# 2012 Storage Report: Progress and Prospects Recommendations for the U.S. Department of Energy

A Report by:
The Electricity Advisory Committee
October 2012

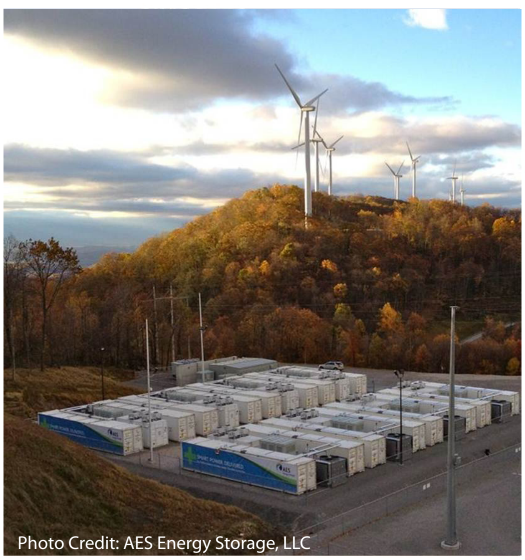


Photo Credit: AES Energy Storage, LLC

Photo Credit: Xtreme Power Inc.

# ELECTRICITY ADVISORY COMMITTEE

## ELECTRICITY ADVISORY COMMITTEE MISSION

**The mission of the Electricity Advisory Committee is to provide advice to the U.S. Department of Energy in implementing the Energy Policy Act of 2005, executing the Energy Independence and Security Act of 2007, and modernizing the nation's electricity delivery infrastructure.**

## ELECTRICITY ADVISORY COMMITTEE GOALS

**The goals of the Electricity Advisory Committee are to provide advice on:**

- **Electricity policy issues pertaining to the U.S. of Energy**
- **Recommendations concerning U.S. Department of Energy electricity programs and initiatives**
- **Issues related to current and future capacity of the electricity delivery system (generation, transmission, and distribution, regionally and nationally)**
- **Coordination between the U.S. Department of Energy, state, and regional officials and the private sector on matters affecting electricity supply, demand, and reliability**
- **Coordination between federal, state, and utility industry authorities that are required to cope with supply disruptions or other emergencies related to electricity generation, transmission, and distribution**

## ENERGY INDEPENDENCE AND SECURITY ACT OF 2007

**The Energy Storage Technologies Subcommittee of the Electricity Advisory Committee was established in March 2008 in response to Title VI, Section 641(e) of the Energy Independence and Security Act of 2007 (EISA).**

**This report fulfills requirements of EISA Title VI, Section 641(e)(4) and (e)(5).**

**Section 641(e)(4) stipulates that "No later than one year after the date of enactment of the EISA and every five years thereafter, the Council [i.e., the Energy Storage Technologies Subcommittee, through the Electricity Advisory Committee], in conjunction with the Secretary, shall develop a five-year plan for integrating basic and applied research so that the United States retains a globally competitive domestic energy storage industry for electric drive vehicles, stationary applications, and electricity transmission and distribution."**

**EISA Section 641(e)(5) states that "the Council shall (A) assess, every two years, the performance of the Department in meeting the goals of the plans developed under paragraph (4); and (B) make specific recommendations to the Secretary on programs or activities that should be established or terminated to meet those goals."**

Electronic copies of this report are available at: http://energy.gov/oe/services/electricity-advisory-committee-eac

# 2012 Storage Report: Progress and Prospects

**October 2012**

**More Information about the EAC in Available at:**
**http://energy.gov/oe/services/electricity-advisory-committee-eac**

## Letter from the Chair

October 2012

On behalf of the members of the Electricity Advisory Committee (EAC), I am pleased to provide the U.S. Department of Energy (DOE) with this report, “2012 Storage Report: Progress and Prospects”. This report provides recommendations that the Electricity Advisory Committee (EAC) offers for the DOE’s consideration as it continues to develop and implement its energy storage program, as authorized by the Energy Independence and Security Act of 2007.

These recommendations were developed through a systematic process undertaken in 2012 by the EAC. The members of the EAC represent a broad cross-section of experts in the electric power delivery arena, including representatives from industry, public interest groups, utilities, and state government. I want to especially thank Ralph Masiello, Senior Vice President, KEMA Inc. for his leadership as Chair of the EAC Energy Storage Technologies Subcommittee and to the EAC members who served on the Subcommittee. Thanks also go to Patricia Hoffman, Assistant Secretary for Electricity Delivery and Energy Reliability, U.S. Department of Energy, David Meyer, Senior Policy Advisor, DOE Office of Electricity Delivery and Energy Reliability and Designated Federal Officer of the Electricity Advisory Committee, and to Matthew Rosenbaum, DOE Office of Electricity Delivery and Energy Reliability.

The members of the EAC recognize the vital role that the DOE can play in modernizing the nation’s electric grid. The EAC looks forward to continuing to support DOE as it develops and deploys energy storage technologies, policies, and programs to help ensure an effective, resilient, 21st century electric power system. This report also fulfills the requirements in Section 641(e)(5)(B) of the Energy Independence and Security Act of 2007.

Sincerely,

Richard H Cowart

Richard Cowart, Chair
Electricity Advisory Committee

## ELECTRICITY ADVISORY COMMITTEE
## MEMBERS

### *INDICATES MEMBERS OF THE ENERGY STORAGE TECHNOLOGIES SUBCOMMITTEE

**Richard Cowart**
*Chair*
Regulatory Assistance Project

**Irwin Popowsky***
*Vice-Chair*
Pennsylvania Consumer Advocate (Ret.)

**William Ball**
Southern Company

**Linda Blair**
ITC Holdings Corporation

**Rick Bowen**
Alcoa

**Merwin Brown***
California Institute for Energy and Environment

**Ralph Cavanagh***
Natural Resources Defense Council

**Paul Centolella**
The Analysis Group

**Robert Curry***
CurryEnergy

**Clark Gellings***
Electric Power Research Institute

**Dian Grueneich**
Dian Grueneich Consulting, LLC.

**Michael Heyeck***
American Electric Power

**Paul Hudson**
Stratus Energy Group

**Val Jensen**
Commonwealth Edison

**Susan Kelly**
American Public Power Association

**Barry Lawson**
National Rural Electric Cooperative Association

**Ralph Masiello***
KEMA

**Vice Admiral Dennis McGinn***
American Council On Renewable Energy

**Clair Moeller***
Midwest Independent Transmission System Operator, Inc.

**M. Granger Morgan***
Carnegie Mellon University

**David Nevius***
North American Electric Reliability Corporation

**Chris Peters**
Entergy Services Inc.

**Wanda Reder***
S&C Electric Company

**The Honorable Phyllis Reha**
Minnesota Public Utilities Commission

**Brad Roberts***
Electricity Storage Association

**Chris Shelton***
AES Energy Storage, LLC

**The Honorable Tom Sloan***
Kansas House of Representatives

**David Till**
Tennessee Valley Authority

**Gordon van Welie***
Independent System Operator of New England (ISO NE)

**The Honorable Rebecca Wagner**
Nevada Public Utilities Commission

**Mike Weedall**
Bonneville Energy Administration (Ret.)

# Table of Contents

# Figures

## Tables

## Executive Summary

This report fulfills a requirement of the Energy Independence and Security Act of 2007 (EISA) that directs the Council[1] to prepare a report addressing the following energy storage issues:[2]

- Assess, every two years, the performance of the Department in meeting the goals of the plans developed under paragraph (4).
- Make specific recommendations to the Secretary on programs or activities that should be established or terminated to meet those goals.

Energy storage has the potential to transform the electric power infrastructure in the United States by greatly facilitating the integration of variable energy resources such as wind and solar and by improving the capacity factor or utilization of the transmission and distribution system as well as that of conventional generation. For decades, the power system has operated on a basis of near-instantaneously adjusting the production of electricity to match demand, and has built infrastructure to meet peak demand with adequate safety margin. In recent decades the "peakiness" of electric demand has increased such that on average the capacity factor or utilization of the grid infrastructure has decreased. Given the cost of constructing generation and transmission, especially, and the difficulty in siting new facilities, this mode of operation is increasingly less sustainable. The growth of variable resources such as wind and solar in the generation mix adds to the utilization problem – much conventional generation would still be required for times when the wind did not blow and the sun did not shine, but would be used on average less and less, resulting in growing in-efficiency of the overall grid.

