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MARKET AND POLICY BARRIERS TO ENERGY STORAGE DEPLOYMENT

A Study for the Energy Storage Systems Program

Dhruv Bhatnagar, Aileen Currier, Jacquelynne Hernandez, Ookie Ma and Brendan Kirby

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Dhruv Bhatnagar and Aileen Currier
Electric Power Systems Research Department

Jacquelynne Hernandez
Energy Storage Technology and Systems Department

Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185

Ookie Ma
U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Washington, D.C. 20585

Brendan Kirby
Consultant

ABSTRACT

Electric energy storage technologies have recently been in the spotlight, discussed as essential grid assets that can provide services to increase the reliability and resiliency of the grid, including furthering the integration of variable renewable energy resources. Though they can provide numerous grid services, there are a number of factors that restrict their current deployment. The most significant barrier to deployment is high capital costs, though several recent deployments indicate that capital costs are decreasing and energy storage may be the preferred economic alternative in certain situations. However, a number of other market and regulatory barriers persist, limiting further deployment. These barriers can be categorized into regulatory barriers, market (economic) barriers, utility and developer business model barriers, cross-cutting barriers and technology barriers. This report, through interviews with stakeholders and review of regulatory filings in four regions roughly representative of the United States, identifies the key barriers restricting further energy storage development in the country. The report also includes a discussion of possible solutions to address these barriers and a review of initiatives around the country at the federal, regional and state levels that are addressing some of these issues. Energy storage could have a key role to play in the future grid, but market and regulatory issues have to be addressed to allow storage resources open market access and compensation for the services they are capable of providing. Progress has been made in this effort, but much remains to be done and will require continued engagement from regulators, policy makers, market operators, utilities, developers and manufacturers.

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FORWARD

This report is one of a series stemming from the U.S. Department of Energy (DOE) Demand Response and Energy Storage Integration Study. This study is a multi-National Laboratory effort to assess the potential value of demand response and energy storage to electricity systems with different penetration levels of variable renewable resources and to improve our understanding of associated markets and institutions. This study was originated, sponsored, and managed jointly by the Office of Energy Efficiency and Renewable Energy and the Office of Electricity Delivery and Energy Reliability.

Grid modernization and technological advances are enabling resources, such as demand response and energy storage, to support a wider array of electric power system operations. Historically, thermal generators and hydropower in combination with transmission and distribution assets have been adequate to serve customer loads reliably and with sufficient power quality, even as variable renewable generation like wind and solar power become a larger part of the national energy supply. While demand response and energy storage can serve as alternatives or complements to traditional power system assets in some applications, their values are not entirely clear. This study seeks to address the extent to which demand response and energy storage can provide cost-effective benefits to the grid and to highlight institutions and market rules that facilitate their use.

The project was initiated and informed by the results of two DOE workshops; one on energy storage and the other on demand response. The workshops were attended by members of the electric power industry, researchers, and policy makers; and the study design and goals reflect their contributions to the collective thinking of the project team. Additional information and the full series of reports can be found at www.eere.energy.gov/analysis/.

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EXECUTIVE SUMMARY

Energy storage resources have the potential to play a large role in the United States' electricity system. The power grid is aging and new infrastructure is required to maintain reliability. Renewable energy sources are approaching significant deployment levels, increasing the need for flexible capacity, while smart grid and microgrid technologies have become more pervasive. Evidently, there are a number of opportunities for energy storage deployment. However, a number of barriers prevent utilities, developers and regulators from capitalizing on these opportunities, as evidenced by there being only a handful of new energy storage deployments beyond existing pumped storage hydropower. This report identifies and discusses the current barriers that exist in the nation's electricity markets to the deployment of energy storage resources.

The barriers identified and discussed in this report are organized into five categories:

- Regulatory issues at the federal and state levels
- Market issues that affect non-ISO/RTO and ISO/RTO markets
- Utility and developer business model issues
- Cross-cutting issues that bridge a number of these categories
- Technology issues that affect the multitude of energy storage technologies

To identify the different barriers applicable to each category, four representative regions of the country were evaluated through stakeholder interviews and regulatory and market research. The regions are differentiated by the different market environments in which their power systems exist. They include: Colorado, representing a vertically integrated bilateral market environment; New Jersey, representing a restructured ISO/RTO market environment; Wisconsin representing a vertically integrated ISO/RTO market environment; and Texas, specifically the ERCOT control area, representing a restructured ISO/RTO market environment that is free from Federal Energy Regulatory Commission (FERC) authority.[1,2]

Stakeholders in each of these regions have identified technology costs as the primary barrier to the deployment of energy storage resources. The fact is that technology costs, in a number of instances, are prohibitively high and alternatives are able to provide the same services at lower overall costs. This is evidenced by the lack of recent energy storage technology deployment on the power system.[3] To address this, the Department of Energy, universities, manufacturers and other organizations are working to reduce the costs of these technologies. It is reasonable to expect cost improvements down the line that would allow energy storage resources to be more competitive in the marketplace. That said, there are a number of current opportunities for deployment in which energy storage resources are competitive with alternatives, yet existing market and regulatory barriers hinder their deployment. As a result, there is both a present and future need to address these barriers, enabling storage

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[1] The ERCOT market is still required to meet national reliability standards set by the North American Electric Reliability Corporation (NERC), which itself is under the authority of FERC.

[2] The ERCOT grid forms the Texas Interconnection, which has a few minor connection points to Western and Eastern interconnections that cover the remainder of the country. The Tres Amigas superstation project will create a much stronger tie between these interconnections but ERCOT will remain outside of most FERC jurisdictional authority.

[3] A number of pumped hydroelectric facilities exist that have been in operation for a number of years. But there have been no recent pumped hydro builds. There are a few grid-level battery systems, a few flywheel systems and a single compressed air energy storage (CAES) system in operation in the country.

resources to compete in the market where they are currently able to and where they will be able to once cost reductions are realized.

A major barrier is outdated regulations. While there are multiple proposals to address key issues, there are numerous difficulties restricting rapid approval and implementation, collectively termed regulatory delay. Potential storage owners are reluctant to consider the deployment of resources until they can be assured and have clear evidence that barriers no longer exist, enabling market access and a predictable revenue stream. Other regulatory issues that present barriers to the deployment of energy storage include complexity and lack of clarity surrounding the functional classification of energy storage and its use to provide simultaneous services across different accounting classifications of production (generation), transmission and distribution and discrepancies in market rules and regulations across the large number of markets in the country.

Revenue compensation mechanisms in the different market environments present a barrier to the further deployment of energy storage resources. These mechanisms are oriented towards the evaluation of traditional power system technologies and may not appropriately compensate energy storage resources for the services they are capable of providing. Restructured markets base pricing on the generation costs of the marginal unit, which is appropriate for generators that have significant operating costs but creates a difficult situation for capital intensive and low operating cost resources like energy storage. Deployment of energy storage resources can collapse ancillary service market prices and energy market price differences, resulting in revenue streams for storage that are not commensurate with the value these resources provide to the system. Other market issues that present barriers include: the lack of markets and associated products; and the lack of transparent price signals for most products in non-ISO/RTO markets and for cost-based products in ISO/RTO markets.

Limited knowledge amongst power system stakeholders and the lack of modeling capabilities for energy storage resources prevent many stakeholders from conducting a thorough evaluation of energy storage technologies for deployment. Because they are a relatively new power system resource, have the unique characteristic of needing to be charged with electricity rather than operating on a conventional fuel, and faster and more diverse performance characteristics relative to other technologies, there is difficulty in the understanding of their varied uses and in the accurate modeling of their technical capabilities and economic performance.

Utility and developer risk and uncertainty is a barrier that follows from the others. The multitude of barriers to the deployment of storage resources creates significant issues of uncertainty and therefore, risk, to potential owners of energy storage systems. These barriers, coupled with the sluggish economy leading to limited electricity demand, uncertainty in fuel prices, and the uncertainty associated with environmental regulations, creates an environment where there is too much of a risk for utilities and developers to deploy a new power system resource.

A number of different organizations are working to address these barriers and clear the way for energy storage resources to compete in the marketplace. This report highlights current initiatives that address some of these obstacles at the federal, regional and state levels. It also presents a number of suggestions for how many of the barriers not being addressed may be mitigated. In the end, energy storage resources have the technical capabilities to be a vital power system resource but there are a number of other technologies that provide similar services. The key is ensuring that all of these technologies have equal market access based on their capabilities and costs, to be a part of the portfolio of resources that will power the nation’s future electricity system.

ACRONYMS

ACE	area control error
AEP	American Electric Power
AGC	automated generator control
ARRA	American Reinvestment and Recovery Act
ASM	ancillary service market
BA	balancing authority
BAA	balancing authority area
CAES	compressed air energy storage
CAISO	California Independent System Operator
CESA	California Energy Storage Association
CPUC	California Public Utilities Commission
DOE	Department of Energy
EGEAS	Electric Generation Expansion Analysis System
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EPIC	Electric Program Investment Charge
EPRI	Electric Power Research Institute
ERCOT	Electricity Reliability Council of Texas
ERP	electric resource plan
ETWG	Emerging Technologies Working Group
FERC	Federal Energy Regulatory Commissions
FRRS	Fast Responding Regulation Service Pilot
FTR	financial transmission right
GW	gigawatt
HSL	High Sustained Limited Test
Hz	hertz [/sec]
IOU	investor owned utility
ISO	independent system operator
JCP&L	Jersey Central Power and Light
LBNL	Lawrence Berkley National Laboratory
LSE	load serving entity
MISO	Midcontinent Independent System Operator
MOPR	minimum offer price rule
MRO	Midwest Reliability Organization
MTEP	MISO Transmission Expansion Plan
MW	megawatt
MWh	megawatt-hour
NERC	North American Electric Reliability Corporation
ISO-NE	Independent System Operator New England
NETL	National Energy Technology Laboratory

NJTIN	New Jersey Technology Incubator Network
NJ BPU	New Jersey Board of Public utilities
NOI	notice of inquiry
NOPR	notice of proposed rulemaking
NRECA	National Rural Electric Cooperative Association
NREL	National Renewable Energy Laboratory
NYISO	New York Independent System Operator
OATT	open access transmission tariff
OE	Office of Electricity Delivery and Energy Reliability
O&M	operations and maintenance
ORNL	Oak Ridge National Laboratory
PJM	PJM Interconnection LLC
PNNL	Pacific Northwest National Laboratory
PSC	public service commission
PSCo	Public Service Company of Colorado (Xcel Energy)
PSH	pumped storage hydropower
PSEG	Public Service Electric and Gas Company
PUC	public utility commission
PUCT	Public Utility Commission of Texas
PV	photovoltaic
QSE	qualified scheduling entity
RECO	Rockland Electric Company
RPS	renewable portfolio standard
RTO	regional transmission organization
SNL	Sandia National Laboratories
SPP	Southwest Power Pool
SWEPCO	Southwestern Electric Power Company (American Electric Power)
T&D	transmission and distribution

INTRODUCTION

Energy storage resources have the potential to play a large role in the electricity system, especially as the grid ages and new infrastructure is required to maintain reliability. There are a number of opportunities for resource deployment, whether at the bulk system scale for transmission or distribution functions, or as a customer-side resource. However, there are a number of barriers that prevent utilities, developers and regulators from deploying storage to meet these opportunities. In order to ensure the evolution of the lowest cost, most efficient power system that meets reliability requirements, any resource that can provide service to the power system should be able to compete with alternatives. This necessitates that all resources receive equal consideration for deployment and open access to markets as long as they meet performance requirements, which should allow the market to select resources, evolving to a lower cost and more efficient electricity grid.

One of these opportunities is the need for ancillary services that the power system requires in order to operate efficiently and meet reliability requirements. Energy storage resources are dynamically more capable than many other resources available on the power system and are well suited to provide ancillary services. At present, there are only a handful of energy storage deployments being used for this purpose. This report explores the market and regulatory environment for energy storage resources to provide ancillary services across the United States. The goal of this effort is to assess the near-term deployment outlook for these resources through:

- Identification of barriers hindering the deployment of energy storage resources.
- Description of current initiatives addressing barriers.
- Proposal of solutions involving changes to the regulatory and policy framework, to power system operational methodologies and planning processes.

Four different states were surveyed to provide a representative approach in understanding regional differences across the United States. Three states, New Jersey, Texas and Wisconsin, are contained within territories of an Independent System Operator (ISO) or a Regional Transmission Organization (RTO). New Jersey falls within the PJM Interconnection (PJM) and Wisconsin within the Midcontinent ISO (MISO) balancing authority areas (BAA). Texas is unique in that the ISO, the Electric Reliability Council of Texas (ERCOT), is contained within a single state with limited interconnection to surrounding regions, effectively freeing itself from Federal Energy Regulatory Commission (FERC) jurisdiction.[4] The fourth state, Colorado, is outside of an ISO/RTO BAA.

