve capacity requirements.

Taken altogether the above grid services amount to various facets of **power quality**, which can be provided on the macro scale in regional markets (i.e., for Independent System Operators or Regional Transmission Operators) or at a more distributed scale by either front-of-meter or behind-the-meter storage, particularly for certain industrial and commercial facilities.

Similarly, storage can help manage power quality across interconnecting systems. Referred to as **area regulation**, energy storage can be used to maintain transmission and distribution system balance, help manage interchange flows with other control areas, and recover from system disturbances quickly. Likewise, this service applies to 'islanded' and microgrid systems, which must regulate and balance supply and demand on a smaller scale.

System Flexibility and Renewables Integration

Energy storage systems provide services that can augment all types of generation assets, both renewables and non-renewable alike. At certain penetrations, the inherent variability of renewable energy can create planning challenges that, in the absence of storage, would require the electricity system operator to obtain greater amounts of system reserves to maintain the balance between generation and load at all times, as discussed above. In addition, while integration techniques have improved significantly, wind and solar generation can still pose forecasting challenges that may result in a need to maintain further fast responding reserves to hedge against forecasting errors. The inherent flexibility of energy storage systems makes them optimal candidates to help smooth the variability associated with integrating high volumes of renewable resources. At currently low penetration levels in most markets, energy storage is not needed to accommodate and integrate renewable energy on the grid. However, as renewable energy and other distributed energy resources continue to grow, there is a growing opportunity for energy storage to provide a valuable service in facilitating the integration of substantially more renewable energy on the grid. Energy storage systems provide the following core services as it relates to renewable energy:

- Energy storage systems can help make certain renewable energy resources more "dispatchable" by subtly adapting to micro-variations and **firming** renewable system output. In this application, the storage system absorbs energy when the renewable generation is exceeding market commitments or demand, and returns that energy when demand outstrips supply. This function closely resembles the system-level frequency applications described previously, and this 'firming' value can be provided effectively both by co-locating renewables with storage or deploying them elsewhere nearby on the grid.

- Storage systems can also support **curtailment avoidance** by ensuring there is enough flexible demand/load on the system for the renewable energy produced, thus preventing 'spillage'.

For traditional fossil fuel or nuclear power plants, which are less dynamic and slower to respond to increasingly variable power system demand, the presence of energy storage on the grid can provide **improved system flexibility**. By accurately following load variations and chasing dynamic grid signals, energy storage can help all generators operate at their peak performance more often. With the increase in dynamic loads, like electric vehicles distributed energy resources, system flexibility is an increasingly valuable attribute that is often overlooked in grid planning and integrated resource planning efforts.

Reliability and Resiliency

Perhaps the most well-known application for energy storage is as a source of **back-up power** in the event of a significant disturbance or outage. Strategically deployed behind-the-meter energy storage can increase resilience—the capacity to recover quickly from a severe disturbance, such as an extreme weather event, fire, or other natural disaster. Energy storage systems distributed throughout the grid, particularly when located on critical infrastructure, can help provide the necessary power to ensure emergency response services and facilities remain on-line during such an event. Under the same circumstances, front-of-meter energy storage can help balance supply and demand fluctuations and mitigate supply disruptions and outages, thus improving overall system reliability and avoided cascading blackouts. Energy storage can also provide **Black Start** capabilities, which is critical power necessary to jump-start an off-line power plant after an outage. Black Start is often classified as an ancillary service.

Grid Infrastructure Congestion Relief

Transmission and distribution (T&D) infrastructure assets that carry electricity can become congested or overwhelmed during periods of high demand. By shifting usage from times of the day with high congestion to periods of low-congestion, energy storage can increase **transmission and distribution network capacity** by better utilizing grid infrastructure. More specifically, a strategically located energy storage system can charge or discharge to ensure that power flows from multiple points on the grid are not limited by the capacity of a single shared transmission line, thus providing important **congestion relief**.

Along similar lines, energy storage can provide **transmission and distribution upgrade deferral**, by mitigating strain on existing infrastructure. Storage may also help increase the hosting capacity of distribution systems to enable further DER expansion on the grid, particularly in areas with high penetration.

System Aggregation and 'Virtual Power Plants'

In addition to being able to deliver each of these applications independently in each system, the emergence of advanced system controls are enabling energy storage systems to be networked together to act in aggregate as a coordinated asset. **System Aggregation** provides the capability for multiple energy storage systems to work in concert and increase their market potential and net benefit.

As an example, an integrated collection of energy storage systems at various sites could export energy simultaneously from independent locations and enter a competitive market as one combined system. Alternatively, these virtually interconnected storage systems could simultaneously modulate their loads to reduce demand during system peaks to lower system operating costs.

Sometimes referred to as **Virtual Power Plants**, these innovative systems are not limited to just one asset type. Energy storage can be combined with a grid-connected renewable asset and a demand response bid into one net asset that can simultaneously deliver energy and reduce load. Technology innovation is continually expanding virtual system capabilities, and markets are creating increasing opportunities for these types of dynamic assets that can deliver multiple value streams simultaneously with an aggregated locational value.