Electricity can be viewed as a commodity product, and the role of storage in other commodity markets provides a valuable perspective for the electricity industry. For example, all other commodity markets use storage to levelize production and meet variable demand at the lowest possible cost. We are accustomed to storing gasoline, for instance, at the refinery, in the pipeline, at the terminal, in gas stations, and in our cars. Storage is relatively cheap, safe, and serves to buffer production from fluctuating demand. But because electricity has been difficult to store, the electric system has continued to operate on a "just in time" business model with sometimes extreme variation in the short-term price of electricity.

We note that there are significant opportunities to take advantage of the fact that many end uses of electricity are associated with thermal inertia (including heating, cooling, water heating, and refrigeration) and/or have flexibility in the timing of when they draw power from the grid (also including pumping loads, industrial batch process, pool pumps, dishwashers, clothes driers, and the charging of vehicles and other battery powered devices.)There are numerous technologies for optimizing demand that have implicit or explicit abilities to not only reduce demand but to shift the energy usage in time in a controlled fashion. Many are controllable "delays" or deferrals of energy usage; some are more flexible in that energy can be consumed,

[1] The Energy Storage Technologies Subcommittee, through the Electricity Advisory Committee.
[2] EISA Section 641(e)(5).

in effect, earlier than really needed and then effectively recaptured when the end use demand is "real." Examples of these technologies and applications include the control of hot water heaters (a delay or deferral of energy usage) and the pre-cooling of buildings with advanced Building Automation Systems (planned early excess consumption followed by controlled re-capture). Another widely discussed technology is EV smart charging which is a controlled deferral (absent vehicle discharge back to the grid which is not being developed commercially as yet) These technologies can provide many of the same benefits and applications as the "grid to grid" storage technologies discussed in this report. The focus of this report is on storage technologies which are '"electrically fungible" in that the storage resource and stored energy can be redelivered to the grid as electric energy in some way.

Since this Committee produced the 2008 report on electricity storage[3] a great deal of progress has been made in developing storage technologies that meet performance and cost targets for grid applications. For some applications such as system regulation or frequency control, it appears that storage is now commercially viable. For other applications it appears that while storage may be capable of meeting technical performance requirements it appears too costly for mainstream adoption. Furthermore, the knowledge gained from pilot and demonstration projects has not been widely absorbed by the utility industry, regulators, and policy makers. Decision makers in the electric industry are generally conservative, and are hesitant to adopt new technologies that may present unknown or unfamiliar risks. A lack of readily available tools and methodologies for evaluating storage and considering storage in system planning presents an additional barrier to the adoption of storage technologies.

Since 2008, when the EAC last provided an in-depth storage market report, the Energy Storage Association estimates that the power industry has installed 97 MWs of new projects, and looking to the future, the ARRA-funded projects are poised to bring an additional 422 MW on line by 2014. An additional number of storage projects have been implemented and "gone commercial" without federal or state incentives or funding support, and some of these are definite storage success stories. An estimated 116 GWh of energy storage is deployed globally of which 1179 MWh or about 1% is new non-traditional (i.e. new technologies, not pumped hydroelectric) today (source Pike research). Another estimate (Lux research, "Grid Storage under the Microscope: Using Local Knowledge to Forecast Global Demand) projects that by 2017 the global market for energy storage will reach 185 GWh, worth on the order of $113 Billion.

There are several major drivers for these projections: the ambitious plans announced by the US Department of Defense for achieving energy security at military bases, which will inevitably involve various applications of energy storage; the commitment of very large commercial users to renewable energy supply; the growing realization that storage is a key asset in achieving high penetration of renewable resources in the grid; and the expected improvements in storage technology, costs, and manufacturing capacity driven by electric vehicles. There are, however, economic, regulatory, policy, and awareness barriers to achieving these projected penetrations.

[3] Bottling Electricity: Storage as a Strategic Tool for Managing Variability and Capacity Concerns in the Modern Grid, Electricity Advisory Committee, December 2008, http://www.sandia.gov/ess/docs/events_news/BottlingElectricity.pdf .

In particular, the current energy situation where low cost natural gas (driven by the shale gas phenomenon) has reduced the operational costs of meeting peak demand and managing variable resources via gas turbines, if not the capital and infrastructure costs associated with their deployment.

This report details the progress that DOE and the storage and electric power industries have made since 2008, and identifies accepted applications of energy storage in grid applications. This report discusses applications that are technically proven and commercially viable today, and it identifies needed Research, Development, and Demonstration efforts that DOE can and should pursue in coming years, including continued research in electrochemistry, materials science, and ongoing cost improvements of these technologies. It also recommends that DOE and others develop the methods and analytical tools (software) for valuing, planning, and operating electric storage systems in different applications and raise industry awareness of the potential of storage and how to realize it.

This report also identifies policy and regulatory barriers at the state and federal levels to the adoption of storage in different applications, recognizing that these are not necessarily issues which DOE itself can address. Most of these barriers are not explicit, but are implicit in lack of familiarity or in existing technical standards developed before today's storage technologies were even imagined.  DOE conducts research, development, and demonstration projects in electric storage primarily via the Office of Electricity Delivery and Energy Reliability (OE) but also via Arpa-e research into electrochemistry and battery technology, and via various programs focused on transportation electrification.  OE is the principal sponsor of grid applications of energy storage and we summarize OE sponsored programs here.

As part of the 2009 ARRA program, the DOE provided $185 million of matching funds to stimulate $772 million of storage projects summarized in **Table 1:**.

**Table 1: ARRA- Funded Energy Storage Technology Demonstration Projects**

| Category | Power (MW) | Project Value | DOE Funds |
|---|---|---|---|
| 1. Battery storage for utility load shifting or wind during operation and ramping control | 57.0 | $145,168,940 | $60,784,483 |
| 2. Frequency regulation ancillary services | 20.0 | $48,127,957 | $24,063,978 |
| 3. Distributed storage for grid support | 7.5 | $44,468,944 | $20,350,142 |
| 4. Compressed air storage (CAES) | 450.0 | $480,962,403 | $54,561,142 |
| 5. Demonstration of promising storage technologies | 2.8 | $53,075,574 | $25,230,027 |
| **TOTAL** | **537.3** | **$771,803,818** | **$184,989,700** |

*Source: SNL ESS 2010*[4]

Most of the ARRA projects should be in service by the end of 2012 with follow-up evaluation programs lasting one to two years.

These projects have been selected for negotiation of awards; final award amounts may vary.

The following are the key recommendations of the Energy Advisory Committee:

**Near-Term Goals (2013-2015)**

The EAC strongly encourages that DOE continue basic electrochemical research aimed at exposing the "genome of the periodic table" over time – exploring the potential for energy storage based on new electrochemistries and their practical realization.

- The DOE should complete detailed studies of the effects of higher penetration of renewable sources on grid operations and the permanent retirement of a large percentage of traditional generation. As noted in Section 5, this is an ongoing and open area due to the complexity of the problem and the continuing discovery of issues by researchers. The goals of RPS studies should be modified to consider changing end use penetrations, changing T&D infrastructure capacity utilization, and how these will affect storage economics. Work in assessing the role of storage as part of a portfolio of flexible generation, storage, and demand response for renewables integration is needed. Demand optimization technologies that have "time shifting" potential as discussed above should be fully considered along with storage. This work should be in the context of a restructuring of the electric power supply chain to incorporate storage at all levels (production, transmission, distribution, and end use) so as to optimally increase capacity utilization factors and better balance capital and operating costs overall.
- The Energy Independence and Security Act of 2007 required DOE to establish four Energy Storage Research Centers. An RFP for one storage hub was released in

[4] DOE Electricity Advisory Committee, Energy Storage Technologies Subcommittee, "Energy Storage Activities in the United States Electricity Grid", May 2011, p.3. http://www.oe.energy.gov/DocumentsandMedia/FINAL_DOE_Report-Storage_Activities_5-1-11.pdf.

February 2012 with an award yet to be made. The EAC recommends that this storage hub should be funded and an award made.

- DOE OE should update and make public for discussion and debate its roadmap for technology development for storage (Energy Storage Planning Document, February 2011) and describe the progression of technologies and applications from Technology Readiness Level (TRL) 1-2-3 to TRL 8-9, including checkpoints, signposts, and decision criteria.
- The activity of funding up to 30% of the cost of energy storage technology investments required to demonstrate performance and effectiveness of technologies should be continued following the development of the technology roadmap and utilizing the decision points established in it to identify suitable demonstration projects and technologies.