ISOs and RTOs operate centrally organized wholesale electricity markets. This is in addition to the transactions conducted through private bilateral agreements that also occur in non-ISO/RTO control areas. At the retail level, two states have undergone electricity restructuring: in both New Jersey and Texas, investor-owned utilities have divested their generation assets and retail electricity customers are able to choose among competitive providers. In New Jersey, incumbent electric utilities continue to serve customer load as default service providers and thereby have supply obligations. However, in Texas, the incumbent utilities are only transmission and distribution (T&D) companies and do not serve retail loads. Electricity service providers in Colorado and Wisconsin are predominantly vertically-integrated utilities that own generation, transmission and distribution, and serve customer load. [5]

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[4] ERCOT must still follow North American Reliability Corporation (NERC) reliability standards. NERC is under FERC jurisdictional authority.

[5] Vertically integrated utilities are located in states often referred to as regulated states, in which state regulatory commissions regulate retail electricity operations of investor owned utilities and provide some regulatory oversight over retail operations of municipal and cooperative utilities. Deregulated, or restructured, states have wholesale generation operations outside of state

Although regional differences remain, these four states are broadly representative of the current market and regulatory environments at both wholesale and retail levels.

The characteristics of wholesale and retail electricity markets and the regulatory structure in which electricity providers operate, strongly impact the financial opportunities for energy storage developers. In areas served by an ISO/RTO, there are transparent prices for some electricity products, and providers can offer into the market if they satisfy standardized requirements. Resource selection can be in the hands of independent power producers and power marketers; and although energy storage technologies could be included in their portfolios, this practice has been limited to a few isolated cases. Opportunities for transmission and distribution utilities may be limited, as energy storage devices deployed as transmission or distribution assets are not currently able to transact in wholesale markets, eliminating an important revenue source, though other deployment opportunities for transmission and distribution functions exist. By contrast, in areas outside ISO/RTO control, buyers and sellers must form bilateral contracts with limited transparency in prices for electricity products. Although, pricing information exists for energy transactions at trading hubs, individual contracts vary in their terms and prices, and no markets exist for ancillary services. Vertically-integrated utilities can propose energy storage solutions to their utility commissions for cost-recovery through retail electricity rates; however, evaluation of the benefits energy storage devices bring has been challenging due to limitations in planning tools and methodologies.

To gain a true understanding of the market landscape in each of these areas, interviews were conducted with representatives from electric utilities, independent power producers (IPPs), regulators and RTO/ISO balancing authorities (BAs). Appendix A includes the interview questions asked throughout the research process. Though organizational information and interviewee details will remain confidential, participant feedback was invaluable in providing information and guidance throughout this report. Research, supplementing interview responses, creates the content for the body of this report. The introduction provides summarized descriptions of energy storage and ancillary services. The second section contains a discussion of the key barriers facing energy storage resources given current market and regulatory conditions, and provides some possible actions to address these barriers. The final section provides a discussion of the current initiatives addressing identified barriers.

Energy Storage

Power system operators have used pumped storage hydropower (PSH) systems for many years, primarily to provide energy services, shifting generation from peak to off-peak, traditionally installed in conjunction with nuclear power plants that have limited ability in modulating their output. Excluding PSH systems, energy storage technologies are relatively new to the electric grid. They can provide a multitude of services generation, transmission and distribution assets traditionally provide. A number of reports discuss these services, technical details of energy storage resources and current research and history in further detail (Akhil, et al., 2013; Eyer & Corey, 2010; Rastler, Energy Storage Options, 2010).

Typically, new energy storage deployments have relied on government financial assistance, but in a few cases, they may be the preferred economic alternative at current price points.[6] Additional opportunities may emerge as

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regulatory economic authority and instead have organized markets. Transmission and distribution operations remain in control of utilities under economic regulatory control of state regulatory commissions.

[6] See: AES Energy Storage Projects (http://www.aesenergystorage.com/projects.html), the *Maui Energy Storage Study* and others (http://www.sandia.gov/ess/publications/pubslist_06.html) and the *Energy Storage for Variable Renewable Energy Resource Integration - A Regional Assessment for the Northwest Power Pool* study (http://energyenvironment.pnnl.gov/ei/energy_storage.asp).

energy storage technology costs decline. Identification and mitigation of non-technology cost barriers will raise cost thresholds for which energy storage is competitive and ensure that resources that perform best, both economically and technically, are those chosen for the electricity system. Research projects funded through the U.S. Department of Energy and other organizations, both inside and outside the United States, aim to increase performance and reduce technology costs. The benefits and costs of energy storage technologies beyond PSH are not well understood in real deployment environments, leading to limited action promoting their further use. This inaction prevents them from being deployed and their benefits and economic value further identified, thus perpetuating limited deployment. In an attempt to address this issue, the Department of Energy has funded, either completely, or via cost-share, energy storage demonstration projects. These demonstrations, a number of which are through the American Recovery and Reinvestment Act (ARRA) and others through the DOE Office of Electricity, are working to validate the technical performance capabilities of energy storage resources.[7]

Ancillary Services

Energy storage resources have the capability to provide a variety of ancillary services to the grid. NERC, the North American Electric Reliability Corporation, defines ancillary services as “those services that are necessary to support the transmission of capacity and energy from resources to loads while maintaining reliable operation of the Transmission Service Provider's transmission system in accordance with good utility practice” (North American Electric Reliability Corporation, 2013). Ancillary services take a number of different forms, including operating reserves, reactive power (voltage support) and black start. Operating reserves consist of frequency regulation, load following reserve and contingency reserves.[8] Contingency reserves are composed of synchronous reserve (spinning reserve) and non-synchronous reserve (non-spinning or quick start reserve). Table 1 provides descriptions and identifies performance requirements of ancillary services and key characteristics important for energy storage resources. A number of different resources are available that describe these services in more depth, highlighting their necessity, requirements, methodologies and the resources that provide them (Ela, Milligan, & Kirby, 2011; Ellison, Tesfatsion, Loose, & Byrne, 2012).

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[7] See *Energy Storage Activities in the United States Electricity Grid, May 2011* (http://energy.gov/oe/downloads/energy-storage-activities-united-states-electricity-grid-may-2011).

[8] FERC Order 755, Pay for Performance, has changed compensation methods in the organized frequency regulation markets to account for speed and accuracy. FERC Order 784, 3rd Party Ancillary Service Provision, indirectly modifies compensation methods by requiring public utility transmission providers to account for speed and accuracy in their determination of frequency regulation requirement. Both Orders are discussed further, starting on page 37.

Table 1. Ancillary services and the characteristics relevant to energy storage (Ellison, Tesfatsion, Loose, & Byrne, 2012; Akhil, et al., 2013; Ela, Milligan, & Kirby, 2011; North American Electric Reliability Corporation, 2013).

Ancillary Service	Description	Performance Requirements			Characteristics Important for Energy Storage
		Max time	Min Capacity Allowed	Min output duration	
Frequency Regulation	An online, system synchronized, fast responding resource or variable load, responsive to automatic generator control (AGC) from a balancing authority.	5-10 minutes	0.1-1.0 MW depending on BA	-[9]	Regulation requires faster response and significant output variance relative to other services, leading to limited market participation and higher prices. Energy storage resources are generally capable of faster response than most other system assets and are well suited to provide regulation service. Resources must undergo performance tests to qualify to provide service.
Synchronous Reserve (spinning)	An online, system synchronized, resource with unloaded generation that can increase output or interruptible load that can reduce demand.	10 minutes	0.1-1.0 MW	30-120 minutes	Minimum duration requirements prevent shorter duration energy storage resources from participation. Longer duration resources can easily meet minimum requirements. Significantly lower market clearing prices relative to regulation.
Nonsynchronous reserve (non-spin)	A resource not online, able to synchronize within a specified timeframe or an interruptible load that can reduce demand.	10-30 minutes	-	30-120 minutes	Minimum duration requirements prevent shorter duration energy storage resources from participation. Longer duration resources can meet minimum requirements. Significantly lower market clearing prices relative to synchronous reserve.
Reactive Power (voltage support)	Power in a different phase from real power, needed to meet electric and magnetic field requirements of alternating current equipment.	-	-	-	Inverter based energy storage resources are able to provide both real and reactive power independently. Pumped storage plants can operate as synchronous condensers, providing real and reactive power simultaneously.
Blackstart	A service provided by a resource able to start without energy from the electricity system and energize system equipment per a transmission operator's requirements.	-	-	-	Often provided by pumped hydroelectric systems. Most storage resources able to provide energy without the need for system power.

[9] Output duration in one direction (providing energy to the grid or drawing energy from the grid) is an important consideration but not a formalized rule. MISO and ERCOT have specific classifications for energy storage resources, allowing participation in frequency regulation service as long as the resource provides minimum 15 minute duration at its offered capacity. Other ISOs/RTOs do not have a formalized requirement (Electric Reliability Council of Texas, Inc., 2013; Midwest Independent System Operator, Inc., 2013).

The different regions across the United States each have electricity markets that classify ancillary services into different categories. The PJM operating manual describes these services and PJM's requirements in further detail.[10] MISO, ERCOT and the Public Service Company of Colorado (PSCo) have their own definitions and requirements.[11] As expected, many of these classifications are similar and generally follow NERC definitions (North American Electric Reliability Corporation, 2013).

Increasing penetration levels of variable generation like wind and solar may increase the need for ancillary services to manage higher levels of variability and uncertainty this generation presents. Reliable system operations may require more frequency regulation and load following reserve, creating a potential market opportunity for energy storage resources. This opportunity is strengthened as research and operational experience indicates that energy storage resources are able to reduce frequency regulation requirements, namely due to their high ramp rate capabilities, providing additional value for the same capacity as competing resources. It has been estimated that fast responding resources have the ability to reduce up to 40% of regulation service capacity requirements in the California Independent System Operator (CAISO) balancing area, saving up to $46 million annually (Makarov, 2008). After implementation of a new ancillary service optimizer and performance-based frequency regulation, the frequency regulation requirement in PJM has decreased from 1.0% of the peak load during peak hours and of the valley load during off-peak hours to 0.70% (PJM Market Monitor Report 2012). Table 2 highlights the generation mix, installed energy storage systems and RPS standards in each of the evaluated regions to highlight the potential for energy storage resources.

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[10] PJM *Energy & Ancillary Services* Market Operations manual. *See* http://www.pjm.com/documents/manuals.aspx.

[11] MISO, ERCOT and PSCO Operations Manuals. *See* <https://www.misoenergy.org/Library/BusinessPracticesManuals/Pages/BusinessPracticesManuals.aspx>, <http://www.ercot.com/mktrules/bpm/> and <http://www.xcelenergy.com/About_Us/Rates_&_Regulations/Regulatory_Filings>.

Table 2. Characteristics of the evaluated regions (U.S. Energy Information Administration, 2013).

State	Generation Mix [12]	Installed Energy Storage	RPS Standard	Other information
Colorado	66% coal 17% natural gas 4% hydroelectric 14% renewables	(1) Cabin Creek Pumped Hydro Plant 359MW capacity. (2) Mount Elbert pumped hydro system, 200 MW capacity. (3) SolarTAC 1.5MW sodium sulfur (NaS) battery (demonstration).	30% by 2020 of supplied retail electricity by IOUs 10% by 2020 of supplied retail electricity by electric cooperatives and municipal utilities. 5% by 2020 from distributed resources.	91 MW of photovoltaic capacity and 3 GW of wind capacity.
New Jersey	61% nuclear 33% natural gas 4% coal 2% renewables 1% petroleum	(1) Yards Creek Station, pumped hydroelectric storage system, 400 MW capacity in Warren County, NJ.	22.5% electricity sold by 2021 (3.5% solar, 1,100 MW offshore wind capacity) with 70% electricity sold from "clean" energy sources by 2050.	The state had the sixth highest residential and industrial and seventh highest commercial electricity prices across the United States for 2011. The state has less than 10% of PJM's generation capacity at 17.2 GW as of 2010, about 84% on NJ peak load of 20.5 GW for that year (State of New Jersey, 2011, p. 16).
Wisconsin	56% coal 23% nuclear 12% natural gas 6% renewables 3% hydro	None	10% electricity sold by 2015.	Though capacity is sufficient in Wisconsin, transmission planning to move energy from the source of generation to customers has been an ongoing challenge (Wisconsin Public Service Commission, 2012).
Texas	47% natural gas 35% coal 9% hydroelectric 8% renewables	(1) 32MW/28MWh Battery at Notrees Wind Farm (2) 4MW/28MWh NaS Battery in Presidio, TX	5,800 MW electric capacity by 2015; goal of 10,000 MW electric capacity by 2025. Goal of 500 MW of non-wind renewables electric capacity.	10 GW of wind capacity. Significant transmission investment in the west part of the state due to the PUCT instituted special economic investment zone.