Credit: S&C Electric Company

Appendix B. Modeling Tools Overview

A range of tools currently exists to analyze the value of energy storage technologies. Using different modeling methods, these tools provide grid operators and stakeholders with information to assist in system planning as well as energy storage screening and optimization. Within those broader objectives, there are five types of modeling categories: resource portfolio planning, production cost simulation, transmission planning, distribution planning, and project-specific energy storage evaluation.

Resource portfolio planning

Resource portfolio planning models are used to determine the optimal mix of resources required to minimize cost and meet other system requirements. These models consider existing and planned supply capacity as well as accounting for other grid operational components, such as demand response and other demand side resources. Portfolio planning models can evaluate the economic and operational impacts of deploying energy storage, but are not able to fully capture the benefits it can provide in both the energy and ancillary services markets.[142]

Production cost simulation

Production cost simulation models incorporate detailed market and system data to produce the hourly and, in some models, sub-hourly dispatch of a system to minimize total system production cost. These models can inform long-term energy storage planning, but can underestimate the operational value of energy storage if the models are not able to simulate its sub-hourly dispatch capability.[143]

Transmission system planning

Transmission system planning models evaluate transmission network reliability under certain conditions, such as power quality violations or loss of generation. These grid disturbance scenarios are modeled using load flow and stability simulations, which can then identify grid locations that could benefit from energy storage. Dynamics simulation tools can be used to identify frequency drift and power factor problems at the transmission level and assess whether storage could prevent any operating violations.

Distribution system planning

Distribution system planning models can be used for short- and long-term distribution planning using load flow simulations. These models can assess the impacts of energy storage at the circuit level and identify the types of benefits it can provide. However, distribution system tools lack the ability to create optimized dispatch plans for different storage applications.[144]

Project-specific energy storage evaluation

Storage-specific tools are used to screen energy storage technologies to determine whether they are cost effective and/or to evaluate the optimal operation or mix of technologies to meet certain objectives. To measure cost effectiveness, these tools quantify the monetizable benefits of energy storage systems which do not include the broader system-level benefits.

As evidenced by the multiple methods used to evaluate energy storage above, there is no standardized method to model the deployment of energy storage systems. System planning requires different tools to model system dispatch, grid optimization, and the ability of energy storage to increase reliability at the transmission or distribution levels. Storage-specific models can demonstrate the value of energy storage, but can be proprietary and used for internal rather than system planning.

In addition to the absence of a standard storage valuation methodology, the existing models do not provide a comprehensive value for energy storage. Even within tools specifically designed to assess the value of specific energy storage projects, all benefits are not fully captured. This must be addressed to evaluate storage on a level playing field with other grid resources.

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27. See IHS, Future of Grid Connected Energy Storage, Nov. 2015, available at: https://technology.ihs.com/512285/grid-connected-energy-storage-report-2015 (accessed Mar. 19, 2017); see also: Slide 17 in Lazard, Levelized Cost of Storage – Version 1.0, Nov. 2015, available at: https://www.lazard.com/media/2391/lazards-levelized-cost-of-storage-analysis-10.pdf#18 (accessed Mar. 19, 2017); Slide 70 in keynote presentation by Michael Liebrich from the BNEF New Energy

Finance Summit, Apr. 5, 2016, available at: https://data.bloomberglp.com/bnef/sites/4/2016/04/BNEF-Summit-Keynote-2016.pdf#71 (accessed Mar. 19, 2017); Navigant Research, Sam Jaffe presentation at NY-BEST Conference, Sep. 2014, cited in slide 9 in NY-BEST presentation Batteries and Energy Storage, Jun. 10, 2015, available at: https://nysolarmap.com/media/1292/acker_nybest.pdf (accessed Mar. 19, 2017); UBS, US Battery Storage: Upstream Supply Chain Biggest Winner of EVs, Oct. 2016, available at: https://neo.ubs.com/shared/d1Wg6h8EJsbg/ (accessed Mar. 19, 2017); GTM Research, Grid-Scale Energy Storage Balance of Systems 2015-2020, Jan. 2016, available at: https://www.greentechmedia.com/research/report/grid-scale-energy-storage-balance-of-systems-2015-2020 (accessed Mar. 19, 2017); IHS, Energy Storage Inverter (PCS) Report, Sept. 2016, available at: https://technology.ihs.com/523547/energy-storage-inverter-pcs-report-2016 (accessed Mar. 19, 2017).

28. State of Charge at xi.

29. Id. at xii (Table 1: Total System Benefits).

30. Id.

31. Judy Chang et al., The Value of Distributed Electricity Storage in Texas, The Brattle Group, Mar. 2015, at 4, available at: http://brattle.com/system/publications/pdfs/000/005/126/original/The_Value_of_Distributed_Electricity_Storage_in_Texas_-_Proposed_Policy_for_Enabling_Grid-Integrated_Storage_Investments_Full_Technical_Report.pdf?1426377384 (accessed Jan. 13, 2017) (hereinafter The Value of Distributed Electricity Storage in Texas) (Finding that the benefits of storage for merchant generators likely do not exceed the costs on their own. The benefits do exceed the costs for system-wide benefits, however, and together the greatest amount of value is likely to be achieved at lower cost).