**Mid-Term Goals (2015-2020)**

- Continue to fund (up to 30%) energy demonstration storage projects of new technologies arising from ARPA-E and other developments targeted at moving technology from TRL 3 to TRL 7-8 that expand the use of storage for grid performance enhancement and show benefits to increasing the use of renewable energy resources.
- Measure and report the impact of PEVs and on performance of the grid in terms of peak loading and any change in the need for ancillary services, and on the impacts of EV load and charging behavior on the T&D system and on methods to address issues identified. Investigate the integration of EV charging with renewable generation. Consider the use of local energy storage as a way to mitigate the impacts of "fast charging" (Level 3 charging) These measurements and analyses have to be performed in the context of local "pockets" of PEV adoption today as in general PEV penetration is not sufficient to exhibit any impacts on a national or regional basis.
- Continue Funding of next-step R&D activities based on the results from the "materials genome project" cited above.
- Develop R&D projects focused on better understanding of storage longevity in different applications for existing and new storage technologies.
- Evaluate ongoing larger-scale demonstrations of energy storage technologies for transportation to include large truck and rail applications and the effect on T&D systems and grid and market operations of such technologies at scale.
- Develop and conduct an educational outreach program to state regulators and legislators involved in energy issues. Conduct this in on site workshops per the preferences expressed by the ESA survey respondents rather than in webinars, publications, or national conferences. Focus especially on commission and legislative staff assigned to renewable integration, advanced energy technology, and other related areas.

- Consider research into better understanding how different incentive designs and longer term performance guarantees / risk mitigation will actually influence investment behavior and support (or not) underlying policy goals, including better anticipation of unintended consequences.
- Support studies to expose the emissions benefits of storage as a source of ancillary services and the impact this has on the net emissions benefits of variable renewable resources.

**Long-Term Goals (2020 and beyond)**

- Implement programs to test and analyze vehicle-to-grid (V2G) performance and the impact on grid operations.

# 1 Introduction

The origins of the electric power industry began with electricity storage – Leyden jars were used to capture static electricity and build up a stored charge that could be used in demonstrations. The telegraph system relied on batteries to supply the electric energy used in conveying the telegraph signals along the lines, as did Alexander Graham Bell in the first telephones. The famous Pearl Street station and other early central DC generating stations employed batteries to help with fluctuating demand and to control voltage. Commercial battery development received a great boost when Cadillac developed electric starters for automobiles. However, advances in the control of interconnected AC power systems rapidly surpassed the need for integrated electric storage.

We should recognize that the amazing growth in consumer electronics, especially mobile computing and smart phones, is built upon the base of advanced battery technologies. Advanced high-density low weight batteries are as critical to this industry as have been power consumption reductions in the electronics themselves. This represents a first wave of “portable energy” which may be a new paradigm for the electric power industry, especially in the developing world where local generation and provisions for charging battery powered lighting, cell phones, computers, and televisions is growing faster than construction of traditional power system infrastructure.

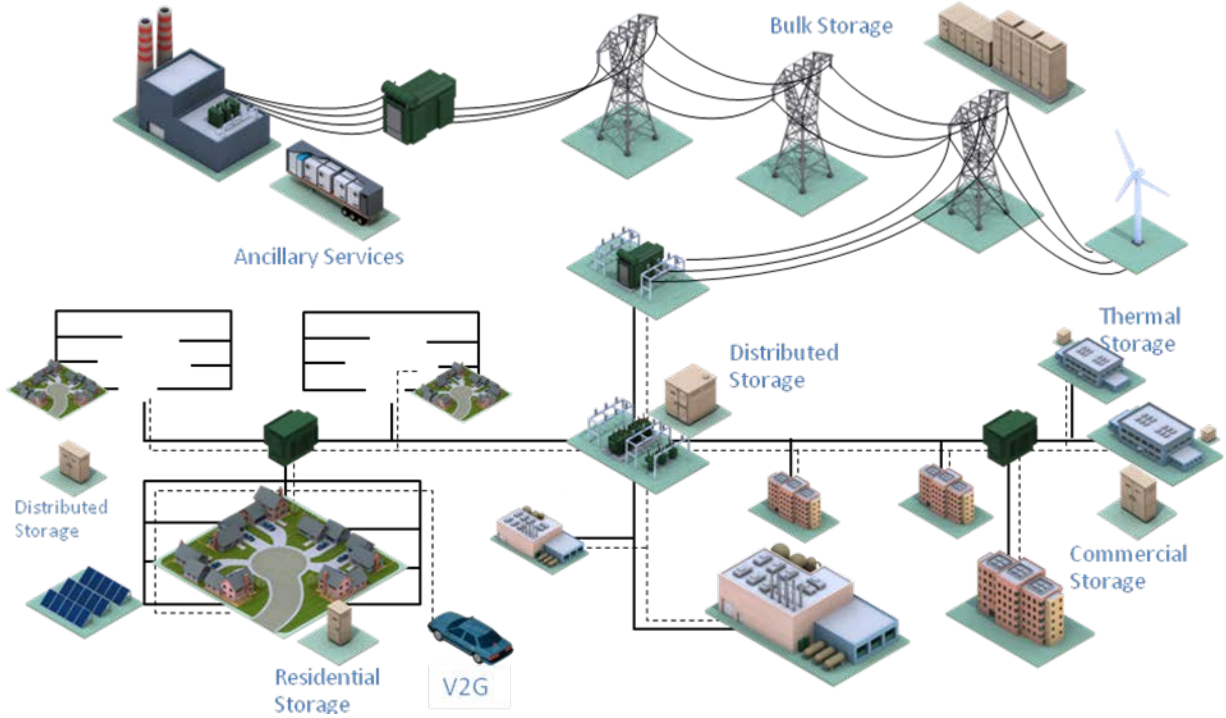
Aside from pilot and demonstration projects, end users, and portable power, the electric power sector today stores energy only in the fuel used to produce electric power: in coal stockpiles, in the natural gas infrastructure, inside nuclear power plants, and behind dams. Almost the only way electric power is “stored” for later use is when it is converted back into water behind a dam at hydroelectric pumped storage plants. End users are adopting battery storage as an alternative to diesel or gas fired backup generation, and there are some commercial projects using battery storage, but these are still uncommon.

In a future vision, energy storage would have a role throughout the electric energy value chain:

It would be stored at generation facilities to capture wind and solar power at peak production and to levelize the use of transmission or to save it for delivery at peak load. In addition to firming renewable production, storage will be used to provide ancillary services such as regulation and balancing energy for which it is especially well suited.

Storage would be used in the transmission system as a way to relieve congestion, to increase transmission utilization off peak, and to provide peak shaving for capital deferral, plus other more technical applications, such as voltage control and stability augmentation.

**Figure 1: Applications for Storage Systems on the Grid**




Storage on the distribution system would assist in managing the fluctuations of photovoltaic production, would provide local backup and reliability in the event of a local distribution outage, and could be used to provide peak shaving for capital deferral similarly to transmission. Such "Community Energy Storage" (CES) facilities could conceivably provide peak shaving and ancillary services support to the grid, provided that regulatory and investment models to allow this could be developed.

Storage at the end user level would provide similar benefits to the community energy storage systems, and could play a key role in accommodating rapid EV charging (level 3) systems without forcing massive upgrades to the T&D system. And end user storage would definitely include the continued growth of portable energy. Just as many incandescent lamp fixtures imitate older gas and indeed candle fixtures today, we may see a future when battery power LED lighting is made to look like today's incandescent fixtures, albeit without a fake cord and plug. The actual demand for electricity will be positively affected by these new devices in the future as more appliances become "smarter" in their use of electric power.

**Objectives of this report**

The Energy Policy Act of 2007 stipulated that the Department of Energy should create an advisory committee on electricity storage which would produce a biannual report to the Secretary of Energy. That storage focused advisory committee has been incorporated into the

Energy Advisory Committee (EAC). The primary objective of this report is to fulfill this statutory requirement and report to the Secretary on:

- The state of development of electricity storage in the electric power system in the United States

- Progress which the Department of Energy (DOE) has made towards achieving its goals for energy storage development as well as progress at the state and local levels and in the private sector

- Progress which the DOE has made in implementing the recommendations made in the prior (2008) report of the EAC on Electricity Storage.

- Identifying gaps in current technology development and demonstration and recommending near and medium term DOE initiatives to address them

- Identifying barriers to the successful adoption of energy storage and the realization of its potential benefits, and making recommendations for ways to reduce or remove these barriers

**Energy Storage Applications Addressed in this Report**

This report describes and addresses the status of energy storage applications associated with the electric power infrastructure – storage in the generation, transmission, and distribution systems of today. It also includes end user storage applications for the storage of electric energy at the end user level for later reuse by multiple end use devices. It explicitly does NOT include energy storage embedded in those end use devices and systems, be they flashlights, smart phones, computers, or electric vehicles, nor as noted earlier, does it address Demand Response time shifting capabilities such as thermal storage. It does address, however, the potential for larger end use storage systems, especially electric vehicles, as a component in the interconnected power system via “Vehicle to Grid” (V2G) application.