RPS standards in states in PJM's territory will lead to the expected integration of 42 GW of wind and 11 GW of photovoltaics by 2026. Past studies indicate that additional resources will be needed to provide reserves to manage this integration. Preliminary results from a current study, contracted by PJM, indicate an upward pressure on regulation requirements; however, this is less than previously predicted by other studies.[13] The integration of renewable technologies in ERCOT has also grown significantly in recent years and the market has over 10,000 MW of wind alone (Electric Reliability Council of Texas, Inc, 2005). Much of this wind is in West Texas, where transmission constraints have limited the transfer of this energy to populous regions of the state, brought

[12] For January 2013 by energy generated.

[13] Based on system operator interviews. Numbers are not available as the final report has not yet been released, *see* http://www.pjm.com/committees-and-groups/task-forces/irtf.aspx/.

nighttime prices to negative values, and limited the deployment of additional wind. The state has classified the region as a special economic zone with $6 billion in funding available for transmission improvements to address the issue. Despite this, ERCOT finds that the impact of wind on regulation needs, based on historical data, is less than a 10% increase relative to the market without wind (Porter, Fink, Rogers, Mudd, Buckley, & Clark, 2012, p. 59). MISO also sees little impact of wind on regulation requirements, despite having upwards of 12 GW installed, identifying that short-term forecast error on wind generation ranges from 0.5% to 1.0% of wind generation capacity. This indicates limited impact on net-load variability (Porter, Fink, Rogers, Mudd, Buckley, & Clark, 2012, p. 64). The Public Service Company of Colorado (PSCo), with 2.2 GW of installed wind capacity, has determined that curtailing wind generation is the economically preferred method to address wind variability in its territory rather than the procurement of additional ancillary services. Flexible reserves, defined by the utility as those available within 30 minutes, provide additional energy when needed due to down ramps or wind cut-off at high speeds. PSCo requires all new wind generation to be able to receive an automated generator control (AGC) signal to enable curtailment (Porter, Fink, Rogers, Mudd, Buckley, & Clark, 2012, p. 67). [14]

Related Energy Storage Guidebooks and Reports

Sandia National Laboratories (SNL) with a number of collaborators, have or will publish a number of energy storage guidebooks in 2012 and 2013.[15] The intent of these guidebooks is to provide a comprehensive understanding of energy storage technologies, technical performance, practical use, valuation methodologies and market and policy issues that surround energy storage resources in the United States. These reports and guidebooks include:

1) Evaluating Utility Owned Electric Energy Storage Systems: A Perspective for State Electric Utility Regulators | SNL | DOE/OE Energy Storage Systems Program.
    a. Intended audience: state utility regulators, their regulated utilities and independent developers.
    b. Content: The report discusses energy storage systems with an attempt at easing the regulatory evaluation process for regulators evaluating procurement by regulated utilities. It includes discussions of past energy storage proceedings proposed by regulated utilities to state regulatory commissions, the lessons drawn from these proceedings, a discussion of challenges for further deployment, a proposed evaluation methodology to simplify the economic evaluation process and an application of this evaluation methodology in two sample economic evaluations.
2) DOE/EPRI 2013 Electricity Storage Handbook in collaboration with NRECA | SNL |DOE Energy Storage Systems Program | EPRI | NRECA
    a. Intended audience: utilities, co-op engineers, system vendors and investors, and regulators and policy makers.
    b. Content: The Handbook is a guide for electric systems engineers, system planners, energy storage system developers and financiers to aid in the selection, procurement, installation, and operation of stationary energy storage systems in today's electric grid. Various perspectives of grid energy storage are presented for different stakeholders: generators, system operators, load-serving entities (LSEs) with various ownership structures and customers. The Handbook includes

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[14] Utility and developer interviews.

[15] See http://www.sandia.gov/ess/projects_home.html.

a review of the status of technical, financial, regulatory and ownership issues that impact energy storage adoption, primarily with a U.S.-centric focus.

3) Methodology to Determine the Technical Performance and Value Proposition for Grid-Scale Energy Storage Systems | SNL | DOE National Energy Technology Laboratory (NETL)

    a. Intended audience: utilities, developers, regulators and manufacturers.
    b. Content: This report is intended to help guide a performance and economic evaluation process for the ARRA (American Reinvestment and Recovery Act) funded energy storage projects. The evaluation processes presented are applicable for utilities, developers and regulators when considering installations in both market and non-market territories.

This report and these guidebooks are intended for different audiences; though as a whole provide a comprehensive overview of electric energy storage technologies in the context of the electricity system. This report differentiates itself from the others in its focus on the provision of ancillary services as they represent a value stream that is immediately available. Identifying and addressing ancillary service challenges is one necessary element in enabling further deployment of energy storage.[16]

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[16] Other research organizations have made significant efforts at addressing issues associated with energy storage resources. These organizations include Pacific Northwest National Labs, Oak Ridge National Labs, the Electric Power Research Institute (EPRI), the National Renewable Energy Laboratory and others. These reports are available at the respective organization's websites:

- *PNNL: http://energyenvironment.pnnl.gov/ei/energy_storage.asp*
- *ORNL: http://www.ornl.gov/sci/physical_sciences_directorate/esr/*
- *EPRI: http://www.epri.com/*
- *NREL: http://www.nrel.gov/publications/*
- *DOE: http://energy.gov/oe/technology-development/energy-storage*

Energy Storage Barriers

The term barrier, as used in this report, is broadly defined as an issue that hinders deployment of energy storage technologies. In some instances, a barrier may *prevent* deployment; and in others, it may *limit* deployment, *limit* revenue or *limit* consideration for deployment. Although, the primary barrier to the further deployment of energy storage resources in many instances may be high capital costs, there are additional barriers imbedded in market rules and regulations that hinder deployment in situations where storage resources are the economically preferred alternative.

The remaining discussion in this section summarizes the barriers identified in the evaluation of the four case study regions, comparing barriers across the different regions and suggesting possible solutions to address their impacts. Except for the issue of high capital costs, power system stakeholders identify these issues as the primary barriers that restrict the further deployment of energy storage technologies. The barriers are broadly categorized into regulatory barriers, market (economic) barriers, utility and developer business model barriers, cross-cutting barriers that cross the different categories, and technology barriers specific to energy storage technical performance and capabilities. Within each of these categories, barriers are ordered by level of impact on hindering deployment. The order is based on feedback from stakeholder interviews, a review of proceedings from installed and proposed projects, regulatory hearings on energy storage issues and a literature review.

Regulatory Barriers

Procedural Issues

Administrative delay in the implementation of new regulations to address barriers to energy storage deployment itself presents a barrier to deployment. Some instances of this delay include: slow adoption of pay for performance (FERC Order 755) requirements by many ISOs/RTOs (all ISO/RTOs except ISO-NE have implemented pay for performance) [17] ; slow modification to market participation rules to allow limited duration energy storage resources to participate in ancillary service markets (for example in ERCOT);; and slow progress by state public utility commissions in requiring that energy storage resources be considered amongst alternatives in planning and procurement processes.

The sluggish progress is due in part to the complexity of regulatory issues facing energy storage and a need for a comprehensive evaluation of the proposed changes to operational and market rules. Numerous stakeholders with varying, and sometimes competing, interests add additional complexity and require careful navigation of the regulatory process. Recognizing these limitations and challenges, administrative delay still remains an impediment for energy storage development. Potential owners indicate they may wait until rules are in place and vetted before considering and deploying storage resources.[18] System stakeholders suggest that placing additional importance and priority on resolving identified barriers through pending regulation, possibly by modifying evaluation processes to reduce the timeframes required or committing additional resources to the evaluation, may be a means to reducing this delay. .

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[17] These are the Midcontinent Independent System Operator, Inc. (MISO); the PJM Interconnection, LLC; the New York Independent System Operator Inc.; the California Independent System Operator Corp.; the ISO New England, Inc. and the Southwest Power Pool, Inc.

[18] Utility and developer interviews.

Functional Classification Restrictions & Cost Allocation Issues

Energy storage resources are technically capable of providing services in each of the functional classifications of production (generation), transmission and distribution (T&D). However, regulatory restrictions along with accounting practices and requirements and the lack of clarity and transparency in these practices and requirements, effectively prevent a utility or developer from obtaining revenue with a resource providing service under multiple classifications. A number of technologies on the power system, such as conventional generators, face this issue, but it is especially relevant for energy storage resources considering some of their advantages, such as modularity and lack of need for a conventional fuel source. This issue is present in ISO/RTO market regions.[19] A developer could use an energy storage resource to participate in the wholesale electricity market providing generation service and transmission congestion relief. However, this developer could not participate in the wholesale electricity market while also earning cost of service recovery providing distribution service, despite the technical ability of a storage resource to provide this service. In non-ISO/RTO regions, a vertically integrated utility can utilize its assets for any purpose across these classifications and recover all value that the asset can provide.

The power system is evolving with the deployment of new resources and changing load patterns. For example, distributed generation resources, such as roof mounted photovoltaics, are on the rise and the traditional lines between generation, transmission and distribution are being blurred. The only way to ensure the emergence of the lowest cost power system is to enable resources that are blurring these traditional lines to be allowed market access in whichever category demands the services they can provide, irrespective of where they are located and irrespective of the type of resource. The current framework, with technologies mapped to specific classifications, may have been sufficient for the centralized thermal generation and transmission line power system, however now, the clear lines of differentiation in this framework may result in unnecessary inefficiency.

For example, a T&D utility may install a battery system in a distribution substation to provide distribution congestion service, but only a portion of its capacity may be needed at most times. The remaining capacity would be available for other services. The utility may wish to use the remaining capacity to sell ancillary services in a wholesale market to strengthen the total value proposition of the resource, improving its case for cost recovery before its regulator. Under current procedures, this utility cannot obtain cost-based rate recovery for the transmission function and simultaneously, market based recovery for providing ancillary services, despite providing two independent services. Doing so would require approval from FERC and likely the public utility commission of the state in which the asset is located. Another example is the situation in which an independent power producer owning a storage asset at a location on the power system where it could provide service to a T&D utility. The developer is effectively restricted from receiving a bilateral agreement with this utility to provide T&D service using 50% of the system's capacity and also participating in the wholesale market to provide energy or ancillary services with the remaining capacity.

FERC has recognized the ability of energy storage resources to provide service across multiple classifications in a number of cases, including its Notice of Proposed Rulemaking (NOPR) on Storage Accounting and Financial Requirements and the subsequent FERC Order 784 based on this NOPR. In the NOPR, the commission states that it has not received proposals to recover costs under both cost-based and market-based rates but it remains open to evaluating such proposals on a case-by-case basis (NOPR: 3rd Party AS; Acct. and Fin. Reporting for Storage, 2012, p. 73). This case-by-case determination requirement may be a barrier to energy storage deployment. Foremost, a

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[19] This issue is separate from the instance in which a generator would alleviate congestion, being compensated through higher locational marginal prices (LMPs) at congested nodes.

potential storage owning entity may not consider an energy storage resource to serve multiple functions because of the financial resources involved in presenting a case before the commission. This may result in a determination by the entity that an energy storage resource is not the economic choice, when it may be. As energy storage resource deployment increases and a number of entities want to obtain both cost-based, and market based cost recovery for owned or contracted energy storage assets, FERC may revisit this position. Until that time, this barrier will remain. FERC has indicated it believes that uncertainty is a challenge to energy storage deployment (NOPR: 3rd Party AS; Acct. and Fin. Reporting for Storage, 2012). This is a form of uncertainty, and as long as this uncertainty exists, energy storage deployment may be inhibited. That said there is a legitimate concern amongst regulators that an entity might take unfair advantage by forcing captive regulated transmission customers to pay for assets that are then used to make profits in the competitive energy and ancillary service markets. It is a difficult regulatory problem, but one that may need to be addressed as the deployment of resources that cross classification boundaries increases. A similar situation exists in ERCOT, where the wholesale market is outside of FERC jurisdiction. In 2008 the Public Utility Commission of Texas (PUCT) granted approval to American Electric Power (AEP) to install a Sodium Sulfur (NaS) Battery to defer transmission upgrade costs, and classified the battery as a transmission asset because the battery provides transmission service benefits. Though this case provides a noteworthy example of the role of energy storage and the services it can provide, when issuing its decision, the PUCT stated the case would not be considered precedent for other energy storage cases. The PUCT still requires a T&D utility to present an energy storage system for rate-base approval, and currently does not allow an approved device to also participate in the wholesale market.[20]

In 2011, FERC ruled on a case involving a pumped storage project in Nevada called The Lake Elsinore Advanced Pumped Storage project (LEAPS) submitted before the commission 2004. The developer intended to use the facility for transmission services and sought cost recovery through the California ISO (CAISO) transmission recovery charge (TAC) as well as an increased rate of return from FERC. The Commission rejected the transmission tariff request indicating that it would not be appropriate for the system to be under exclusive control of CAISO as would be required under the TAC.[21] Under the proposer's operational profiles, the system would have the potential for the ISO to obtain profit from time sensitive pricing. The Commission made the point that other pumped hydro systems collect revenue through participation in wholesale power markets and allowing rate recovery would provide an unfair advantage.[22] The Commission made a different determination in its hearing on *Western Grid Development, LLC*. In this case, the *Western Grid* requested transmission rate recovery with increased rate of return for a number of Sodium Sulfur (NaS) batteries installed at selected areas in CAISO territory intended for transmission relief.[23] The Commission found that since the proposal called for CAISO to maintain full control over discharge, that no power would be bid into energy or ancillary service markets, and that any additional revenue from price differentials in charge and discharge would be credited to ratepayers. The proposal was approved for transmission rate recovery and increased rate of return under Federal Power Act (FPA) section 219 and FERC Order 679 for transmission investment promotion.[24] FERC explicitly mentioned that the *Nevada Hydro Co.* case was a different situation.[25] These cases highlight the uncertainty discussed in this section.