32. Josh Eichman, et al., Operational Benefits of Meeting California's Energy Storage Targets, National Renewable Energy Laboratory (NREL), Dec. 2015, available at: http://www.nrel.gov/docs/fy16osti/65061.pdf (accessed Mar. 20, 2017); Paul Denholm et al., The Value of Energy Storage for Grid Applications, NREL, May 2013, available at: http://www.nrel.gov/docs/fy13osti/58465.pdf (accessed Mar. 20, 2017); Paul Denholm et al., The Relative Economic Merits of Storage and Combustion Turbines for Meeting Peak Capacity Requirements under Increased Penetration of Solar Photovoltaics, NREL, Sept. 2015, available at: http://www.nrel.gov/docs/fy15osti/64841.pdf (accessed Mar. 20, 2017).

33. PJM Interconnection, Performance Based Regulation: Year One Analysis, 2013, available at: http://www.njcleanenergy.com/files/file/Renewable_Programs/Meeting%20Notes/PJMReport2013October12.pdf (accessed Mar. 20, 2017).

34. Samuel Newell et al., Cost-Benefit Analysis of ERCOT's Future Ancillary Services (FAS) Proposal, The Brattle Group, Dec. 2015, available at: http://www.brattle.com/system/news/pdfs/000/000/982/original/Cost-Benefit_Analysis_of_ERCOT's_Future_Ancillary_Services_(FAS)_Proposal.pdf?1450901946 (accessed Mar. 20, 2017).

35. Emission reductions are dependent on the energy generation mix and the time of charging and discharging.

36. State of Charge at 79.

37. For a more thorough discussion of the various contexts in which valuation of storage may arise, and the associated challenges, see Navigant Consulting, Inc., Survey of Modeling Capabilities and Needs for Stationary Energy Storage Industry, May 2014, Executive Summary available at: http://energystorage.org/resources/executive-summary-survey-modeling-capabilities-and-needs-stationary-energy-storage (accessed Mar. 20, 2017) (hereinafter Survey of Modeling Capabilities and Needs for Stationary Energy Storage Industry).

38. California Public Utilities Commission (CPUC), Docket No. 15-03-011, Order Instituting Rulemaking to Consider Policy and Implementation Refinements to the Energy Storage Procurement Framework and Design Program (D.13-10-040, D.14-10-045) and Related Action Plan of the California Energy Storage Roadmap, at 14, Apr. 2, 2015, available at: http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M149/K976/149976766.PDF (accessed Jan. 13, 2017).

39. See State of Charge at 108.

40. The Electric Power Research Institute has developed a successor tool to ESVT, called the Storage Value Estimation Tool (StorageVET).

41. See State of Charge at 108.

42. See Id. at xvi.

43. See Portland General Electric, 2016 Integrated Resource Plan, at 235, 2016, available at: https://www.portlandgeneral.com/our-company/energy-strategy/resource-planning/integrated-resource-planning (accessed Jan. 13, 2017).

44. The utility's analysis "consider[ed] a generic energy storage device without specific locational information," and therefore received "zero locational value" for purposes of the analysis. Id. at 237.

45. See, e.g., New York Dept. of Public Service (DPS), In the Matter of the Value of Distributed Energy Resources, Docket No. 15-E-0751, opened 2015; CPUC, Distribution Resources Plan proceeding, Docket No. 14-08-013, opened 2014.

46. DPS, Docket No. 15-E-0751, Staff Report and Recommendations in the Value of Distributed Energy Resources Proceeding, at 8, Oct. 23, 2016, available at: http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B59B620E6-87C4-4C80-8BEC-E15BB6E0545E%7D (accessed Jan. 13, 2017).

47. See CPUC, Renewable Feed-In Tariff Program, Feb. 7, 2017, available at: http://www.cpuc.ca.gov/feedintariff/ (accessed Feb. 9, 2017) and CPUC, Decision 12-05-035, Decision Revising Feed-In Tariff Program, 2012, available at: http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/167679.pdf (accessed Mar. 20, 2017).

48. See Walton, Robert, The non-wire alternative: ConEd's Brooklyn Queens pilot rejects traditional grid upgrades, Utility Dive, Aug. 3, 2016, available at: http://www.utilitydive.com/news/the-non-wire-alternative-coneds-brooklyn-queens-pilot-rejects-traditional/423525/ (accessed Mar. 15, 2017). See also New York DPS, Case Number 14-E-0302, Petition of Consolidated Edison Company of New York, Inc. for Approval of Brooklyn/Queens Demand Management Program, all filings available at: http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterSeq=45800 (accessed Mar. 20, 2017).

49. Will Driscoll, Making the Case for Energy Storage in Integrated Resource Planning, Greentech Media, Dec. 1, 2016, available at: https://www.greentechmedia.com/articles/read/making-a-case-for-energy-storage-in-integrated-resource-planning (accessed Jan. 13, 2017).

50. See Oregon Energy Storage Workshop, held at the White Stag Building, Portland, Oregon on March 19, 2014. Video recording of workshop available at: https://www.youtube.com/watch?v=5jCizMeZuNI (accessed Mar. 21, 2017).