# 2 Storage Applications

In the EAC's report delivered in December 2008, Chapter 2 (Bottling Electricity) provided an extensive overview of storage applications in the grid. These applications ranged from bulk storage benefits to the transmission system to small storage devices deployed at the very edge of the grid to protect small numbers of individual energy users. Since that report, DOE and the storage industry have made significant strides in deploying a variety of storage applications. At the same time, FERC Order No. 755 has allowed the benefits of storage to be realized in the ancillary services market. This section of the report will provide updates and actions taken in each major storage application.

**Figure 2: AES Lithium-Ion Battery Plant near a Wind Farm in West Virginia**

This picture shows a Lithium-Ion battery plant near a wind farm in West Virginia. The use of battery systems to turn wind power into a schedulable and controllable resource has found viable applications in remote and island situations where it is necessary to "firm" the wind power in this way. Also, this figure shows the battery systems as a collection of modular components in ISO containers. This is another trend which facilitates standardization and enables re-use of the systems at future additional locations should the need arise.

*Source: AES Energy Storage LLC*

## 2.1 Generation and Renewables Integration

The first large scale storage systems developed in the United States were pumped storage hydroelectric facilities such as the TVA Raccoon Mountain project. The major driver for this and other similar projects was to levelize daily and weekly demand so that the coal and oil fired steam generation of the era and the large, inflexible nuclear plants being constructed could be used most efficiently. These pumped hydro-electric facilities have performed very well over the years and have served their original purpose of providing large scale peak shaving/valley filling as well as providing ancillary services such as system regulation, real time dispatch, and spinning and quick start reserves that made use of their natural controllability and rapid response. In some markets, they also served as Demand Response reserve resources when in the pumping mode, as their (large) pumping load could be curtailed rapidly and easily. When suitable siting is available and transmission to the inevitably remote location can be constructed, pumped storage hydroelectric remains a very attractive option.

Today there are 22 gigawatts (GW) of installed capacity, most of this capacity has been in service for more than 30 years, but active programs for adding more pumped storage are in process. Currently, preliminary permits have been issued for adding over 38 GW of new pumped storage projects in eleven states, plus an additional 7 GW in five states with pending permits, according to a FERC as of July 2012[5]. These projects require thorough environmental impact reviews, and take considerable time to approve and construct. How much of this capacity will ultimately be built is uncertain; however, it is envisioned that much of this capacity will be very useful as the amount of variable wind and solar power resources grow in the US grid.

Advancements in pumped hydro machine design using variable speed drive technology in the pumping cycle greatly increases the overall system efficiency and flexibility of system operation. To better analyze system performance, the U.S. DOE's Wind and Water Power Program allocated funds in the FY12 budget to develop improved modeling and analysis programs to better assess the value of these advanced pumped storage hydro power systems.

States with high renewables penetrations today and / or with aggressive plans for renewable portfolio development are also taking action to develop storage resources. Here we describe recent activities in Texas and California, both driven by a desire to have storage play a role in integrating high renewable production levels reliably and economically. We also describe the NY-BEST (Battery Energy Storage Technology) initiative which additionally factors technology and industrial development policy into the equation.

### *Texas SB943*

The Texas legislature passed a bill (SB943), which clarified that energy storage that is used to offer energy into the competitive wholesale market is entitled to the same rights as generation specifically in regard to transmission access and inter-connection. The Texas PUC (Project 39917) established favorable settlement and cost allocation for energy storage resources. This ruling established that storage resources are exempt from retail and load fees and charges including ancillary service costs and transmission cost allocation. ERCOT has developed revised protocols in recognition of these proposed and established proceedings.

### *California's AB2512*

In September, 2010, the California legislature enacted Assembly Bill 2514, directing the California Public Utility Commission (CPUC) to convene a proceeding by March 1, 2012, to

[5] http://www.ferc.gov/industries/hydropower/gen-info/licensing/pump-storage.asp

determine energy storage procurement targets, if any, for investor-owned utilities[6]. Under the statute, similar targets would be required for publicly-owned utilities on a slightly later time frame. In December 2010, the CPUC issued an Order for Rulemaking Pursuant to AB 2514, initiating the process more than a year ahead of the statutory deadline. A CPUC Scoping Memo, issued April 21, 2011, determined that the proceeding would be divided into two phases - the first phase would develop the overall policies and guidelines for energy storage systems (ESS), while the second phase would develop the costs and benefits for ESS and establish how they should be allocated[7]. Although AB 2514 directed the Commission to open a proceeding by March 1, 2012 to determine energy storage procurement targets, if any, the Commission chose to open it sooner, i.e., December 16, 2010, explaining that it "see[s] the enactment of AB 2514 as an important opportunity for this Commission to continue its rational implementation of advanced sustainable energy technologies and the integration of intermittent resources in our electricity grid.

The CPUC staff submitted its Final Energy Storage Framework Staff Proposal (Final Proposal) on April 3, 2012[8]. The Final Proposal includes a Storage Barriers Regulatory Matrix, which summarizes the various barriers and policies faced by energy storage developers. Based on this matrix, the CPUC staff proposed a framework to analyze energy storage. This proposed framework identifies 20 "end uses" for energy storage and specifies where in the value chain storage can be used. The identified Energy Storage "End Uses" are presented in **Table 2** below. Note that the CPUC framework end uses are slightly different than the applications presented in the 2008 EAC report or in other documents, pointing out the need for industry agreement on standard definitions and terminology – one of the later recommendations of this report.

[6] Andris Abele, Ethan Elkind, Jessica Intrator, Byron Washom, et al (University of California, Berkeley School of Law; University of California, Los Angeles; and University of California, San Diego) 2011, ***2020 Strategic Analysis of Energy Storage in California***, California Energy Commission. Publication Number: CEC-500-2011-047. Accessed August 29, 2012 at http://www.law.berkeley.edu/files/bccj/CEC-500-2011-047.pdf.

[7] Peevey Agenda Dec. Revision 1 Adopting Proposed Framework for Analyzing Energy Storage Needs. CPUC 8/2/2012 Item 35. Accessed August 29, 2012 at http://docs.cpuc.ca.gov/published/AGENDA_DECISION/171740.htm#P70_1559.

[8] D1208016 Adopting Proposed Framework for Analyzing Energy Storage Needs, Section 2. Accessed August 29, 2012 at http://docs.cpuc.ca.gov/published/Final_decision/172201-02.htm#TopOfPage.

Table 2: Energy Storage “End Uses”

| Category | | Storage `End Use' |
|---|---|---|
| Describes at what point in the value chain storage is being used | | Describes what storage is being used for, i.e. its application. |
| ISO/Market | 1 | Ancillary services: frequency regulation |
| | 2 | Ancillary services: spin/ non-spin/ replacement reserves |
| | 3 | Ancillary services: ramp |
| | 4 | Black start |
| | 5 | Real time energy balancing |
| | 6 | Energy price arbitrage |
| | 7 | Resource Adequacy |
| Generation | 8 | Intermittent resource integration: wind (ramp/voltage support) |
| | 9 | Intermittent resource integration: photovoltaic (time shift, voltage sag, rapid demand support) |
| | 10 | Supply firming |
| Transmission/ Distribution | 11 | Peak shaving |
| | 12 | Transmission peak capacity support (upgrade deferral) |
| | 13 | Transmission operation (short duration performance, inertia, system reliability) |
| | 14 | Transmission congestion relief |
| | 15 | Distribution peak capacity support (upgrade deferral) |
| | 16 | Distribution operation (voltage / VAR support) |
| Customer | 17 | Outage mitigation: micro-grid |
| | 18 | Time-of-use (TOU) energy cost management |
| | 19 | Power quality |
| | 20 | Back-up power |

*Source: CPUC*[9]

[9] D1208016 Adopting Proposed Framework for Analyzing Energy Storage Needs, Section 5. http://docs.cpuc.ca.gov/published/Final_decision/172201-05.htm.

The Final Proposal states that decomposing energy storage into various end uses will allow for more manageable analysis. The CPUC staff further stresses that analyzing each individual end use for storage should not obviate more comprehensive analysis of energy storage. "[By] focusing on the specific 'end uses' it will become apparent which aspects of energy storage are unique to specific applications and which aspects of storage are common across all uses". The analytic approach would consist of four major categories - regulatory framework, cost effectiveness, procurement objectives and energy storage roadmap.