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[20] Presidio NaS final order by the PUCT.

[21] *Nev. Hydro Co. 122 FERC ¶ 61,272, at 82-83 (2006).*

[22] *Nev. Hydro Co. 117 FERC ¶ 61,204, at 29 (2006).*

[23] *Western Grid Development 130 FERC ¶ 61,209, at 1-5 (2010).*

[24] *Western Grid Development 130 FERC ¶ 61,209, at 43-52 (2010).*

[25] *Western Grid Development 130 FERC ¶ 61,209, at 17 (2010).*

A number of commenters in the FERC NOPR on cost allocation suggest that energy storage resources should have their own functional classification. This echoes calls for a different classification since the renewal of interest in energy storage technologies. A new classification, however, could create further lines of differentiation in the power system when newer technologies are blurring these lines. This would increase confusion in the classification of resources into appropriate categories and itself become a barrier to the deployment of new technologies.

FERC has determined that existing classifications are sufficient to support all uses of energy storage systems and that a new classification, in its opinion, does not provide additional benefits compared to creating new accounts within the existing classifications as it proposes has done in Order 784 (Final Rule Order No. 784: Third-Party Provision of Ancillary Services; Accounting and Financial Reporting for New Electric Storage Technologies, 2013). However, despite the creation of new accounts, the issue of service across multiple functional categories remains. Some commenters on the NOPR and the Order suggest that the commission may want to consider a more in-depth evaluation of the establishment of clear procedures within the current classification framework to address this issue or some form of reformulation of the accounts classification system to remove the formal demarcations that prevent capable resources from providing service in different parts of the power system.

A separate barrier to deployment, but relevant to the asset classification topic, exists in ERCOT. Current market rules require that an energy storage system register as both a generating entity and as controllable load. This rule opens storage up to modeling, testing and performance questions that storage developers then have to negotiate, not to mention, the simple administrative difficulty in registering a singular system as both generation and load.[26] The additional costs associated with this process present an additional barrier to energy storage consideration. System stakeholders suggest that clear procedures allowing the bridging across generation and load could address this issue without requiring a separate asset category for energy storage. These procedures could also address the ability of resources to provide services across multiple classifications.

Discrepancies in Rules Across Markets

In efforts to maximize potential revenue, many developers intend to operate in a number of different markets. This grows increasingly difficult as each of these markets has its own system characteristics, stakeholders, regulations and market designs. This inconsistency adds a level of complexity for developers who want to deploy storage system resources across multiple markets. Separate analyses are required for each market to determine the regulatory outlook, market requirements and profit potential.[27] To deal with this issue and hedge against market uncertainty, developers may have to explore development in multiple markets. This issue applies for all resources, but is perhaps more important for energy storage due to the difficulty of making a business case for energy storage, with revenue streams that are difficult to predict.

The case of energy storage in ERCOT presents a good example where discrepancies across markets create difficulty for potential energy storage developers. In the settlement of energy used to charge an energy storage resource, ERCOT and the PUCT classify cooling skids, heat exchangers and other equipment as auxiliary loads, similar to air conditioning loads in operator inhabited sections of thermal power plants. This interpretation follows from ERCOT's definition of Wholesale Storage Load (WSL) in Section 2.1 of ERCOT Protocols, which follows from the PUCT definition in PUC Substantive Rule 25.501(m)(2) (Electric Reliability Council of Texas, Inc., 2013).[28] However,

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[26] Utility and developer interviews.

[27] Utility and developer interviews.

[28] Wholesale Storage Load (WSL) continued on the next page:

the interpretation of the definition does not recognize that the cooling skids, heat exchangers and other equipment are necessary components of the energy conversion process. As a result, a battery system operator will have to pay a retail rate on these loads rather than the wholesale rate it pays to charge the resource. The interpretation of the definition presents a problem as it negatively impacts the economics of an energy storage resource and arguably, puts it in an unfair position against thermal generation. Other market operators consider these loads to qualify for wholesale rates as they are integral to the operation of an energy storage system.[29]

FERC Order 755, Pay for Performance, requires that certain standards be met, yet does not require a specific implementation plan or mechanism (FERC Order No. 755, 2011). FERC's position is that it should not mandate how market rules and standards are established, thus each ISO/RTO, and now local public transmission utility with the implementation on FERC Order 784, has or will create its own rules around operations and compensation mechanisms. Though FERC's position is fair and perhaps the generally preferred option, especially when most stakeholders operate in only one or two regions, these varying requirements and compensation mechanism create difficulty for potential storage owners to evaluate storage resource deployments. For example, PJM and MISO have different requirements and compensation mechanisms in their respective pay for performance frequency regulation markets and ERCOT which does not yet have a pay for performance mechanism established, is likely to have its own set of requirements and compensation mechanisms when it institutes one. A developer evaluating deployment would have to have sufficient resources to build separate business cases in each of these markets. The consideration of non-ISO/RTO regions such as Colorado, adds further complexity. Price signals are not available to provide ancillary services and thus other, costly analyses may be required. Each of the different non-ISO/RTO states has their own requirements and asset or contract approval processes. A developer attempting to navigate across different ISO/RTOs and non-ISO/RTO states will face difficulty in identifying the best opportunities for possible deployment.

An option proposed to address this, rather than FERC dictating that each entity comply with a stricter set of requirements, would be increased communication amongst different power system entities to work out a means to simplify and better align market and policy requirements. A good example of this might be FERC Order 1000, "Transmission Planning and Cost Allocation," that requires regional transmission operators to coordinate their transmission planning processes and cost allocation methods for transmission investment (FERC Order No. 1000, 2011). FERC could potentially extend a similar coordination requirement across ancillary service market rules, including ISO/RTOs and non-ISO/RTO areas. Alternatively, other stakeholders suggest that there could be a formal process, perhaps through NERC, that brings rules and requirements (including compensation) for ancillary services across different markets closer with the intention to simplify the deployment analysis process.

ERCOT Protocol 2.1: Energy that is separately metered from all other Facilities to charge a technology that is capable of storing energy and releasing that energy at a later time to generate electric energy. WSL includes losses for the energy conversion process that are captured by the WSL EPS Meter. WSL is limited to the following technologies: batteries, flywheels, compressed air energy storage, pumped hydro-electric power, and electro chemical capacitors

PUC Substantive Rule 25.501(m)(2): Wholesale storage occurs when electricity is used to charge a storage facility; the storage facility is separately metered from all other facilities including auxiliary facilities; and energy from the electricity is stored in the storage facility and subsequently re-generated and sold at wholesale as energy or ancillary services (Electric Reliability Council of Texas, Inc., 2013).

[29] Developer interview.

Market (Economic) Barriers

Revenue Compensation Mechanisms

FERC and market operators have taken steps to address a number of issues, but barriers persist for energy storage resources to receive proper compensation in providing ancillary services. An example is the basis of ancillary service compensation on marginal costs of generation. Another is the pay for performance mechanism established by FERC for frequency regulation markets, Order 755.

Ancillary service markets are inherently designed around the concept that ancillary services are provided as additional services required by the power system: services that are in addition to the primary mission of supplying energy. Ancillary service prices reflect the opportunity costs generators incur when they withhold capacity from the energy market in order to supply ancillary services (Kirby, Ancillary Services: Technical and Commercial Insights, 2007).[30] Hourly ancillary service market prices are set by the highest cost unit selected; the unit with the highest opportunity cost that hour. All of the organized markets recognize the importance of opportunity costs and automatically include each generator's opportunity cost in their co-optimization algorithms that simultaneously clear energy and ancillary service markets. The generators do not have to include their opportunity costs in their bids; the market does that for them automatically. Generators then maximize their profits by bidding in near zero costs for supplying ancillary services and accepting the price that the ancillary service market clears.

The market situation for energy storage is different than for traditional generation. A storage device designed exclusively to provide ancillary services has no energy market based opportunity cost. As a result, if there is enough of this energy storage to completely supply the specific ancillary service needed, the market price collapses to zero. With no energy market income to cover capital costs, the storage device is not economically viable even if their total costs are less than the traditional generators' marginal opportunity costs. This same problem exists for demand response resources supplying reserves (Kirby, Demand Response for Power System Reliability: FAQ, 2006). Marginal cost based markets simply do not work for resources that are dominated by fixed costs.

Specific market rules often make the general problem worse. The PJM synchronous reserve market requires resources to provide a synchronous reserve offer price that has a maximum of their O&M (marginal) costs with a margin adder (PJM Interconnection LLC, 2012, p. 72). If called upon for service, compensation for a resource would be the offer price plus the lost opportunity cost for the marginal unit. Compensation, therefore, is based on marginal cost of the system's generation. This presents a barrier as potential energy storage owners in ISO/RTO markets have limited ability to account for the high capital costs of their energy storage resources. In this situation, the market does not account for the benefit a storage system might provide to the system at large while serving synchronous reserve. This includes a possible reduction in thermal generation starts, system efficiency increases leading to reduced fuel use and a reduction in the overall cost of generation and emissions produced. All of these are benefits to the system and the ratepayer for which the energy storage owner does not receive compensation. The PJM and MISO regulation markets attempt to address this issue with a required cost-based offer based on marginal cost of generation and an optional price based offer that allows the bidder to address other costs and benefits (PJM Interconnection LLC, 2012, p. 53). Unfortunately, this approach could price an energy storage resource out of the market. A new approach that would allow storage resource owners to recover these benefit streams, while selecting best performing least cost units may need to be considered. In non-ISO/RTO markets, a vertically integrated utility would be able to recover value for all of these benefits.

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[30] Supplying regulation can also lower a generator's efficiency.

With Order 755, Pay for Performance, FERC required compensation for both capacity and performance in frequency regulation markets of ISO/RTOs. This process attempts to address incomplete compensation in frequency regulation markets, but remains, arguably, incomplete, and leaves the issue as is for other ancillary services.[31] Despite the progress made with Pay for Performance, a number of power system stakeholders still believe that the new mechanisms may not completely address the issue of performance compensation. For example, PJM has a 2-part frequency regulation signal: a slow signal and a dynamic signal (PJM Interconnection LLC, 2012, p. 52). MISO has a 5-part signal, allowing resources that are more capable in terms of dynamic response (faster ramp rates), to respond to signals that require faster response and receive increased performance payments for doing so (Midwest Independent System Operator, Inc., 2013, p. 284). The 2-part signal of PJM, and even the 5-part signal of MISO, limits the revenue obtainable for resources that may be capable of response faster than the fastest signal, or capable of response within the time increment of the different signals.[32,33] A flywheel system, for example, is capable of much faster response than a compressed air energy storage system, which itself is capable of much faster response than a coal-fired power plant. This is potentially a barrier, as the faster performing resource would not receive complete compensation in accordance with its performance capabilities. This presumes that the market requires faster response. If it does not, the market operator will not dispatch a faster signal to the resource. A move by other markets to NYISO's regulation formulation, where each resource receives its own signal corresponding to its capabilities would increase power system efficiency and allow capable resources to obtain compensation in-line with their capabilities.

The pay for performance barrier persists in ERCOT, which has its markets under Public Utility Commission of Texas (PUCT) jurisdiction and is not required to comply with Order 755. Resources do not receive compensation in providing frequency regulation service in accordance with their performance, only with capacity reserved and net energy provided (Electric Reliability Council of Texas, Inc., 2013). It is exploring the potential for a pay for performance market through its Fast Responding Regulation Service Pilot (FRRS), discussed in the current initiatives section.

None of these markets address performance in other ancillary service products. Markets compensate these products through capacity, energy and lost opportunity costs, leaving the possibility open that energy storage systems providing these other services would not be compensated for their performance. This setup may deter efficient resource selection and thus, market efficiency.