51. Massachusetts Dept. of Public Utilities (DPU), Docket No. 15-ESC-1, Stakeholder Conference on Energy Storage, held Jul. 9, 2015.

52. Nevada Public Utilities Commission (PUCN), Docket No. 16-01013, Investigation Regarding Energy Storage Technologies, opened Jan. 2016, available at: http://pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2015_THRU_PRESENT/2016-1/10735.pdf (accessed Jan. 14, 2017).

53. See Washington State Utilities and Transportation Commission (UTC), Docket No. UE-151069, Modeling Energy Storage in Integrated Resource Planning, 2015.
54. UTC, Docket No. U-161024, Rulemaking for Integrated Resource Planning, 2016.
55. Arizona Corporation Commission, Docket No. E-OOOOOJ-13-0375, Emerging Technologies in Energy, 2014.
56. Arizona Corporation Commission, Docket E-00000Q-16-0289, Review, Modernization and Expansion of the Arizona Energy Standards and Tariff Rules and Associated Rates, 2016.
57. See New Mexico Energy, Minerals and Natural Resources Department website, http://www.emnrd.state.nm.us/ECMD/RenewableEnergy/RenewableEnergyStorage.html (accessed Jan. 14, 2017).
58. New Mexico Energy, Minerals and Natural Resources Department, Seizing our Energy Potential: Creating a More Diverse Economy in New Mexico, 2015, available at: http://www.emnrd.state.nm.us/EnergyPolicy/documents/EMNRD_EnergyPolicy.pdf (accessed Mar. 20, 2017).
59. See Minnesota Department of Commerce, White Paper Analysis of Utility-Managed, On-Site Energy Storage in Minnesota, Dec. 2013, available at: http://mn.gov/commerce-stat/pdfs/utility-managed-storge-study.pdf (accessed Mar. 20, 2017).
60. See New Jersey Board of Public Utilities, Solicitation, Oct. 23, 2014, available at: http://www.njcleanenergy.com/files/file/Renewable_Programs/EnergyStorage/FY2015_Renewable_Electric_Storage_Solicitation_FINAL_%20with_Appendices_A-E_10_9_14.pdf (accessed Mar. 20, 2014).
61. CPUC, D.16-06-052, Docket No. 11-09-011, Order Instituting Rulemaking on the Commission's Own Motion to Improve Distribution Level Interconnection Rules and Regulations for Certain Classes of Electric Generator and Electric Storage Resources, Jul. 1, 2016.
62. North Carolina Utilities Commission, Docket No. E-100 Sub 101, In the Matter of Petition for Approval of Revisions to Generator Interconnection Standards, 2014.
63. Public Service Commission of South Carolina, Docket No. 2015-362-E, Order Adopting Interconnection Standard and Supplemental Provisions, 2016.
64. Minnesota Public Utilities Commission, Docket No. E-999/CI-16-521, In the Matter of Updating the Generic Standards for the Interconnection and Operation of Distributed Generation Facilities Established Under Minn. Stat. sec. 216B.1611, 2016.
65. Iowa Utilities Board, Docket No. RMU-2016-0003 (NOI-2014-0001), Order Adopting Amendments, Dec. 28, 2016.
66. PUCN, Docket No. 16-01013.
67. District of Columbia Public Service Commission, Formal Case 1130, Modernizing the Energy Delivery System for Increased Sustainability, MEDSIS Staff Report, Jan. 25, 2017.
68. CPUC, Docket No. 12-11-005, Order Instituting Rulemaking Regarding Policies, Procedures and Rules for the California Solar Initiative, the Self-Generation Incentive Program and Other Distributed Generation Issues, 2012.
69. CPUC, D.14-05-033 (issued May 23, 2014), Docket No. 12-11-005.
70. CPUC, D.16-04-020 (issued Apr. 28, 2016), Docket No. 12-11-005.
71. See, e.g., Kristi Shallenberger, Growing pains: Hawaii solar sector howls as grid-supply incentives hit caps, Utility Dive, Sept. 13, 2016, available at: http://www.utilitydive.com/news/growing-pains-hawaii-solar-sector-howls-as-grid-supply-incentives-hit-caps/426149/ (accessed Jan. 13, 2017); Peter Maloney, Hawaiian Electric: self-supply solar incentive starting to take off, Utility Dive, Nov. 7, 2016, available at: http://www.utilitydive.com/news/hawaiian-electric-self-supply-solar-incentive-starting-to-take-off/429800/ (accessed Jan. 13, 2017).
72. See Massachusetts Executive Office of Energy and Environmental Affairs, Development of the Next Solar Incentive, available at: http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/development-of-the-next-solar-incentive.html (accessed Jan. 13, 2017).
73. Robert Walton, Colorado approves Xcel Energy's landmark solar settlement, Utility Dive, Nov. 10, 2016, available at: http://www.utilitydive.com/news/colorado-approves-xcel-energys-landmark-solar-settlement/430130/ (accessed Feb. 9, 2017).
74. Dan Cross-Call and Aman Chitkara, Design Matters: Unpacking Xcel's Current Rates Proposal, Rocky Mountain Institute, Jun. 2, 2016, available at: http://blog.rmi.org/blog_2016_06_02_design_matters_unpacking_xcels_rates_proposals (accessed Feb. 9, 2017) (hereinafter Design Matters).
75. CPUC, Docket No. R.15-12-012; see also CPUC, Docket No. R.12-06-013, Rulemaking On The Commission's Own Motion To Conduct A Comprehensive Examination Of Investor Owned Electric Utilities' Residential Rate Structures, The Transition To Time Varying And Dynamic Rates, And Other Statutory Obligations, opened Jun. 21, 2012.
76. For instance, Hawaii utilities implemented a pilot TOU rate in October 2016, which provides significant spreads that are likely to incentivize storage. See Hawaiian Electric, Time-of-Use rates program off to a brisk start, Oct. 31, 2016, available at: https://www.hawaiianelectric.com/time-of-use-rates-program-off-to-a-brisk-start (accessed Feb. 10, 2017); PEPCO has conducted a successful pilot of TOU rates in Pennsylvania. See Gavin Bade, Inside the surprising lessons from PECO's time-of-use rate pilot, Utility Dive, May 22, 2015, available at: http://www.utilitydive.com/news/inside-the-surprising-lessons-from-pecos-time-of-use-rate-pilot/399629/ (accessed Feb. 10, 2017).
77. See CPUC Docket No. 12-11-005, D. 14-05-033 and D. 16-04-020.
78. See, e.g., Kari Lyndersen, In Illinois, New Rules Expected to Make Solar Faster and Cheaper, Midwest Energy News, Oct. 19, 2016, available at: http://midwestenergynews.com/2016/10/19/in-illinois-new-rules-expected-to-make-solar-faster-and-cheaper/ (accessed Jan. 13, 2017). See also IREC, Thumbs Up for Illinois Proactive Action on Interconnection, Oct. 19, 2016, available at: http://www.irecusa.org/2016/10/thumbs-up-for-illinois-proactive-action-on-interconnection/ (accessed Jan. 13, 2017).
79. See CPUC Rulemaking to Consider Policy and Implementation Refinements to the Energy Storage Procurement Framework and Design Program, Docket No. R.15-03-011. "Track One" resulted in CPUC decision D.16-01-032 (Jan. 28, 2016), clarifying issues related to storage targets, project eligibility and cost recovery. "Track Two" is underway and concerns longer term issues regarding the storage framework, including systems valuation, station power for storage systems and multiple-use applications. This track is proceeding in tandem with the second phase of CAISO's Energy Storage Roadmap Stakeholder Initiative ("ESDER 2").
80. Public Utility Commission of Oregon, Docket No. UM-1751, HB 2193 Implementing An Energy Storage Program Guidelines, 2015.
81. H. 4568, enacted in August 2016, directs DOER to determine if energy storage goals are prudent for the state, and if so, to set a procurement target for 2020.
82. New York Public Service Commission, Docket No. 16-M-0411, Order on Distributed System Implementation Plan Filings, at 33, Mar. 2017.
83. See Connecticut Department of Energy and Environmental Protection, Demonstration Projects for Grid-Side System Enhancements to Integrate Distributed Energy Resources, Aug. 2016, available at: http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/0365b2ceae5f13608525800d006f5c43/$FILE/2016.08.12_FINAL%203rd%20Grid%20Side%20Notice.pdf (accessed Mar. 20, 2017).