### *New York's NY-BEST*

One of the states that have taken a very pro-active approach to finding ways to make energy storage work in the grid is New York. The state government formed the New York Battery and Energy Storage Technology Consortium (NY-BEST) to act as a catalyst for academia, entrepreneurs, industry, and federal advocates to spearhead the development and acceleration of energy storage technologies statewide. At the end of 2011, the State granted NY-BEST $15 million for battery storage R&D; and allocated $1 billion for development of an energy superhighway system to deliver power including renewable energy from upstate and western New York to urban and downstate high population areas. This initiative strongly supports storage development, deployment, and commercialization efforts. The primary objectives of this program are to[10]:

- Reduce constraints on the flow of electricity and expand the diversity of power generation sources
- Assure the long-term reliability of the electric network
- Increase the efficiency of power generation
- Increase the efficiency of generation in urban areas

The overall goals for the State in meeting the objectives of this program are to create jobs in the energy sector; contribute to an environmentally sustainable future; advance technology; maximize ratepayer value and; adhere to market rules. This last goal underscores the importance of developing a workable regulatory framework that is vital making storage work for the modern grid.

To help accelerate these efforts, the New York legislature approved a law[11] supporting swifter development of all energy storage types by reducing the regulatory burdens for approval. The law adds batteries of all types, flywheels, CAES and other storage devices to the definition of "alternative energy production", and exempts plants smaller than 80 MW from regulation by the New York PSC. This approach will accelerate the deployment of plants providing ancillary services such as frequency regulation and peak load reduction facilities. Additional legislation is under consideration to offer tax credit incentives of 20% for R&D and manufacturing properties in the State plus 10% tax credit for qualified storage R&D expenditures.

[10] New York Battery and Energy Storage Technology Consortium™ Final Report Prepared for the New York State Energy Research and Development Authority, Albany, NY www.nyserda.org Jason H. Doling Project Manager NYSERDA March 2010
[11] New York Senate S.7145 July 2010

## 2.2 Transmission and Distribution

In May 2011 the EAC issued an interim report on energy storage activities in the United States Electric Grid[12]. That report showed 1.3 GW of electric storage systems have been installed in addition to the 22 GW of pumped storage. These are smaller systems targeted at transmission reliability issues, ancillary services, and distribution projects such as peak load reduction and asset upgrade deficiencies in utility substations. The EAC is issuing a white paper on "Non Wires Solutions" which discusses storage applications as one alternative to traditional T&D construction.

With regard to transmission issues, the State of Texas PUC granted a one-time exemption to a transmission provider to install a 4.0 MW / 5MVA six-hour battery as a lower cost solution other than the traditional transmission upgrade with new lines. Similar projects were installed in three Midwestern states by AEP to test the improvement in system reliability and capital deferment.

In the area of ancillary services, several pilot programs were begun in the 2008 to 2009 timeframe to show the advantages that fast-acting resources like flywheels and batteries could provide in frequency regulation applications. The FERC responded to this opportunity and issued Order 755 in October 2011. This ruling named, "Pay for Performance" directs the RTOs and ISOs to develop a compensation method for frequency regulation that recognizes the value of a rapid response to the frequency regulation requirements of the system operators. While the order is technology neutral (and indeed developers of other fast responding resources have taken notice) the effect has certainly been to encourage fast storage systems to be developed for this application. The net result of these and other factors has been the expanded deployment of storage installations totaling 124 MWs by the end of 2012.More of these storage plants are expected to be deployed over the next two-three years as well.

One of the most noteworthy storage applications being tested across the U.S. and in other countries is extending storage to the edge of utility grids at the street level. This concept has been named Community Energy Storage (CES), since the targeted load is several residents on a single utility distribution transformer typically sized from 25 kVA to 75 kVA (photograph of CES unit in **Figure 3**). Current utility distribution control technologies stop at the substation level, with feeders running to customers designed for average loads that have been predictable over time. Today with the proliferation of grid-tied photovoltaic (PV) panels on residential roofs and the potential for growth in plug-in electric vehicles, utilities could be challenged to properly control the voltage on local feeders and maintain acceptable levels of reliability. The CES concept deploys stored energy at these points of use plus the CES power electronics provide the utility with dynamic control of system voltage and load power factor. This stored energy in the CES units also compensates for load intermittency caused by passing clouds during the day and battery charging of PHEVs. By aggregating a number of CES units, utilities can increase system

[12] DOE Electricity Advisory Committee, Energy Storage Technologies Subcommittee, "Energy Storage Activities in the United States Electricity Grid", May 2011, p.3. http://www.oe.energy.gov/DocumentsandMedia/FINAL_DOE_Report-Storage_Activities_5-1-11.pdf.

voltage control, manage peak loads and integrate local renewables with an extended layer of intelligence in the grid. This concept is being tested in several of the DOE Smart Grid ARRA projects. Production delays typical of new technologies have resulted in fewer CES installations in place today than anticipated in 2008-9 but CES is still seen as a primary technology to mitigate the impact of distributed Photovoltaic generation on distribution feeders.

A variation on the CES technology being tested in one ARRA project at Detroit Edison (DTE) with the participation of the Chrysler Corporation is to test the use of recycled EV batteries in the CES application. The concept is that EV batteries will be replaced when their capacity (depth of charge available) has deteriorated to 75% or so of the original capacity, so as to maintain vehicle range. But at that level a recycled EV battery may still be useful in the CES application, especially if the application does not require charging duty cycles as demanding as the EV application. There are many additional issues to be worked through before this concept will be commercially viable including testing, repackaging, and sorting out good vs. bad battery cells.[13]

**Figure 3: Community Energy Storage Unit**

*Source: American Electric Power*

## 2.3 Stationary End-user Applications

Another application for energy storage being tested is in micro-grids. This concept applies storage as part of an end-user owned and operated electrical system such as a college campus, hospital complex, or military base. As large users attempt to optimize energy consumption and integrate more renewable resources, storage plays a pivotal role in this process to insure maximum reliability for the power in this small local network. Being the largest energy user in the US, the Department of Defense has launched programs to meet regulatory goals for energy intensity, renewables usage and greenhouse gas reduction. Matching these goals with a mandate to enhance energy security at mission-critical bases presents the need for deployment

[13] Detroit Edison's Advanced Implementation of A123s Community Energy Storage Systems for Grid Support

of advanced micro-grids, which will require energy storage as a component of the design. These DOD efforts are being conducted under the Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP) and cover all energy uses including electricity. One of the goals on these programs is to greatly increase the use of renewable energy resources. In 2011 the DOD reported that 10 MW of renewable energy resources were in use at U.S. bases. Their plan for 2025 is to have 1,000 MW in place with a goal to achieve this through third party financing and partnerships with private business potentially owning microgrid power systems at U.S. bases.

Even without a microgrid as formally defined (containing generation and capable of islanding) electrical storage is finding additional end user applications. Some data centers are installing large scale storage as an alternative to back up generation. While still too expensive for most consumers, storage as backup power in a garage is commercially available today. One end user application that is attracting real interest is associated with rapid EV charging. The automotive industry is developing so called Level 3 chargers which can charge a vehicle in less than an hour. These impose significant demands on the local distribution system (7 kW or more) which would normally necessitate upgrading the customer service to commercial levels at major expense. A battery that charges slowly within system capabilities and then supports the rapid charging is a technically attractive alternative, and may be economically more attractive than upgrading the distribution service or even the feeder circuit if 3 phase service is not in place.

## 2.4 Portable Power

In the introduction the concept of portable power was first described. Storage technologies, especially batteries, offer the ability to bring electricity to where it is needed without the need for the T&D infrastructure. For instance, ISO containers of battery systems could be used to restore electric service to customers where storms have damaged the distribution infrastructure beyond a day's repair time. One can imagine "fleets" of such systems available regionally and pre-positioned where severe storms are forecast to assist in restoration efforts and improve customer reliability. Such systems could also avoid the need for diesel generation for portable power systems for large open air events or other temporary demand.

As a variation on such a scheme, larger truck sized EV, rail, or shipboard V2G applications could similarly provide electric energy to locations where weather or other factors create a temporary need.

## 2.5 Conclusions

There is an emerging consensus on a definition of storage applications with EPRI / DOE, ESA, and state initiatives all contributing. While the different sources may differ slightly and not all have all the same line items, the similarities far outweigh the differences and the industry can expect to converge to consensus definitions before long. DOE can help this process by seeking to "map" the other definitions to the EPRI / DOE work.