Lack of Markets

The lack of markets for inertial response, governor response, black start and reactive power in most regions, presents a barrier to the deployment of energy storage resources in ISO/RTO markets. Currently, on-line spinning generation provides inertial response,[34] though markets do not pay for this service. Dynamic resources, such as energy storage, are capable of providing a service similar to inertial response, namely immediate energy in the case of system frequency shortfalls. Governor response is another product that any generation providing

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[31] Developer interviews.

[32] Developer interviews.

[33] NYISO provides separate regulation signals to resources based on their ramp capability. However, NYISO has not yet implemented pay for performance and thus faster resources do not receive compensation in accordance with the service they provide (developer interview).

[34] On-line spinning generation refers to round rotor generation, or magnet generator powered generation, such as gas, coal, oil, and nuclear power plants.

regulation response is expected to provide. In both of these cases, there is no market compensation for these services.

Black start and reactive power services are both paid under cost of service rates under the transmission operator's open access transmission tariff (OATT) in most ISO/RTO markets. In PJM, NYISO, SPP and MISO, black start services are paid at cost of service rates. In ISO-NE, black start resources are paid at either a black start standard rate (the same flat rate for all resources providing black start relative to capacity) or under the traditional cost of service rate (ISO New England Inc., 2013). In ERCOT, however, black start is competitively procured through bi-annual bidding by resources and selected by ERCOT based on performance and costs, though again, as in ISO-NE, paid a flat availability rate (PJM Interconnection LLC, 2012; Electric Reliability Council of Texas, Inc., 2013). In most regions, energy storage resources, outside of pumped hydroelectric systems, are not considered to provide these services, though not formally restricted. There are ongoing discussions at PJM to allow energy storage to provide black start.[35] PJM, MISO and ERCOT currently do not have markets for reactive power. All three procure reactive power through member scheduling, paid at FERC approved cost of services rates (PUCT approved cost of service rates in the case of ERCOT).

The lack of markets and market prices makes it difficult and sometimes impossible, depending on the situation, for an energy storage developer to consider a resource to provide these services, either independently or as part of providing other system services, and thus makes it difficult for a developer to make a business case for deployment.[36] This issue is relevant for all generation technologies, but perhaps more important as energy storage, at its current cost point, may necessitate a need to provide multiple services to be economically competitive. To address these issues, proposals have been made to FERC and ISOs/RTOs, to develop markets for these services. There has been much discussion of doing this with governor response to increase system operational efficiency. This would allow the market to select the least cost technologies to meet requirements, whether or not this includes energy storage resources. Though this option is feasible, there are issues involved with the transition for some of these services. Reactive power, for example, may be difficult to structure as a market product because of locational requirements leading to small physical markets potentially restricting competition. Even in this situation, additional transparency in prices and compensation mechanisms may allow other resources to compete to provide service, even if through a bilateral arrangement.

Similarly, in non-ISO/RTO market regions, compensation methodologies for reliability services may need to be modified and functionally unbundled to allow resources that cannot compete to do so and an efficient bilateral market environment to be established with transparent prices and compensation mechanisms. At present, the bundling of different reliability services in a transmission utility's OATT may restrict the deployment of resources such as energy storage to provide service to meet individual reliability requirements. Further study may be needed to evaluate the unbundling of reliability services.

Lack of Price Signals

In non-ISO/RTO market regions, the lack of price signals presents a barrier to energy storage deployment. Difficulty in determining market prices for ancillary services makes it challenging for independent developers to consider energy storage resources and competed against other resources in procurement calls. Developers in the state of Colorado do have the ability to evaluate energy prices through price indices at various trading hubs; however,

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[35] Stakeholder interviews.

[36] Utility and developer interviews.

prices for ancillary services are not available. Only vertically integrated utilities may be able to determine the value of these 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. Particularly when the resources are intended for ancillary service use, the regulator is not able to look at market prices for ancillary services to determine justified investments.[37] Bilateral contracts are commonplace; however, the contract values may or may not be public and may or may not adequately represent the value that an energy storage resource might be able to negotiate considering that a storage resource would likely be considered to provide a number of services where other grid assets may not. A commission evaluating a bilateral contract involving energy storage may find difficulty in approving its terms and negotiated rates, again because price signals are not present and there is difficulty in evaluating this "new" resource next to alternatives in determining the best path to minimize ratepayer burdens.

It may help developers and regulators to look at prices in nearby markets to estimate the value available to provide different services. Vertically integrated utilities may also be more forthcoming in helping developers and regulators evaluate system economics. In general, additional transparency in prices and compensation procedures should help increase system efficiency and reduce costs for ratepayers.

[37] Regulator interviews.

UTILITY & DEVELOPER BUSINESS MODEL BARRIERS

UTILITY AND DEVELOPER UNCERTAINTY AND RISK

Interviews with utilities and developers and their testimonies before their respective public utility commissions indicate that they hold issues of uncertainty and the resulting risk as critical in the consideration of deploying new resources. They highlight the following issues of uncertainty as being the key drivers of risk that may prevent their consideration of energy storage resources:

1. Economics, technical capabilities, life-cycle performance and longevity of energy storage resources are not well understood by many power system stakeholders.
2. Uncertainty in economic health leads to variability in demand, and energy and ancillary service prices.
3. Variability in fuel prices, especially in natural gas prices. The combination of shale gas resources and slow economic growth has kept natural gas prices low. This may change.
4. Pollution regulations, namely carbon dioxide, when and if Congress or the Environmental Protection Agency (EPA) will implement these, and what form they will take.
5. Continued technological development of current and new power system resources including energy storage technology development.
6. Continuing regulatory protocol changes: market mechanisms, accounting standards, renewable energy mandates and fuel restrictions, amongst a number of other possibilities.

There is always a degree of uncertainty in any power system deployment, but this is magnified when considering relatively unproven technologies, such as energy storage, which are under continued development and have the potential for significant cost reductions in the near future (especially if electric vehicles materialize as a mass-market product). Many developers are not willing to take the risk of deploying a relatively new technology without financing from the marketplace. This financing is difficult to acquire for resources participating in the ISO/RTO marketplace, as revenue is not predictable. It is also difficult to acquire in the non-ISO/RTO marketplace as rate base approval from regulators is unlikely due to the uncertainty regulators see with a relatively new technology unnecessarily increasing ratepayer price risk. T This does not, however, apply for all stakeholders: there are a few energy storage deployments in the current environment without any government support.[38]

Utilities may avoid or reduce risk by contracting energy storage services to third party developers, which then assume any associated risk. There are a few examples of storage deployments in which an independent developer has assumed risk without government support. In these, the developer has had a strong financial backbone to mitigate the associated risks.[39] Other developers, equally as strong financially, are not willing to take the same risk. This process of offloading risks to developers does not eliminate risk, only moves the risk from a utility (and thus ratepayers) to an independent developer, but it may be a sufficient means for increased deployment in non-ISO/RTO region. Tying energy storage resources to renewables is another means for utilities and developers to address risk as has been done in Hawaii.[40] An energy storage system tied in with a long-term power purchase

[38] See: AES Energy Storage Projects (http://www.aesenergystorage.com/projects.html).

[39] See: AES Energy Storage Projects (http://www.aesenergystorage.com/projects.html).

[40] Xtreme Power Systems on Oahu and Maui built with wind power plants. The power plants (including the energy storage systems) are under power purchase agreements with the Hawaiian Utilities. These PPAs was approved by the Hawaii PUC and allow the power plant developers a predictable and guaranteed revenue stream. See: *Hawaii Clean Energy Update.* Hawaiian Electric Company. September 2012.

agreement on a renewable energy power plant also shifts the apparent risk off a utility relative to a standalone system being tied to renewable generation, while at the same time, guaranteeing a revenue stream to the developer. Incentives can also help reduce risk to utilities or developers investing in energy storage systems. This topic is discussed further in the next section.

CROSS-CUTTING BARRIERS

LIMITED KNOWLEDGE OF ENERGY STORAGE TECHNOLOGIES AMONG POWER SYSTEM STAKEHOLDERS

The Department of Energy has made efforts in educating industry and utilities on the benefits and functions of energy storage technologies through its outreach programs and demonstration projects. Though these efforts are impactful, utility and industry inexperience with energy storage resources is still relatively commonplace and can be a challenge to further deployment. Inexperience with storage technologies can lead to a lack of consideration of storage resources amongst utilities, developers and regulators who may not fully understand the technologies and their capabilities. Limited knowledge of energy storage technologies leads to:

1. A general lack of knowledge about the different functions and capabilities of energy storage resources and the belief that energy storage is useful only when supporting renewable integration.
2. Lack of consideration to use energy storage technologies for transmission and distribution purposes.
3. A lack of consideration of using energy storage resources to provide multiple services.
4. A lack of consideration of the enhanced performance abilities of energy storage resources relative to other technologies.
5. An assumption that all energy storage technologies provide similar capabilities and performance at similar costs.
6. Complexity in the use and operations of energy storage resources.

This lack of consideration prevents energy storage technologies from being demonstrated and their benefits and values identified, thus perpetuating limited deployment. The Department of Energy through its national laboratories, EPRI, universities and other organizations, is working to further educate through publication of reports and the communication of expertise through demonstrations, webinars, conferences and direct interaction with power system stakeholders. These demonstrations, a number of which are through the American Recovery and Reinvestment Act (ARRA), are working to validate the technical performance capabilities of energy storage resources in different landscapes in real deployment environments.[41] Developers of energy storage resources also work towards the same goal by targeting possible deployments and informing associated developers, utilities and regulators. Potentially, manufacturers could play a larger role in promoting their products by identifying real deployment scenarios, with a full consideration of performance and economics, presenting this work to developers and utilities.

MODELING RESTRICTIONS AND THE LACK OF MODELING CAPABILITIES

Though modeling capabilities are increasing in sophistication, additional variables have increased the complexity of modeling a power system. The modeling capabilities of many utilities are limited to modeling traditional resources for a traditional power system with predictable generation and predictable load. With the deployment of variable renewable generation, energy storage and other technologies on the generation side, and demand response, energy efficiency programs and consumer electronics on the load side, these capabilities are no longer sufficient. Tools are often inadequate for a utility to make the case to its regulatory commission on the value of energy storage relative to other investments. This applies to resource procurements for integrated resource plans (IRPs), for contracts with independent developers and for short term procurements, both for integrated utilities in

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[41] See *Energy Storage Activities in the United States Electricity Grid, May 2011* (http://energy.gov/oe/downloads/energy-storage-activities-united-states-electricity-grid-may-2011).

vertically integrated markets and for T&D utilities in ISO/RTO market environments. The lack of modeling ability also affects transmission coordination amongst ISO/RTOs and coordinating groups like WECC, who are unable to incorporate storage fully. ISO/RTOs are unable to adjust tariffs for non-market services because they may be unable to determine value to the system for storage resources such as reactive power, black start or T&D assets.

Typical modeling capabilities available on the power system do not adequately account for all of the capabilities of energy storage and can undervalue their use, especially considering resources providing multiple services. This inability to accurately and completely measure the full benefits of energy storage resources represents a significant challenge to deployment as utilities, developers and regulators are then unable to fairly compare resources. A good example of this is production cost modeling. Most production cost models operate at the hourly resolution, looking only over a 1-year horizon, and thus do not account for generation and load variability at shorter time frames, which can present a significant limitation in evaluating the full range of capabilities of newer technologies. Many energy storage technologies are well suited to provide services at fine time scales due to their quick ramping capabilities. Although newer production cost models do go to finer resolutions, they are still limited to the 5 minute optimization horizon, which undervalues the use of energy storage to address second to second and minute to minute variability. At longer timeframes, capacity expansion models have difficulty in optimally locating energy storage resources and properly accounting for their value compared with conventional resources. This leads to difficulty in the consideration of energy storage resources as alternatives to new generation and transmission investment.

Though current modeling limitations create a barrier to energy storage deployment, the issue can be addressed in a number of ways. Utilities should coordinate with organizations such as EPRI, the DOE National Laboratories and some engineering consulting firms who are working on the development of tools better suited to modeling energy storage resources. Continued development of modeling tools by these organizations may help utilities, developers and regulators understand the use and valuation of energy storage resources. The organizations developing these tools have a responsibility to inform utilities, developers and regulators about their capabilities and should work with utilities in their use to evaluate real deployments. These tools should continue to be updated and improved upon as power system and energy storage resource characteristics change as well as validated against real data to improve stakeholder confidence in their prediction capabilities. Utilities and developers should work together to share common experiences with modeling of resources and their systems to help address deficiencies in an individual entity's abilities.