84. See Vermont General Assembly, No. 56: An act relating to establishing a renewable energy standard, H.40, Jun. 11, 2015, available at: http://legislature.vermont.gov/assets/Documents/2016/Docs/ACTS/ACT056/ACT056%20As%20Enacted.pdf (accessed Jan. 13, 2017).

85. See John Ballam, P.E., Massachusetts Alternative Portfolio Standard for Combined Heat & Power (CHP)

86. State of Charge at 157.

87. See Connecticut Department of Energy and Environmental Protection, Notice of Request for Proposals from Private Developers of Clean Energy, Mar. 2016, available at: http://www.dpuc.state.ct.us/DEEPEnergy.nsf/c6c6d525f7cdd1168525797d0047c5bf/ffee9c54378d404a85257f710054fb32?OpenDocument (accessed Mar. 20, 2017).

88. See CPUC, Docket No. R.12-11-005. In June 2006, the CPUC issued D.16-06-055, revising the program to allocate 75 percent of the incentive budget to energy storage, with 15 percent of the storage budget dedicated to residential projects. A result of the SGIP's expansion to include energy storage has resulted in 106.5 MW of funded energy storage. (State of Charge at 142).

89. See, e.g., Eric Wesoff, The State of US Energy Storage in 7 Slides, Dec. 9, 2016, available at: https://www.greentechmedia.com/articles/read/The-State-of-US-Energy-Storage-in-7-Slides (accessed Jan. 14, 2017).

90. DPS, Docket No. 14-M-0094, Proceeding on Motion of the Commission to Consider a Clean Energy Fund, opened 2014.

91. See Jeff St. John, Why Washington State's $14.3M Storage Program Is So Different From Others, Greentech Media, Jul. 9, 2014, available at: http://www.greentechmedia.com/articles/read/washington-state-sinks-14.3m-into-energy-storage-plus-standards (accessed Jan. 13, 2017).