Some applications appear to have found a toe hold for technical and commercial viability, meaning that independent for profit entities are investing in and deploying storage in these applications without the benefit of federal or state funding or incentives. These include:

- Storage for ancillary services, especially regulation services, in deregulated and organized wholesale markets in North America.
- Storage for wind farm firming on island systems.
- Storage for wind farm firming where transmission congestion causes frequent curtailment of wind production.
- End user deployment of storage for reliability as a substitute for back up fossil fired generation and/or local photovoltaic energy capture, firming, and/or time shifting. (microgrid applications) (usually additional motivations such as zero net energy and/or zero emissions are part of the justification).

Some applications are of significant interest to utilities, but have not become mainstream. Examples include:

- Storage for transmission peak shaving/ capital deferral. (remote substations served by single circuit, example).
- Storage for distribution substation capital deferral.

Some applications, while promising, have yet to be technically proven and do not appear to be financially viable as yet.

End-User Energy Storage:  The applications that are made solely on a private economic (for profit) basis are the ones that have gained the most traction. These applications share a common characteristic that the revenue stream or avoided costs that justify the storage investment are obvious, transparent, and easily assessed. The risk associated with the investment decision – in terms of whether the revenue streams degrade or not, and whether the technology is successful – lie solely with the investor. The organizations making these decisions are typically experienced at assessing and taking risks, (or believe themselves to be) and view risk taking as part of the business model.

Applications that require regulatory approval appear to be slower developing. The reasons for this and the nature of the barriers are discussed in Section 5 of this report.

# 3 Projects

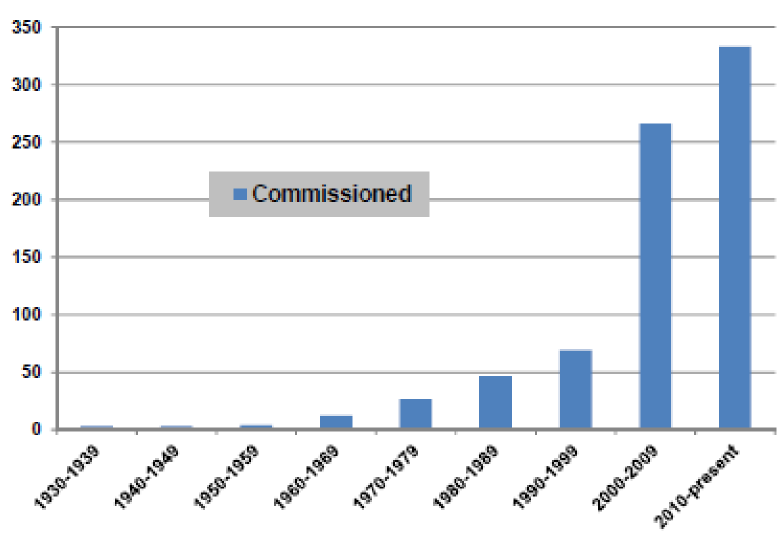
The latest research indicates that there are over 650 energy storage projects for electric grid applications worldwide. These energy storage projects employ a wide range of energy storage technologies, such as pumped hydroelectric power, compressed air energy storage (CAES), batteries, flywheels, and thermal systems (molten salt or ice storage[14]). These projects are described in this chapter, with a focus on the United States. The chapter is organized as follows:

- Worldwide Energy Storage Projects
- U.S. Energy Storage Projects
- Project Examples
- Research and Development (R&D) Activity
- Market Perspective
- Conclusions

## 3.1 Worldwide Energy Storage Projects

Energy storage projects have been growing over time as indicated in **Figure 4**. These growth trends could accelerate sharply in the coming decade driven by goals for increased generation from intermittent renewable resources and smart grid development.

**Figure 4: Worldwide Energy Storage Projects by Decade**




*Source: Pike Research[15]*

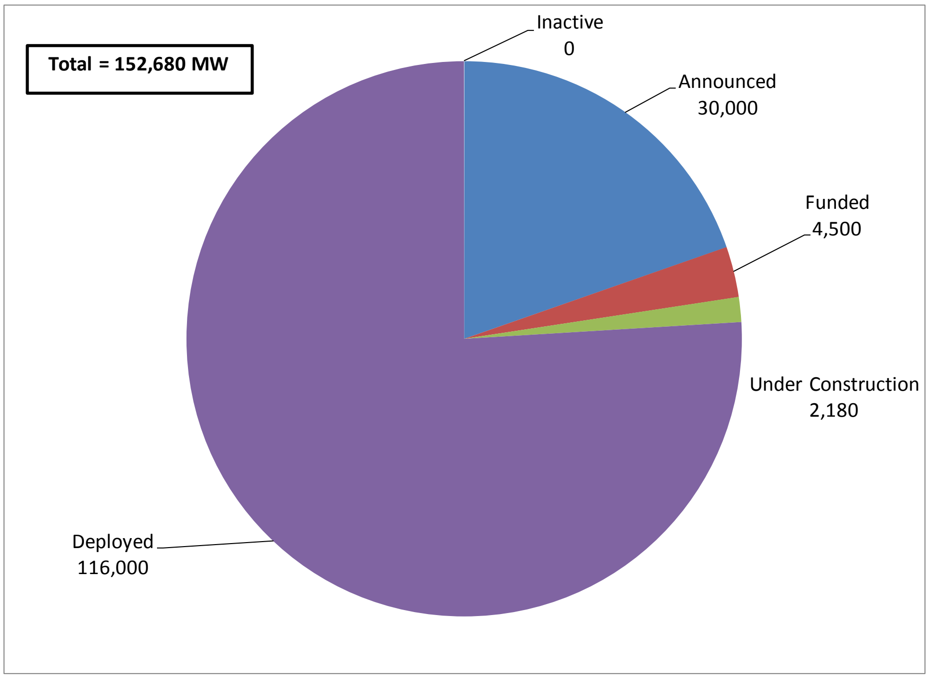
[14] See, for example, Energy Storage Toolkit, by Daiwa. http://asiaresearch.daiwacm.com/eg/cgi-bin/files/EnergyStorageToolkit1202.pdf.

[15] Pike Research, Energy Storage Tracker, 2Q 2012, http://www.pikeresearch.com/research/energy-storage-tracker-2q12.

Worldwide, there are an estimated 665 energy storage projects currently in various stages of development.[16] Asia Pacific is the world leader with 278 deployed projects (42% of all 665 projects), followed by North America with 147 deployed projects (22%) and Western Europe with almost 60 deployed projects (9%). All other regions of the world combined account for about 30 deployed projects (5%).

As indicated in **Figure 5** worldwide energy storage projects total over 150 GW of capacity, with approximately 116 GW, or 76%, deployed).

**Figure 5: Energy Storage Capacity (MW), Worldwide[17]**



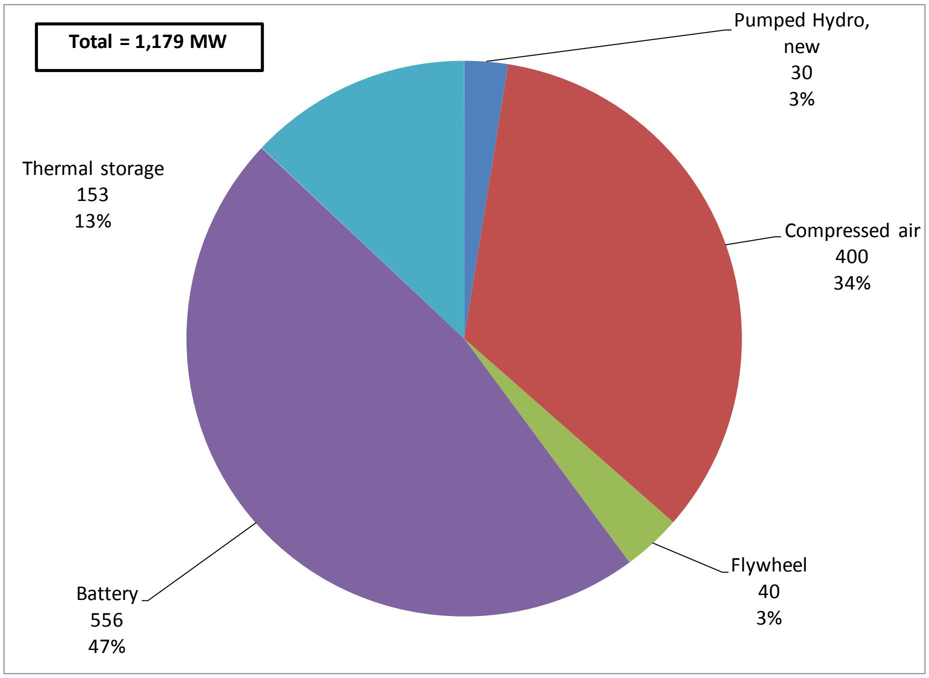

Pumped hydro, which was used as early as 1882 in Switzerland[18], is the dominant energy storage technology, and accounts for 99% of the worldwide capacity at 151.5 GW. Other energy storage technologies include compressed air energy storage (CAES), batteries, flywheels, and thermal systems (which includes molten salt and ice storage).[19]