For a more in depth discussion of energy storage modeling limitations and new tools and techniques being used to counter these limitations, see the *DOE/EPRI 2012 Electricity Storage Handbook in collaboration with NRECA*, EPRI's forthcoming report on energy storage modeling tools, *Bulk Energy Storage Value and Impact Analysis: Proposed Methodology and Supporting Tools,* and PNNL's forthcoming report, *National Assessment of Energy Storage for Grid Balancing and Arbitrage.*

Technology Barriers

High Technology Costs

Despite the misconceptions about the use of energy storage technologies, it is true that technology costs are high. In a number of instances, developers and utilities have experience with energy storage and have evaluated the use of a storage system to provide multiple services, yet still do not see an economic justification for their use. In these situations, alternatives to energy storage resources are more competitive. PSCo and MISO for example, find wind curtailment to be the preferred economic alternative to the installation of a new resource to manage wind ramp issues.[42] In the *2011 Energy Master Plan,* the state of New Jersey highlights a number of different energy storage technologies that may be valuable for its power system but indicates its belief that, "despite its promising future from a technical perspective, the primary barrier to implementation of energy storage projects is the high cost of available technologies (State of New Jersey, 2011, p. 123)." This sentiment is repeated by a number of regulators, utilities and developers.[43]

Continued research into energy storage technologies to reduce costs is crucial in making energy storage more competitive. Rather than the typical process of marginal improvements to obtain marginal gains in performance, research could be targeted towards technologies providing specific performance capabilities that meet power system needs at the lowest possible costs. The Department of Energy Office of Electricity Delivery and Energy Reliability Energy Storage program has set specific long-term goals towards decreasing the cost of energy storage technologies. In February of 2011, the program published the *Energy Storage Program Planning Document,* which identifies goals for the program. Included in these goals are cost targets. The planning document lists near team (within five years) cost goals of $250/kWh system capital costs and levelized costs under 20 cents/kWh/cycle. Long term goals lower costs more significantly to $150/kWh total system costs and levelized costs under 10 cents/kWh/cycle. In additional to the DOE/OE, DOE ARPA-e projects are targeting low costs and sufficient performance to quickly commercially deploy technologies.

Resource life cycle costs, which are generally not clear, also present challenges to energy storage deployment. These costs are important for a long-term consideration of storage resource use. At present, a number of reports and tools exists that may help potential developers, however, the costs presented in these reports may be inflated relative to actual costs.[44,45] Increased and targeted marketing of individual systems in specific situations, with an accurate discussion of benefits and costs, could help educate utilities, developers and regulators on the financial competitiveness of energy storage resources compared to other technologies.

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[42] Stakeholder interviews.

[43] Stakeholder interviews.

[44] See the *Related Energy Storage Guidebooks and Reports* section for references to these tools and reports.

[45] Developer interviews.

CURRENT INITIATIVES

Federal and state organizations have recognized many of the barriers discussed in this report. Current initiatives under progress at the federal, state and local levels are discussed in the following sections. These initiatives include:

- Initiatives addressing revenue compensation: those addressing revenue compensation mechanisms for energy storage resources and lack of available markets into which to offer energy storage resources.
- Initiatives addressing regulatory barriers: those identifying the need for an appropriate functional classification mechanism of energy storage to ensure that the classification allows resources to provide multiple benefits to the system.
- Initiatives addressing cross-cutting barriers: those making efforts to reduce technology costs, deploy demonstration projects, develop modeling tools and others intended to increase knowledge and understanding of the multiple benefits of energy storage resources.

Many of these initiatives are not specifically focused on increasing the deployment of energy storage resources, but also focus on the increased deployment of other emerging technologies such as renewable generation and demand response programs. These initiatives alone will not fully remove barriers facing the deployment of energy storage systems, but will help provide a framework for which other initiatives can be formed.

To illustrate the varying impacts of current initiatives, Figure 1 maps initiatives to the specific barrier they help to address.

	FERC Order 755: Pay for Performance	FERC Order 784: 3rd. Party Provision of A/S and Financial Reporting for New Electric Storage	FERC Order 719: Wholesale Competition	Fast Frequency Regulation Service (FRRS) Pilot	MISO Ramp Capability Product	Texas Docket 39917 & TX SB943	Colorado Section 123	NJ Clean Energy Program	MISO Energy Storage Studies	CA AB2514 Proceeding & Other CA Initiatives	ERCOT's Emerging Technologies Working Group
Functional Classification & Cost Allocation		●	●								
3rd. Party Ancillary Service Provision		●									
Inadequate Compensation Mechanisms	●	●	●	●							
Minimum System Requirements: Operation & Duration Constraints				●		●					
Lack of Available Market Products				●	●						
Lack of Price Signals		●									
Utility & Develop Risk & Uncertainty		●				●	●	●	●	●	
Limited Knowledge of ES Technologies							●	●	●	●	●
Modeling Limitations									●	●	●
High Technology Costs							●			●	

Figure 1. Mapping current initiatives to the barriers they intend to address.

Initiatives Addressing Revenue Compensation

In recent years there have been a number of federal initiatives to help ensure fair and adequate consideration and compensation for emerging technologies such as energy storage. These include FERC Order 755 Pay for Performance, FERC Order 784 Third Party Ancillary Service Procurement & Storage Resource Accounting and Financial Reporting, FERC Order 719 Wholesale Competition and FERC Order 745 Demand Response Compensation. State and ISO/RTO initiatives are also under consideration and include ERCOT's Fast Frequency Regulation Service (FRRS) pilot project, MISO storage products and California state initiatives and mandates.

FERC Order 755: Pay for Performance

On October 20, 2011, FERC issued Order No. 755. The order addresses compensation for frequency regulation in wholesale power markets with the purpose of ensuring "just and reasonable, and not unduly discriminatory or preferential" frequency regulation rates. The order applies only to secondary frequency response, or regulation, which is a fast-acting service provided by generators and other grid assets to address system energy imbalances. FERC cited evidence showing that regulation markets do not compensate resources providing differing amounts of regulation service based on the amount of service provided, only on capacity bid. As a result, FERC found that existing market rules for compensation were "unjust, unreasonable and unduly discriminatory" to faster acting resources, such as energy storage (FERC Order No. 755, 2011).

Order 755 requires a two-part payment for frequency regulation service: a capacity payment and a performance payment. The capacity payment must be based on a uniform market-clearing price, while the performance payment must reflect the accuracy of the performance of a device providing frequency response service and must be market based. The final rule requires that all markets with centrally procured frequency regulation resources provide compensation for cross product and inter-temporal opportunity costs. As discussed in previous sections of this report, Order 755 does not mandate a compensation methodology for capacity or performance payments, and the specific process for determining these payments and specifying resources is dependent on each individual market operator (RTO or ISO). All affected market operators have submitted compliance filings for Order 755, with PJM, MISO, CAISO and NYISO having received FERC approval and recently have begun operations with the new market methodology. Table 3 highlights key properties of the different ISO/RTO market designs to institute pay for performance frequency regulation markets. Since these markets have only been in place for a limited amount of time, pricing data and an understanding of the impact of the order is limited.

Table 3. Frequency regulation market designs by ISO/RTO, complying with FERC Order 755.[46]

	PJM	MISO	NYISO	ISO-NE	CAISO
Capability (Capacity) Offer	Total cost – performance price ($/MW)	Marginal unit offer + opportunity cost ($/MW)	Marginal unit offer + opportunity cost ($/MW)	Highest price for "efficient" payments ($MW)	Marginal unit offer + opportunity cost ($/MW)
Performance Offer	Highest offer ($/ΔMW)	Highest offer ($/ΔMW)	Marginal unit offer ($/ΔMW)	Highest offer ($/ΔMW)	Marginal unit offer ($/ΔMW)
Market Clearing	Merit order ranking of total offers (summed) plus opportunity costs	Merit order ranking of total offers (summed) plus opportunity costs	Two part to satisfy both capability and mileage offers	Merit order ranking of total offers (summed) plus opportunity costs	Two part to satisfy both capability and mileage offers
Dispatch Signals	2: Type A (slow) and Type D (fast)	Fast-first: 5 signals	Fast-first	Fast-first	Fast-first
Implementation	October 1, 2012	December 17. 2012	June 14, 2013	Expected: January 1, 2015	June 1, 2013

FERC Order 784: Third Party Provision of Ancillary Services and Financial Reporting for New Electric Storage Technologies

Following its Notice of Public Rulemaking in 2011, the Federal Energy Regulatory Commissions (FERC) issued Order No. 784 on July 18, 2013. It goes into effect after November 12, 2013. With Order 784, FERC is modifying its regulations with the intent of promoting competition and transparency in ancillary service markets (Final Rule Order No. 784: Third-Party Provision of Ancillary Services; Accounting and Financial Reporting for New Electric Storage Technologies, 2013).

Prior to Order 784, the Commission's *Avista* policy effectively restricted public utility transmission providers from procuring ancillary services from third parties to fulfill their *pro-forma* OATT requirements due to market power concerns. Order 784 reforms this policy, enabling third parties to sell ancillary services. It allows the sale of imbalance service at market based rates to public utility transmission providers as long as the balancing areas in which these utilities are located have implemented intra-hour scheduling. It also allows the sale of operating reserves in balancing areas that have intra-hour scheduling and allow the delivery of operating reserve across balancing areas. Sales of reactive supply, voltage control and regulation and frequency response will either be allowed at rates not higher than the purchasing utility's OATT rate for that service or at market rates through competitive procurement meeting requirements of the Order. Next, the order requires each public utility transmission provider to add a consideration of speed and accuracy in its calculation of regulation and frequency response service requirements. This allows utility customers who choose to self-supply the service have their reserve requirements reflect the capability of the resources they use to self-supply. Additionally, the order requires the utility to post certain area control error (ACE) data on the open access same-time information system (OASIS) to increase transparency in its regulation and frequency response service considerations.

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[46] ISO/RTO FERC Order 755 compliance filings.

With Order 784, FERC intends to promote transparency, address discrimination and promote competition in ancillary service markets. Public utility transmission providers will be able to procure ancillary services from third parties, potentially reducing the costs of this procurement relative to internal procurement. The utilities and their customers will have to consider speed and accuracy in the determination of regulation and frequency response requirements, opening this market to new, faster performing resources such as energy storage and removing the market access barrier. The final impact will depend on the implementation of these reforms.

FERC Order 719: Wholesale competition & FERC Order 745: Demand Response Compensation

FERC Order 719, in addition to other requirements, requires that RTOs and ISOs must accept bids from demand response resources to participate in providing energy and ancillary services, thus treating these resources equally as other resources. Another requirement is that there be a five-minute calculation of minimum prices for energy and ancillary services , improving the payment mechanism by capturing short term market variability, something energy storage and demand response are able to reply to more effectively than most thermal generation sources (FERC Order No. 719, 2008). In Order 745, FERC requires that market operators compensate demand response resources participating in an RTO or ISO energy market at the market price of energy, the LMP (locational marginal price). This requires that the demand response resource be capable of balancing supply and demand and be cost-effective as determined by an identified net-benefits test (FERC Order No. 745, 2011).

While these orders are intended to address issues related to demand response, they are valuable for distributed energy storage resources that act as demand response. These resources include residential or commercial water heaters, ice cooling systems and customer-sited battery resources. Order 719 and 745 enable these resources full participation in the wholesale energy and ancillary service markets. Additionally, demand response resources are important to understand as often they are direct competition for bulk energy storage in providing ancillary services

Fast Responding Regulation Service (FRRS) Pilot

ERCOT has a Fast Responding Regulation Service (FRRS) Pilot underway, with the intention of determining whether a new ancillary service can respond first to large frequency events before conventional regulation service comes online, with the intention of maintaining system reliability while reducing costs. This pilot is similar to PJM's (and other ISO/RTOs') multi-signal regulation markets, with faster signals for dynamic resources. The pilot aims to 1) determine whether the FRRS can improve the ISO's ability to address frequency drops during unit contingencies, 2) determine the optimal means of deploying the service and what units are qualified to provide service, 3) determine whether the service can reduce the system's regulation requirements and therefore reduce costs, 4) assess the operational benefits and challenges of deploying the service and 5) provide data for ERCOT to determine a new settlement methodology that takes into account performance as is the case for the markets developed in response to FERC Order 755 (Electric Reliability Council of Texas, Inc., 2012).

The pilot requires that any qualified participating resource be able to provide full or partial deployment of its obliged capacity within 60 cycles (1 second) of the receipt of a deployment signal or a substantial deviation in frequency (0.9 Hz above or below 60 Hz). There are two components to this pilot, FRRS-up to provide energy or curtail load, or FRRS-down to reduce energy output or increase load. Any ERCOT registered generation resource or controllable load that meets the qualification requirements and passes the qualification test is able to participate and is not precluded from providing other ERCOT market services. ERCOT intends the service to take advantage of faster acting resources such as energy storage and demand response. The pilot was scheduled to begin the week of February 25, 2013, and end August 23, 2013. ERCOT will release a preliminary report to the PUCT on July 1, 2013 with a final report following the end of the pilot. Presuming the pilot is successful, ERCOT intends to propose a Nodal Protocol Revision Request (NPRR) to implement the FFRS as an ancillary service (Electric Reliability Council of Texas, Inc., 2013) (Electric Reliability Council of Texas, Inc., 2013).