92. See State of Utah, Sustainable Transportation and Energy Plan Act, S.B. 115, Jan. 29, 2016, available at: http://le.utah.gov/~2016/bills/sbillint/sb0115.pdf (accessed Jan. 13, 2017).

93. See Utah Public Service Commission, Docket No. 16-035-36, Rocky Mountain Power Solar and Energy Storage Program, Sept. 2016, available at: https://www.rockymountainpower.net/content/dam/rocky_mountain_power/doc/About_Us/Rates_and_Regulation/Utah/Regulatory_Filings/Docket_16_035_36/09-08-16_Application_and_Direct_Testimony/Application/exhibits/Exhibit_D_(redacted).pdf (accessed Mar. 20, 2017).

94. Rachel Wilson and Bruce Biewald, Best Practices in Electric Utility Integrated Resource Planning: Examples of State Regulations and Recent Utility Plans, Regulatory Assistance Project, at 2, Jun. 2013, available at: http://www.raponline.org/wp-content/uploads/2016/05/rapsynapse-wilsonbiewald-bestpracticesinirp-2013-jun-21.pdf (accessed Jan. 13, 2017) (hereinafter Best Practices in Electric Utility Integrated Resource Planning) ("An integrated resource plan is a utility plan for meeting forecasted annual peak and energy demand, plus some established reserve margin, through a combination of supply-side and demand-side resources over a specified future period.")

95. See, e.g. CPUC, Docket No. R.14-08-013, Distribution Resources Plan, Aug. 13, 2014; DPS, Docket No. 16-M-0411, In the Matter of Distributed System Implementation Plans, 2016; MA DPU, Docket Nos. 15-120, 15-121 & 15-122, Grid Modernization Plans, 2015; Hawaii Public Utilities Commission, Docket No. 2014-0192, Distributed Energy Resource Policies, 2014.

96. See, e.g., CPUC, R. 14-08-013, Assigned Commissioner's Ruling (1) Refining Integration Capacity And Locational Net Benefit Analysis Methodologies And Requirements; and (2) Authorizing Demonstration Projects A and B, May 2, 2016; DPS, Docket No. 14-M-0101, Order Adopting a Regulatory Policy Framework and Implementation Plan, Feb. 26, 2015; Minnesota Public Utilities Commission, Docket No. E002/M-15-962, Order Certifying Advanced Distribution-Management System (Adms) Project Under Minn. Stat. § 216b.2425 and Requiring Distribution Study, Jun. 28, 2016.

97. See, e.g., DPS, Docket No. 15-E-0751; CPUC, Docket No. 14-08-013.

98. See, e.g. CPUC, Docket No. R.14-08-013; DPS, Docket No. 16-M-0411; DPU, Docket Nos. 15-120, 15-121 & 15-122.

99. DPS, Docket No. 14-M-0101, Order Adopting a Ratemaking and Utility Revenue Model Policy Framework, May 19, 2016.

100. CPUC, R. 14-10-003, D. 16-12-036, Decision Addressing Competitive Solicitation Framework and Utility Regulatory Incentive Pilot, Dec. 22, 2016.

101. Missouri Public Service Commission, Docket No. EO-2016-0232, In the Matter of the Resource Plan of Kansas City Power & Light Company, 2016.

102. Hawaii Public Utilities Commission, Docket No. 2014-0183, In the Matter of Instituting a Proceeding to Review the Power Supply Improvement Plans for Hawaiian Electric Company, Inc., Hawaii Electric Light Company, Inc., and Maui Electric Company, Limited, Dec. 23, 2016.

103. UTC, Docket No. U-161024.

104. UTC, Docket No. UE-151069.

105. For example, to address significant challenges relating to fire code and permitting with microgrid and energy storage pilot projects, New York has developed a comprehensive guide, available at: https://nysolarmap.com/media/1450/decdghub_energystoragesystemspermittingandinterconnectionguide.pdf (accessed Mar. 20, 2017).

106. See Herman Trabish, A Silver Bullet? Inside FERC's landmark energy storage rulemaking, Jan. 10, 2017, available at: http://www.utilitydive.com/news/a-silver-bullet-inside-fercs-landmark-energy-storage-rulemaking/433559/ (accessed Jan. 14, 2017).

107. Although this paper focuses on barriers that state regulators can help address through policy action, ISO/RTO and FERC rules are also responsible for the problem of energy storage's classification, and likely would need to be addressed alongside barriers within states' jurisdiction. See, e.g., Garrett Fitzgerald et al., The Economics of Battery Energy Storage, Rocky Mountain Institute, Oct. 2015, at 36, available at: http://www.rmi.org/Content/Files/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf (accessed Mar. 20, 2017) ("under prevailing ISO/RTO rules, a utility would not be allowed to use a fleet of batteries to participate in the wholesale electricity market while simultaneously providing distribution upgrade deferral services and collecting cost-of service recovery payments"); see also FERC, Docket RM16-12-0000, Notice Inviting Post-Technical Conference Comments re Review of Generator Interconnection Agreements and Procedures, et al under RM16-12 et al, 2016 (inquiring into the appropriate interconnection process for energy storage systems that are behaving as "transmission assets" vs. generators).