While pumped hydro dominates the market today, growth for traditional pumped hydro is expected to be slow due to the limited availability of remaining reservoirs that are economically feasible and can meet environmental concerns. Moving forward, much of the growth in grid-scale electricity storage is expected to include other technologies, including CAES, batteries,

[16] Pike Research, Energy Storage Tracker, 2Q 2012, http://www.pikeresearch.com/research/energy-storage-tracker-2q12.
[17] Values in **Figure 5:** are estimates prepared by report authors based on data in Pike report.
[18] National Hydropower Association, Challenges and Opportunities for New Pumped Storage, Development, 2012, p24, http://hydro.org/wp-content/uploads/2012/07/NHA_PumpedStorage_071212b1.pdf .
[19] Pike Research, Energy Storage Tracker, 2Q 2012, http://www.pikeresearch.com/research/energy-storage-tracker-2q12.

flywheels, and thermal systems (data on thermal systems is also available from Pike Research). A breakdown of energy storage projects, excluding traditional pumped hydro, is shown in **Figure 6**[20]. As this figure indicates, over 80% of the energy storage capacity is captured by batteries (47%) and CAES (34%).

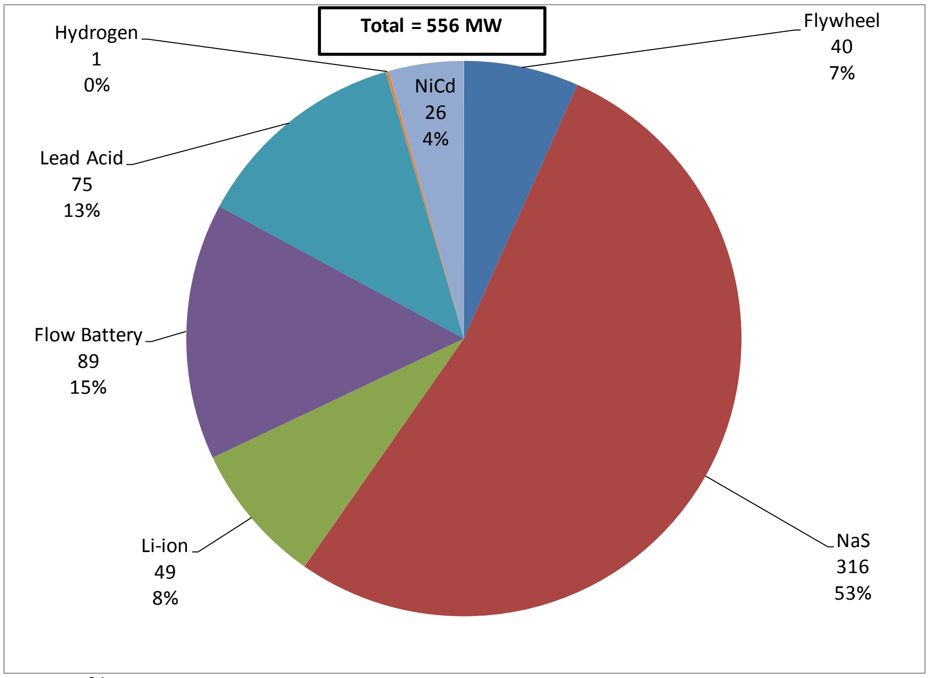
**Figure 6[21]: Energy Storage Capacity (MW), Excluding Traditional Pumped Hydro, Worldwide[22]**




Historically, CAES has represented the largest share of the energy storage market, excluding pumped hydro. As indicated in **Figure 6**, however, batteries have now surpassed CAES, driven primarily by the growth of Sodium-Sulfur (NaS) battery projects. In the battery segment, NaS batteries account for over 50% (316 MW) of the capacity (see **Figure 7** shows battery development by technology). While NaS battery projects have been numerous in recent years, new NaS battery projects have been halted due to a high profile fires that occurred at a site in Japan utilizing NaS batteries after the recent earthquake. The Japanese company, NGK, which supplies NaS technology, suspended distribution of NaS batteries~~,~~ pending investigation. The Company has launched a recall program to retro-fit all systems in the field.

[20] Pike Research, Energy Storage Tracker :http://www.pikeresearch.com/research/thermal-energy-storage
[21] http://www.pikeresearch.com/research/thermal-energy-storage
[22] Includes announced, funded, under construction, and deployed projects. In an August 2012 survey, Strategen Consulting LLC found installed (deployed) worldwide energy storage capacities of 440 MW for compressed air, 42 MW for flywheels, 594 MW for batteries, 1,000 MW for cooling thermal storage, and 601 MW for solar thermal storage.

**Figure 7: Battery Capacity (MW), Worldwide**[23]



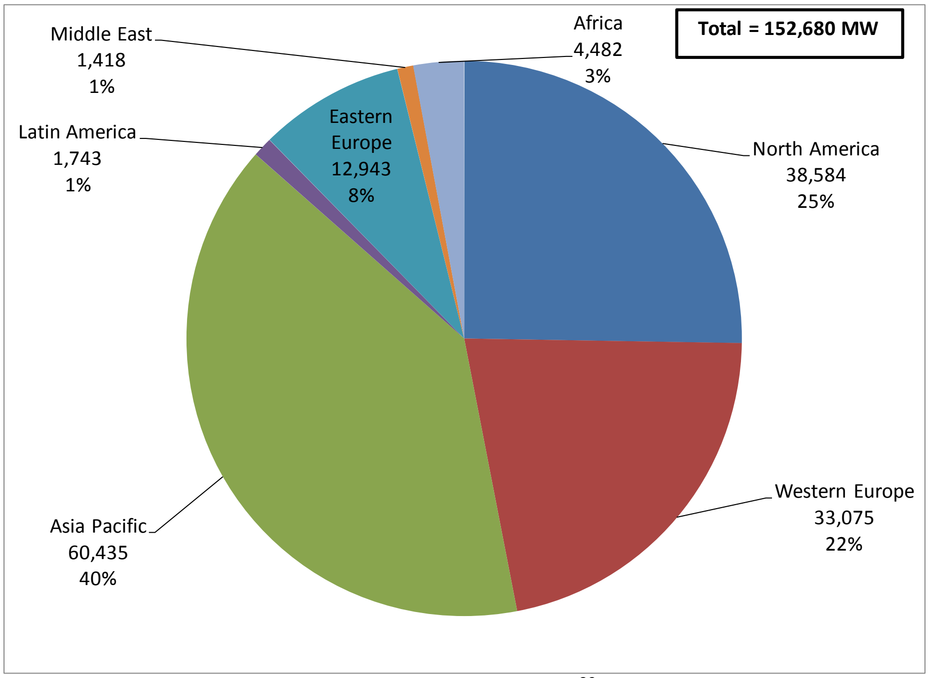

*Source: Pike Research*[24]

**Figure 8** shows a breakout of capacity by geographic region[25]. The Asia Pacific region, which includes China and Japan, accounts for the largest share of installed capacity (40%), followed by North America (25%), and Western Europe (22%). In Europe and Japan, 10% to 15%[26] of delivered power is cycled through an energy storage facility, whereas in the United States the 2009 percentage is 2.3%[27]. These data include thermal storage as well as announced, funded, and projects under construction. Factors that drive energy storage in other parts of the world compared to North America include the availability of suitable pumped hydro sites, high electricity prices, and large differences between peak and off-peak prices.

---

[23] Includes announced, funded, under construction, and deployed projects.
[24] Pike Research, Energy Storage Tracker, 2Q 2012, http://www.pikeresearch.com/research/energy-storage-tracker-2q12.
[25] Includes announced, funded, under construction, and deployed projects.
[26] EPRI-DOE Handbook of Energy Storage for Transmission and Distribution Applications, 2003, http://www.sandia.gov/ess/publications/ESHB%201001834%20reduced%20size.pdf .
[27] Energy storage capacity from ESA data cited in EAC report, *Energy Storage Activities in the United States Electricity Grid*, May 2011 (www.doe.gov/sites/prod/files/oeprod/DocumentsandMedia/FINAL_DOE_Report-Storage_Activities_5-1-11.pdf), and net summer generating capacity from *Electric Power Annual 2010*, U.S. Energy Information Agency, November 2011 (http://www.eia.gov/electricity/annual/pdf/epa.pdf).