ERCOT will pay resources based on the day-ahead market clearing price for regulation service capacity during this pilot. Average market clearing prices for regulation in the day-ahead market were $9/MW-hr. for regulation up and $6/MW-hr. for regulation down. ERCOT will require resources to provide their full capacity for up to six minutes in one direction during each deployment. There are likely to be multiple deployments for each service during an hour. To meet performance requirements, resources must provide service, with a 60 cycle (1 second) response and output at 95% to 110% of their obliged capacity in 70% of deployments in an hour (Electric Reliability Council of Texas, Inc., 2012). An issue with the pilot, as cited by storage technology developers, is the short timeframe, generation connection requirements and limited revenue stream, making it very difficult for developers who do not have installed resources in place to participate.[47] This has the possible effect of excluding the consideration of some energy storage technologies as ERCOT formulates a new market design around the service.

Ramp Capability Products

In an effort to ensure ramp capability as renewable resources increase, MISO and CAISO are considering ramp capability for load following products in their markets. The product will address market conditions that will help ensure that there is enough ramp capability in the system to handle variations in forecasting errors and unit deviations. MISO hopes that by creating a market process that will help address these issues, the product will increase the responsiveness of the system and reduce scarcity conditions. This product will establish new market processes for the payment of ramp capability and resources such as energy storage may have an opportunity to commit and receive ramp capacity payments, adding a new revenue stream in the MISO marketplace (Midwest Independent Transmission System Operator, Inc, 2012).

Texas Docket 39917 & State Bill 943

During the 2011 legislative session, a number of discussions regarding energy storage issues emerged and three key rules relating to energy storage resources established. In June of 2011, the Texas legislature signed into law Senate Bill 943 identifying in further detail how energy storage would be regulated in ERCOT. The bill defines energy storage as a generation asset that must register as such when used to sell energy or ancillary services in the wholesale market. The bill requires that storage systems receive the same interconnection rights and transmission access as traditional generation sources and storage systems must follow Texas law in regards to selling energy or ancillary services in the wholesale market (Public Utility Commission of Texas, 2011).

To address SB943, ERCOT opened Project 39567 which discusses compressed air energy storage (CAES), specifically classifying CAES as a generation asset, allowing it to participate in energy and ancillary service markets. (Rulemaking to Implement SB 943, Relating to Electric Energy Storage Equipment or Facilities: Order Adopting Amendments to §25.5 and §25.109 as Approved at the November 10, 2011 Open Meeting, 2011). Even with this implementation, operators of energy storage would be required to register as both generation and load assets, an issue that introduces complexity and delays for storage operators.[48] A key issue is to resolve how to treat a storage facility when it is *acquiring* energy. In the pending Nodal Protocol Revision 340, ERCOT has proposed that an

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[47] Developer and utility interviews.

[48] Utility and developer interviews.

energy storage device can only charge (withdraw energy) and provide regulation service if ERCOT has issued a regulation down control signal. Alternatively, when ERCOT issues a regulation up control signal as the device is charging, the resource operator, or QSE (qualified scheduling entity), must add the amount being charged to its control signal. This effectively would allow an energy storage resource to provide regulation service during charging. Per this protocol revision, an energy storage resource, referred to as a duration limited resource, is not allowed to provide synchronous (spinning) or non-synchronous reserves. The protocol is still under consideration by ERCOT (Electric Reliability Council of Texas, Inc., 2011).

In Texas Docket 39917, and the associated ERCOT Nodal Protocol Revision Request 461 (approved December 2012), the Commission determined that energy storage, during both charge and discharge modes, would be considered a wholesale transaction and settled at the node, rather than zonally like load and face retail rates and associated retail transmission and ancillary services charges (PUCT Project 39917, 2012).[49] Until ERCOT approved this protocol revision, energy storage resources faced a difficult environment in which electricity would have to be purchased at zonal retail rates and sold at lower wholesale nodal rates creating market distortions in the location and operation of resources.

[49] Public Utility Commission of Texas, Order Adopting Amendements to §25.192 and §25.501 as Approved at the March 7, 2012 Open Meeting, 2012.

Initiatives Addressing Regulatory Barriers

FERC Order 784: Financial Reporting for New Electric Storage Technologies

Order 784 also requires utilities to better account for and report transactions related to the use of energy storage resources by revising accounting and reporting procedures under the Commission's Uniform System of Accounts (USofA) (Final Rule Order No. 784: Third-Party Provision of Ancillary Services; Accounting and Financial Reporting for New Electric Storage Technologies, 2013).

It creates new electric plant accounts specific to energy storage assets in the existing functional classifications of production, transmission and distribution. Asset costs will be allocated across these accounts depending on the function performed by the storage system. Additionally, the order creates a new account for the power purchased during startup and operating of a storage system, creates a new expense account for operation and maintenance expenses and amends existing schedules under USofA forms to better clarify the accounting and reporting process for energy storage assets.

Specifying new accounts and procedures for energy storage resources should address the complexity involved in their accounting and remove a barrier to their increased deployment. The final impact will depend on the implementation of Order 784 as these reforms go into effect.

Initiatives Addressing Cross-Cutting Barriers

While research by the DOE, national labs and industry have made significant efforts in expanding knowledge and experience, and reducing costs of energy storage resources, other entities, such as the State of California, Colorado, New Jersey and Texas have a number of initiatives and studies working to further educate developers and also reduce energy storage costs. This section provides a summary of these initiatives.

Colorado Studies and Initiatives

The State of Colorado has expressed interest in energy storage, having sponsored a study into its potential for the state and having held a commission information session on energy storage with utilities and developers. The PUC has approved funding for R&D development of energy storage and PSCo has a research and development storage facility, called SolarTAC, developed through the state's *Innovative Clean Technology Program*. This facility, just outside of Denver, has a 1MW/1MWh Xtreme Power battery system for photovoltaic support. The funding for this project included deferred rate base approval from the PUC (Xcel Energy Inc., 2011).[50]

Colorado contains a number of potential sites for pumped hydroelectric and compressed air energy storage. A number of studies identify and evaluate the potential use of these sites (Aitken & DuVivier, 2011). These storage projects and studies highlight the potential for further deployment of energy storage technologies in the state though this would require either PSCo or other utilities to evaluate and propose energy storage resources to provide grid services, or storage developers to propose projects that are economically competitive in open bidding requests. In 2009 for example, two storage developers bid into PSCo's open bid process for 1,200 MW of generation and capacity but the PUC did not find them to be competitive with other proposed resources.[51]

Colorado has a general initiative on new power system technologies that includes research staff for emerging issues and a special legislative monetary set aside for new energy resources. This initiative, called *Section 123 Resources,* requires the commission to provide complete consideration and possible rate based financing to alternative technologies without a need for them to be economically competitive. There must however, be a compelling reason for their use, primarily that the resource shows a potential of being economically competitive with other resources in the near future (In the Manner of the Emergency Rules Amending the Commission's Electric Resource Planning Rules, 2007, pp. 10-11).[52] The *Section 123 Resources* initiative does not specify specific technologies or the exact amount installed for each year. Total capacity is determined in the resource planning process. It is estimated that for the current (2013) process, this may be in the 120 MW range.[53] A solar power tower system has been granted local approvals in Alamosa County and appears to be proposing to use the *Section 123* provision for revenue recovery.[54]

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[50] Deferred rate base approval by the PUC indicates that PSCo can claim the resource as part of its rate base of system assets and earn recovery on the resource through retail rates. Rate base recovery provides for recovery of capital and operating costs including a PUC determined rate of return (Xcel Energy Inc., 2011).

[51] Utility and developer interviews.

[52] See reference for the specific criteria outlined by the commission for use of Sec 123 resources.

[53] Utility and PUC interviews.

[54] Utility and PUC interviews.

NJ Clean Energy Program, Studies and Initiatives

New Jersey has a clean energy program through its Board of Public Utilities (BPU) that is a result of the state's Energy Conservation and Clean Energy Act of 1995. This act involves a societal benefits charge on electricity rates to fund the program. It includes renewable portfolio standards (RPS), net metering and interconnection standards and has led to a significant deployment of distributed solar resources in the state. The state also has a clean energy development authority that has setup a clean manufacturing fund to support state manufacturers. New Jersey's market potential study, released in August of last year, informs state support for emerging technologies. The most recent study includes energy storage but indicates that the state does not believe there is a significant market for the resource in the state (Navigant Consulting, Inc., 2012).

The state's *Energy Master Plan* is a document intended to "promote a diverse portfolio of new, clean in-state generation" and "capitalize on emerging technologies for transportation and power production." Within the plan are long-term objectives and the implementation of interim measures for emerging technologies such as energy storage resources. This includes the creation of a technology evaluation and verification process; promoting support for the NJ Technology Incubator Network (NJTIN); and funding new technologies through the EDA, the state's bank for business support, and its green funding programs. These include the Edison Innovation Green Growth Fund that provides $1 million to class 1 renewable energy sources or clean energy technology companies, or the Energy Efficiency Revolving Load Fund, that provides up to $2.5 million to support project costs of commercial or industrial entities to integrate energy efficiency measures (State of New Jersey, 2011, p. 136).

MISO Energy Storage Studies

In 2011, in response to recommendations from the 2011 MISO Transmission Expansion Plan (MTEP), the ISO launched two energy storage studies, the Manitoba Hydro Wind Synergy Study and the Energy Storage Study, to understand the effects of energy storage technologies on reliability and market price benefits in MISO. These studies come as a response to MISO's efforts to incorporate storage technologies in the transmission planning process. Information from the studies will be used to inform in MISO's transmission and generation planning (Rastler, MISO Storage Study, 2011).[55]

The four phase Manitoba Hydro Wind Synergy Study, scheduled to be complete in the summer of 2013, is an effort to better understand the value of Manitoba Hydro as a large scale energy storage resource, specifically a large scale pumped storage plant with minimum load and a fast ramp rate. As a coordinating member of MISO, Manitoba Hydro is considering adding transmission to supply power, partially to help mitigate the effects of increasing variable resources in MISO. The study will determine how much benefit Manitoba Hydro can provide and the results will help determine the impact and potential benefits of this long-term energy storage in the ISO. Phases 1 and 2 of the report have been completed; modeling hydro energy using PLEXOS, as well as research into using existing transmission between Manitoba Hydro and MISO. Phase 3, completed in January of 2013 studied the benefits of expanding transmission between Manitoba Hydro and MISO. Phase four will provide recommendations that will likely be included in the 2013 MISO Transmission Expansion Plan (Bakke, 2013).

MISO's energy storage study was aimed at determining the reliability, market and planning benefits of battery storage, PSH and CAES technologies in the territory. Using specific scenarios from the 2011 MTEP, Electric Generation Expansion Analysis System (EGEAS) results indicated that there is value for long-term energy storage, but given MISO's current market prices and tariffs, long term energy storage would not be economically

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[55] MISO, Energy Storage Study Meeting, 2011.

supported. Communicating the possible benefits to stakeholders would be a direct result of MISO's work and may help to address uncertainty associated with energy storage (Rastler, MISO Storage Study, 2011). MISO terminated the energy storage study at the end of the first phase.

CA AB2514 and other PUC Proceedings

The State of California has an energy storage initiative underway through its Public Utility Commission (CPUC) rulemaking process. Assembly Bill (AB) 2514 passed by the state legislature directed the PUC to begin this rulemaking on December 16, 2010. It requires the PUC to "determine whether energy storage procurement targets should be established for regulated load serving entities." As part of this proceeding, the commission is interested in "considering whether steps need to be taken to reduce barriers to the deployment of storage." This includes evaluating the need for procurement policies, developing a cost-effectiveness framework and designating energy storage as a "preferred resource" for new resource procurements (Malashenko, O'Donnell, & Gupta, 2013, p. 3). As of August 2013, the CPUC has proposed a 1,325 MW procurement target for energy storage resources (excluding PSH) for its IOUs. This target is separated into targets for generation, transmission and distribution level investment. The proposed target is currently under review and open to stakeholder comment (Assigned Commissioner Ruling Proposing Storage Procurement Targets and Mechanisms and Noticing All-Party Meeting, 2013). If implemented, it may make a significant impact in addressing barriers to the deployment of energy storage in California and other states by forcing deployment and requiring utilities and other electricity system entities to deal with barriers as they arise. It may also create the manufacturing scale necessary to bring system costs down.