108. See Dhruv Bhatnagar et al., Market and Policy Barriers to Energy Storage Deployment, Sandia National Laboratories, Sept. 2013, at 22, available at: http://www.sandia.gov/ess/publications/SAND2013-7606.pdf (accessed Jan. 13, 2017) (hereinafter Market and Policy Barriers to Energy Storage Deployment).

109. The Value of Distributed Electricity Storage in Texas at 4.

110. By contrast, in regulated, or "vertically integrated," regions, a "utility can utilize its assets for any purpose across these classifications and

recover all value that the asset can provide." Market and Policy Barriers to Energy Storage Deployment at 22. Nevertheless, vertically integrated states can present other barriers to storage deployment. Since utilities in these states do not "price" each of storage's services individually but rather as a whole package, the value of individual services is not transparent. This can make it difficult to effectively "monetize" energy storage's services, an issue discussed further below.

111. See Public Utility Commission of Texas, Docket 46368, Application of AEP Texas North Company for Regulatory Approvals Related to the Installation of Utility-Scale Battery Facilities, available at: http://interchange.puc.state.tx.us/WebApp/Interchange/Documents/46368_22_916138.PDF (accessed Mar. 15, 2017)

112. The Value of Distributed Electricity Storage in Texas at 53.

113. Federal Energy Regulatory Commission, Docket No. PL17-2-000, Utilization of Electric Storage Resources for Multiple Services When Receiving Cost-Based Rate Recovery, Policy Statement, Jan. 19, 2017, available at: https://www.ferc.gov/whats-new/comm-meet/2017/011917/E-2.pdf (accessed Jan. 19, 2017).

114. Id.

115. See Jim Lazar, Electricity Regulation in the US: A Guide (Second Edition), Regulatory Assistance Project, at 87, 2016, available at: http://www.raponline.org/knowledge-center/electricity-regulation-in-the-us-a-guide-2/ (accessed Jan. 12, 2017); see also McConnell, et. al., Easing the Transition to a More Distributed Electricity System, IREC, May 2015, at 11, available at: http://www.irecusa.org/2015/02/landmark-report-released-by-irec-easing-the-transition-to-a-more-distributed-electricity-system/ (accessed Mar. 20, 2017) (describing how the two investment tests of "prudency" and "used and useful" impact utility decision making).

116. Coley Girouard, Understanding IRPs: How Utilities Plan for the Future, Advanced Energy Economy, Aug. 11, 2015, available at: http://blog.aee.net/understanding-irps-how-utilities-plan-for-the-future (accessed Jan. 7, 2017) ("According to AEE's PowerPortal, 33 states - either by state statute or regulation - require utilities to file publicly available IRPs or their equivalent with their PUC.").

117. For a useful discussion of IRPs and best practices, see Best Practices in Electric Utility Integrated Resource Planning.

118. For further discussion of how to consider energy storage in IRP proceedings, see Jason Burwen, Including Advanced Energy Storage in Integrated Resource Planning: Cost Inputs and Modeling Approaches, Energy Storage Association, Nov. 2016, available at: http://energystorage.org/IRP (accessed Mar. 20, 2017).

119. The recent decision by the Oregon Commission adopting guidance for the energy storage procurement target recognizes the need for utilities to seek out information from the stakeholder community in order to ensure they are operating with the most up-to-date information about storage capabilities and costs. OR PUC, Order No. 16-504, Guidelines And Requirements Adopted To Implement HB 2193, at 11, Dec. 28, 2016.

120. The New York Public Service Commission recently issued an order requiring the utilities in the state to develop a more robust framework for consideration of non-wires alternatives. See NY PSC, Docket No. 16-M-0411, Order on Distributed System Implementation Plan Filings, at 18-25, Mar. 2017. The CPUC is also beginning a pilot program to test out a method for requiring utilities to deploy non-wires alternatives on the distribution system. See CPUC, Docket No. R. 14-10-003, Decision 16-12-036, Decision Addressing Competitive Solicitation Framework and Utility Regulatory Incentive Pilot, Dec. 15, 2016.

121. State of Charge at xiv.

122. See, e.g., CPUC, Docket No. R.15-12-012, Order Instituting Rulemaking to Assess Peak Electricity Usage Patterns and Consider Appropriate Time Periods for Future Time-of-Use Rates and Energy Resource Contract Payments, 2015; see also CPUC, Docket No. R.12-06-013, Rulemaking On The Commission's Own Motion To Conduct A Comprehensive Examination Of Investor Owned Electric Utilities' Residential Rate Structures, The Transition To Time Varying And Dynamic Rates, And Other Statutory Obligations, opened Jun. 21, 2012.

123. Robert Walton, Colorado approves Xcel Energy's landmark solar settlement, Utility Dive, Nov. 10, 2016, available at: http://www.utilitydive.com/news/colorado-approves-xcel-energys-landmark-solar-settlement/430130/ (accessed Jan. 13, 2017).