As part of this effort, PUC staff, with the help of stakeholders, has identified use cases for energy storage, identified perceived barriers to energy storage adoption, identified possible policy actions to address these barriers and is working to develop a global cost-effectiveness methodology. In its Phase 2 Interim Staff Report, PUC staff identifies barriers to adoption in California and groups them into nine broad categories. These are:

1. Lack of definitive operational needs for energy storage
2. Lack of a cohesive regulatory framework
3. Evolving markets and market product definitions
4. Resource adequacy accounting not accounting for energy storage
5. Lack of cost-effectiveness evaluation methods
6. Lack of a cost recovery policy
7. Lack of cost transparency and price signals
8. Lack of commercial operating experience
9. Lack of a well-defined interconnection process

Energy storage issues are also under consideration in other proceedings in front of the CA PUC. These proceedings include the long-term procurement proceeding to address capacity and operating requirements in the face of renewables integration, the resource adequacy proceeding to meet state resource adequacy requirements, the renewable portfolio standard proceeding, the Rule 21 proceeding and the Electric Program Investment Charge (EPIC) proceedings underway for each of the state's load serving entities.[56]

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[56] Further information on these proceedings is available in the "Energy Storage Phase 2 Interim Staff Report" referenced previously.

ERCOT's Emerging Technologies Working Group and Pilot Projects

ERCOT's Emerging Technologies Working Group (ETWG) has identified potential revisions to ERCOT rules to help increase the participation of emerging technologies, such as energy storage, into the market. This work has included exploration of creating a new asset class for energy storage. ERCOT permits pilot projects for energy storage and at times exempts projects from certain ERCOT rules and regulations. Pilot project proposals are presented to the ERCOT governing board who consults with market participants and PUCT staff on their deployment (PUCT Project 39917, 2012).[57] These pilot projects have enabled ERCOT and facility owners to gain experience working with storage facilities and provide data that could be used in the future to revise ERCOT rules and regulations that limit the entry of energy storage resources.

[57] Public Utility Commission of Texas, Order Adopting Amendements to §25.192 and §25.501 as Approved at the March 7, 2012 Open Meeting, 2012.

CONCLUSIONS

Energy storage technologies have the potential to significantly impact the electric grid, especially as the current system will require considerable infrastructure investment to maintain reliability as assets get older and demands on the system increase because of more variable loads and generation. As these modernization efforts continue, there is an opportunity for energy storage technologies to provide a number of different services. With the deployment of distributed generation resources, deployment of electric vehicles, increasing demand response programs, increased energy efficiency programs and deployment of microgrid systems creating a smarter grid while continuing to blur traditional classification lines, energy storage technologies can help ensure that reliability needs are met. Though an opportunity certainly exists for energy storage in building a more resilient and reliable grid, there are, however, a number of barriers restricting further deployment of these technologies as discussed in this report. Some organizations have taken action to help remove these barriers, and initiatives to remove these barriers are underway in a number of states and at regional and federal levels.

Though there are a number of regulatory and market barriers preventing the increased deployment of energy storage technologies, the primary barrier to deployment is high capital costs. Despite other barriers that exist, in most situations, this prevents a potential owner from creating a business case and further research is needed to decrease costs. Government, academia and manufacturers have an opportunity to play a key role here. Research should focus on reducing costs rather than improving marginal performance with the goal of a system that meets grid requirements at lowest possible costs. That said, despite their high costs, other barriers prevent developers from deploying storage devices in situations where they are economically preferred. These barriers restrict market access, prevent compensation for all services rendered and create difficulty in the evaluation of storage technologies by potential developers, market operators and regulators.

In addition to research focused on decreased storage system costs, additional initiatives aimed at opening market access for all resources to provide any services of which it is capable, should be implemented. Resource neutrality here is crucial. Requirements to provide services should be based on what the grid requires rather than centered on dictating which technologies are allowed to provide specific services. The classification of technologies by the traditional framework of resources separated into generation, transmission or distribution assets, contributes to this problem. Emerging technologies, such as demand response and energy storage resources, are blurring this line and should be able to provide services and receive compensation across these classifications. These changes, in addition to further knowledge about the technology amongst system stakeholders and new modeling tools that appropriately characterize their abilities, will allow for economically preferred energy storage resources to be deployed on the electricity system. Other issues, such as siting, permitting and safety requirements will require developers to navigate these requirements and regulators will have to adjust their codes to ensure that energy storage resources can be deployed.

Energy storage has a great potential to be a major electricity system asset. However, it requires regulations that enable market access, and research that reduces costs.

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Appendix

Interview Templates

This section highlights the topics discussed in stakeholder interviews. They are organized by type of stakeholder and in the general order the authors asked the questions to achieve the interview goal.

Interview Goal

Obtain interviewee's perspective of energy storage deployment inside their region: Where do they see it going? What challenges are there to further deployment? What needs to be done to address these challenges?

Disclaimer read to participants

Thank you for agreeing to participate in an interview about energy storage. Your input will be very valuable as we move forward with our study on the *Market and Policy Challenges for Energy Storage Deployment.* Unless you specify otherwise during our discussion, all information provided is assumed acceptable for public release. Your comments will not be directly attributed. Instead, they will be presented as part of a case study in our final public release document. Your name and any confidential information you provide will be maintained in confidence by Sandia and DOE personnel and shall not be disclosed to any third party. By participating, you agree to this disclaimer.

Interview Topics: Energy Storage Developers, IPPs, Integrators, Manufacturers

1. What is your target market for energy storage? (Uses and geographic location)

2. What role do you see energy storage playing in providing grid services including:
   - Energy
   - Capacity
   - Ancillary Services: spinning reserves, regulation reserves, ramping product
   - Capital (T&D or generator) deferment
   - Smart grid or microgrid applications
   - Distribution services

3. If you believe market rules and regulations stand as challenges hindering energy storage from **providing** services, then answer the following questions from your organization's perspective:
   - What effect do you see resulting from the implementation of FERC Order 755 and do you believe it will address cost recovery issues associated with providing ancillary services (in regulated environments, FERC NOPR for 3rd Party A/S Provision)?
   - What are the top challenges that limit the deployment of energy storage?
   - What do you believe needs to be done to overcome each of these challenges? Which are easy to overcome and which will make implementation possible?
   - What is your perception of the likelihood that such efforts will be undertaken to overcome each of these in the next five (5) years?

4. If you believe economic and business model issues stand as challenges hindering energy storage from being a **viable** service provider, then answer the following questions from your specific organization's perspective:

- List and rank the top three (3) such challenges that limit your organization from developing or promoting energy storage?
- What do you believe needs to be done to overcome each of your top three (3) challenges?

5. If you believe siting and permitting issues (and other local implementation issues) stand as challenges hindering energy storage from being a **viable** service provider, then answer the following questions from your organization's perspective:
   - List and rank the top three (3) such challenges that limit the development or promotion of energy storage?
   - What do you believe needs to be done to overcome each these challenges?

6. If all of these barriers are removed, what do you believe this will mean for your organization's energy storage efforts in the next five (5) years?

7. Over the next five (5) years, what role do you see state entities (e.g., legislators, regulators) and/or federal entities (e.g., FERC, NERC) playing to remove barriers and promote energy storage as an ancillary service provider?

8. What additional actions could be taken to promote energy storage as a viable ancillary service provider?

9. What specific role do you believe DOE should have in promoting energy storage as a viable ancillary service provider? Would your organization be willing to further partner with DOE as they play such a role?

10. Any additional contacts you might be able to provide to us?

Interview Topics: LSE Development Staff

1. What current initiatives does your organization have that deal with the deployment of energy storage systems?

2. What role do you see energy storage playing in providing grid services in CO?
   a. Energy
   b. Capacity
   c. Ancillary Services
   d. Capital (T&D) deferment
   e. Smart grid or microgrid applications
   f. Distribution services

3. If you believe market rules and regulations stand as challenges hindering energy storage from **providing** services, then answer the following questions from your organization's perspective:
   a. *In regulated environments, do you anticipate any effects from the FERC NOPR for 3rd Party A/S Provision?*
   b. What are the top challenges?
   c. What do you believe needs to be done to overcome each of these challenges?

4. If you believe siting and permitting issues (and other local implementation issues) stand as challenges hindering energy storage from being a **viable** service provider, then answer the following questions from your organization's perspective:
    a. List and rank the top three (3) such challenges that limit the development or promotion of energy storage?
    b. What do you believe needs to be done to overcome each these challenges?

5. If you believe economic and business model issues stand as challenges hindering energy storage from being a **viable** service provider, then answer the following questions from your specific organization's perspective:
    a. List and rank the top three (3) such challenges that limit your organization from developing or promoting energy storage?
    b. What do you believe needs to be done to overcome each of your top three (3) challenges?
    c. Are there issues related to modeling and evaluating the value of energy storage resources? (A lack of proper modeling tools/methodology?)

6. If all of these barriers are removed, what do you believe this will mean for your organization's energy storage efforts in the next five (5) years?

7. Over the next five (5) years, what role do you see state entities (e.g., legislators, regulators) and/or federal entities (e.g., FERC, NERC) playing to remove barriers and promote energy storage as an ancillary service provider?

8. What additional actions could be taken to promote energy storage as a viable ancillary service provider?

9. What specific role do you believe DOE should have in promoting energy storage as a viable ancillary service provider? Would your organization be willing to further partner with DOE as they play such a role?

Interview Topics: ISO/RTO ES Staff or AS Market Development Staff

1. What current initiatives does your organization have that deal with the deployment of energy storage systems?

2. What role do you see energy storage playing in providing the following services in your service territory?
    a. Ancillary Services
    b. Energy (including RE integration)
    c. Capacity
    d. Capital (T&D or generator) deferment
    e. Smart grid or microgrid applications
    f. Distribution services

3. What effect do you see resulting from the implementation of FERC 755 and do you believe it will address the market barriers associated with **providing** ancillary services?

4. Do you believe there are additional market rules and regulations that stand as barriers hindering energy storage from providing services despite the implementation of FERC 755?
    a. What do you believe needs to be done to overcome these issues?

5. If you believe market rules and regulations stand as challenges hindering energy storage from **providing** services, then answer the following questions from your organization's perspective:
    a. List and rank the top three (3) such challenges that limit the deployment of energy storage technologies?
    b. What do you believe needs to be done to overcome each of these challenges? Which are easy to overcome and which will make implementation possible?
    c. What is your perception of the likelihood that such efforts will be undertaken to overcome each of these in the next five (5) years?

6. If you believe economic and business model issues stand as challenges hindering energy storage from being a **viable** service provider, then answer the following questions from your specific organization's perspective:
    a. List and rank the top three (3) such challenges that limit the development or promotion of energy storage?
    b. What do you believe needs to be done to overcome each these challenges?

7. What do you believe the implementation of FERC 755 and the addressing of the other challenges discussed above will mean for energy storage efforts in the next five (5) years within your organization and within your service territory?

8. Over the next five (5) years, what role do you see state entities (e.g., legislators, regulators) and/or federal entities (e.g., FERC, NERC) playing to remove barriers and promote energy storage?

9. What additional actions could be taken to promote energy storage?

10. What specific role do you believe DOE should have in promoting energy storage as a viable service provider? Would your organization be willing to further partner with DOE as they play such a role?

Interview Topics: PUC Staff and/or Commissioners

1. What current initiatives does your organization have that deal with the deployment of energy storage systems?

2. What role do you see energy storage playing in providing the following services?
    a. Energy
    b. Capacity
    c. Ancillary Services
    d. Capital (T&D or generator) deferment
    e. Smart grid or microgrid applications
    f. Distribution services

3. What is your organization's perspective on promoting the deployment of energy storage technologies and their rate basing?
    a. What can/will the PUC do to promote the deployment of energy storage technologies or is it up to your LSEs to submit/suggest energy storage deployments?
    b. How do state laws factor into the equation?

4. If you believe market rules and regulations stand as challenges hindering energy storage from **providing** services, then answer the following questions from your organization's perspective:
    a. List and rank the top three (3) such challenges that limit the deployment of energy storage?
    b. What do you believe needs to be done to overcome each of these challenges? Which are easy to overcome and which will make implementation possible?
    c. What is your perception of the likelihood that such efforts will be undertaken to overcome each of these in the next five (5) years?

5. If you believe economic and business model issues stand as challenges hindering energy storage from being a **viable** service provider, then answer the following questions from your specific organization's perspective:
    a. List and rank the top three (3) such challenges that limit your organization from developing or promoting energy storage?
    b. What do you believe needs to be done to overcome each of your top three (3) challenges?

6. If you believe siting and permitting issues (and other local implementation issues) stand as challenges hindering energy storage from being a **viable** service provider, then answer the following questions from your organization's perspective:
    a. List and rank the top three (3) such challenges that limit the development or promotion of energy storage?
    b. What do you believe needs to be done to overcome each these challenges?

Over the next five (5) years, what role do you believe your organization will play in removing barriers and promoting energy storage as a service provider? Do the state and federal governments have a role to play here?

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