124. See Design Matters.

125. CPUC, Docket No. 12-11-005.

126. Jeff St. John, Sweeping Changes Proposed for Demand Response in California, Greentech Media, Sept. 7, 2016, available at: https://www.greentechmedia.com/articles/read/big-changes-proposed-for-demand-response-in-California (accessed Feb. 10, 2017).

127. Jeff St. John, The Details Behind California's Demand Response Auction Mechanism, Greentech Media, Oct. 23, 2015, available at: https://www.greentechmedia.com/articles/read/The-Details-Behinds-Californias-Demand-Response-Auction-Mechanism (accessed Feb. 10, 2017).

128. Id.

129. In restructured states, on the other hand, monetization of energy storage may depend on the number of storage's services that can participate in energy markets. A report on the value of energy storage in Texas found that "approximately 30–40% of the total system-wide benefits of storage investments are associated with reliability, transmission, and distribution functions that are not reflected in wholesale market prices and, therefore, cannot be captured by merchant storage investors." See The Value of Distributed Electricity Storage in Texas at iii.

130. Market and Policy Barriers to Energy Storage Deployment at 29 ("only vertically integrated utilities may be able to determine the value of ancillary services to their systems, limiting consideration of energy storage resources to these entities, and creating difficulty for regulators to verify the value of a resource in utility and developer proposals").

131. Id.

132. See D. Steward and E. Doris, The Effect of State Policy Suites on the Development of Solar Markets, NREL, Nov. 2014, at 3-4, available at: http://www.nrel.gov/docs/fy15osti/62506.pdf (accessed Mar. 20, 2014) (identifying interconnection policies as foundational for distributed generation market growth).

133. IREC, Model Interconnection Procedures, 2013, available at: http://www.irecusa.org/publications/model-interconnection-procedures/ (accessed Mar. 20, 2017).

134. For information on emerging issues in interconnection, including those where best practices have yet to emerge, see IREC's Greentech Media blog series, available through IREC's website at: http://www.irecusa.org/regulatory-reform/interconnection/ (accessed Mar. 20, 2017).

135. For more information on smart or advanced inverter settings, see NREL, Advanced Inverter Functions to Support High Levels of Distributed Solar Policy and Regulatory Considerations, Nov. 2014, available at: http://www.nrel.gov/docs/fy15osti/62612.pdf (accessed Mar. 20, 2017); Emerson Reiter, et al., Industry Perspectives on Advanced Inverters for U.S. Solar Photovoltaic Systems: Grid Benefits, Deployment Challenges, and Emerging Solutions, NREL, Sept. 2015, available at: http://www.nrel.gov/docs/fy15osti/65063.pdf (accessed Mar. 20, 2017).

136. See, e.g., FERC, Small Generator Interconnection Agreements and Procedures, Order No. 792, 145 FERC ¶ 61,159, at ¶ 228, 2013 (revising the pro forma small generator interconnection standards and agreement to expressly include energy storage in the definition of generator); Iowa Utilities Board, Docket No. RMU-2016-0003, Order Adopting Amendments, Dec. 28. 2016 (incorporating energy storage into the definition of a distributed generation facility and also incorporating energy storage into various portions of the standards to clarify applicability and unique operating capabilities).

137. See, e.g., Id. at ¶ 230 (Requiring the utility to evaluate the system based on the capacity identified by the applicant in the interconnection application, so long as the utility agrees that the method used to limit the max capacity will not adversely affect the safety and reliability of the electric system.); CPUC, D. 16-06-052 at 20 and Attachment C (allowing customers to specify in their interconnection application the operating characteristics of the proposed system).

138. See, e.g., Pacific Gas and Electric Company, Guide to Energy Storage Charging Issues For Rule 21 Generator Interconnection, Oct. 2016, at 6-8, available at: https://www.pge.com/pge_global/common/pdfs/for-our-business-partners/interconnection-renewables/GuidetoEnergyStorageChargingIssues.pdf (accessed Mar. 20, 2017) (discussing different review processes depending upon the selection of charging operation modes).

139. CPUC, D. 16-06-052. (The California Public Utilities Commission adopted a process that allows the utilities to review the charging and discharging functions concurrently in most cases, but clarified that the cost allocation rules for new load will be applied before the rules that would apply to a new generator. This prevents energy storage systems from receiving discriminatory treatment when compared to other load, but also ensures they bear the responsibility of upgrades caused solely by their generating characteristics.)

140. See, e.g., FERC, Notice of Proposed Rulemaking, Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators, Nov. 17, 2016, at ¶ 13 (noting that some ISOs require interconnection agreements for any demand response resource that also would inject power into the system.); FERC, Docket RM16-12-0000. (inquiring into interconnection challenges for energy storage systems, including jurisdictional and “classification” challenges); see also FERC, Docket No. AD16-20-000, Response of PJM, Electric Storage Participation in Regions with Organized Wholesale Electric Markets, May 16, 2016.

141. For an example of this type of working group, see the Massachusetts Technical Standards Review Group, which meets quarterly to continually address and advance interconnection process and technical refinements: https://sites.google.com/site/massdgic/home/interconnection/technical-standards-review-group (accessed Jan. 7, 2017).

142. See Survey of Modeling Capabilities and Needs for the Stationary Energy Storage Industry.

143. Id.

144. Id.