**Figure 8: Energy Storage Capacity (MW), by Region, Worldwide[28]**




*Source: Pike Research[29]*

And similar to worldwide trends, the installed base in the U.S. is dominated by pumped hydro. It accounts for 95% (22,000 MW) of the total deployed energy storage capacity (23,251 MW) in the U.S. [30] EIA puts the U.S. pumped hydro capacity in 2009 at 22,160 MW, which is over 99% of the 22,337 MW of pumped hydro capacity in North America[31].

In the U.S., thermal storage consists primarily of ice storage or chilled water storage, which is used for peak shaving with air conditioning systems. (Here we do not consider large thermal mass storage as part of building design which is not associated directly with energy conversion but is an energy efficiency measure. Concrete, brick, and other high thermal density materials are generally employed.) Such systems are able to "pre-cool" off peak at night, and then the AC systems cool the refrigerant directly from the thermal storage instead of to the atmosphere, greatly reducing electric peak load. The concept seems simple, but the firms that offer these systems have made major investments in the technology to allow high round trip efficiencies to be obtained.

---

[28] Includes announced, funded, under construction, and deployed projects.
[29] Pike Research, Energy Storage Tracker, 2Q 2012, http://www.pikeresearch.com/research/energy-storage-tracker-2q12.
[30] ESA data cited in EAC report, *Energy Storage Activities in the United States Electricity Grid*, May 2011, www.doe.gov/sites/prod/files/oeprod/DocumentsandMedia/FINAL_DOE_Report-Storage_Activities_5-1-11.pdf.
[31] U.S. EIA International Energy Statistics. Accessed August 15, 2012 at http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=2&pid=82&aid=7&cid=regions&syid=2004&eyid=2010&unit=MK.

Domestic hot water heaters offer a similar potential at a residential scale. These devices are already used as very flexible and fast responding demand response assets[32] and can be used for time shifting energy consumption if the stored temperature is elevated and mixing with cold water employed before the water is delivered to faucets, showers, etc. One aspect of this concept is that larger hot water storage volumes conflict with energy efficiency standards which limit storage size as an efficiency measure.

As noted in the executive summary, thermal storage effects as managed demand optimization that "time shift" energy consumption, and other similar technologies that allow managed time shifting of energy consumption, can have similar benefits to electric / energy storage. The amount (MW, MWH) of these technologies that is potentially available may be quite large and may represent cost effective alternatives to electricity storage for some of the applications discussed in this report.

A small but growing fraction of thermal storage is molten salt solar thermal energy storage technology, which is used in concentrating solar thermal (CST) power generation plants. While there are many design concepts for CST, the most prevalent designs are the "power tower" design which uses a field of mirrors to concentrate sunlight on a thermal receiver on a tower, and the elliptical trough designs which use parabolic mirrors in a trough configuration to heat a working fluid in a central pipe. The heat captured in the working fluid can then be stored in tanks either via heat transfer to molten salt or directly when molten salt is the working fluid itself. All these systems then use the heat in the working fluid/storage to generate steam which is used in conventional steam turbine-generator equipment. It is noteworthy that in August 2012 the CPUC disapproved CST Purchase Power Agreements for Southern California Edison (purchased from the CST developer BrightSource[33]) that did not include thermal storage, but allowed other PPAs to go forward for consideration based upon the CST facilities incorporating thermal storage. While quantitative benefits to the storage were not evaluated per se, the CPUC believed that the ability of these plants to "firm" solar energy and even provide flexibility to the grid outweighed the additional costs. In general, the cost of the thermal storage systems is not a large factor in the CST plants, but the costs of the mirror arrays and the receiver plus the steam systems make CST more expensive than photovoltaic systems if the value of firming and flexibility is not considered. CST plants can be configured with 6, 8, or more hours of storage.

## 3.2 Project Examples

There has been significant energy storage activity in the United States in recent years, driven largely by American Recovery and Reinvestment (ARRA) funding administered by the U.S. DOE. A discussion of representative ARRA projects is provided in subsequent sections of this chapter. In this section, the energy storage projects listed in **Table 3** are summarized; these represent a cross-section of the technologies, capacities, and applications that are being addressed by innovative energy storage projects now underway. The status of these projects

[32] Grid Interactive Renewable Water Heating http//www.sterffes.com
[33] Public Utilities Commission Of The State Of California, Item# I.D. # 11487 Energy Division Resolution E-4522 August 23, 2012

range from deployed energy storage facilities to a new manufacturing facility to support future energy storage projects around the world.

**Table 3: Project Examples**

| Title | Status | Technology | Location | Capacity (MW) |
|---|---|---|---|---|
| Beacon Power's 20 MW Flywheel Frequency Regulation Plant | Deployed | Flywheel | New York | 20 |
| Increased Turbine Efficiency with Ice Storage | Deployed | Thermal storage | Arizona | 12 (as 3,500 tons of cooling capacity) |
| Compressed Air Energy Storage Facility | Under construction | CAES | California | 300 |
| Eagle Mountain Hydro-Electric Pumped Storage Project | Announced | Pumped hydro | California | 1,300 initially (could exceed 4,000) |
| AES 400 MW Energy Storage Plant | Proposed | Battery | New York | 400 |

### *Beacon Power's 20 MW Flywheel Frequency Regulation Plant*

**Figure 9: 20 MW Beacon Flywheel Energy Storage Plant for Frequency Regulation**

*Source: U.S. DOE*[34]

Beacon Power has commissioned and now operates a utility-scale 20 MW flywheel energy storage frequency regulation plant in Stephentown, New York, and plans to build another one in Hazle Township, Pennsylvania[35]. These flywheel facilities provide frequency regulation services for the New York Independent System Operator (NYISO). These flywheel projects will demonstrate the technical, cost, and environmental attributes of fast-response flywheel-based frequency regulation management at the 20 MW scale. Each 20 MW facility is comprised of 200 high-speed 100 kW (25 kWh) flywheels. The Stephentown facility was highlighted by the White House as one of the "100 Recovery Act Projects that are Changing America".

[34] *Progress in Grid Energy Storage*. Accessed August 8, 2012 at http://www.doe.gov/sites/prod/files/Presentation%20to%20the%20EAC%20-%20Progress%20in%20Grid%20Energy%20Storage%20-%20Imre%20Gyuk.pdf.

[35] *Status of Flywheel Storage Operation of First Frequency Regulation Plants*, Matthew Lazarewicz, Beacon Power Corporation, 2011. Accessed August 9, 2012 at http://www.beaconpower.com/files/EESAT_2011_Final.pdf.

### *Increased Turbine Efficiency with Ice Storage*

**Figure 10: CALMAC Ice Storage tanks at the University of Arizona**

*Source: University of Arizona*[36]

The University of Arizona has added ice thermal storage to its heating, ventilation, and air conditioning (HVAC) plant serving the campus in Tucson, Arizona[37]. The ice storage can provide up to 3,500 tons (12 MW of cooling) of additional cooling capacity during peak cooling hours, thereby reducing electric demand by 2.7 MW. The ice is made with the electric chillers during off-peak, nighttime hours (using only 0.783 kW of electricity per ton). Ice storage then uses the stored “thermal” energy of the ice (up to 23,400 ton hours of cooling capacity) to cool the buildings during the daytime peak-usage periods. This effectively shifts the electrical load to off-peak, thus avoiding higher-priced energy and demand charges that are imposed by many utilities. When combined with the other equipment at their HVAC plant (gas-fired turbines (by Solar Turbines), boilers (by Rentech), electric chillers (by Trane), pumps, and water cooling towers), ice storage increases the cooling capacity and the operating efficiency, and reduces operating costs and the environmental impact. Ice storage also serves the useful purpose of providing a nighttime load for the cogeneration plant.

[36] *Fire and Ice*, Al Tarcola, University of Arizona. Accessed August 8, 2012 at http://www.calmac.com/downloads/documents/UniversityofArizona_DistributedEnergyMagazine.pdf.
[37] *Fire and Ice*, Al Tarcola, University of Arizona. Accessed August 8, 2012 at http://www.calmac.com/downloads/documents/UniversityofArizona_DistributedEnergyMagazine.pdf.

### *Compressed Air Energy Storage Facility*

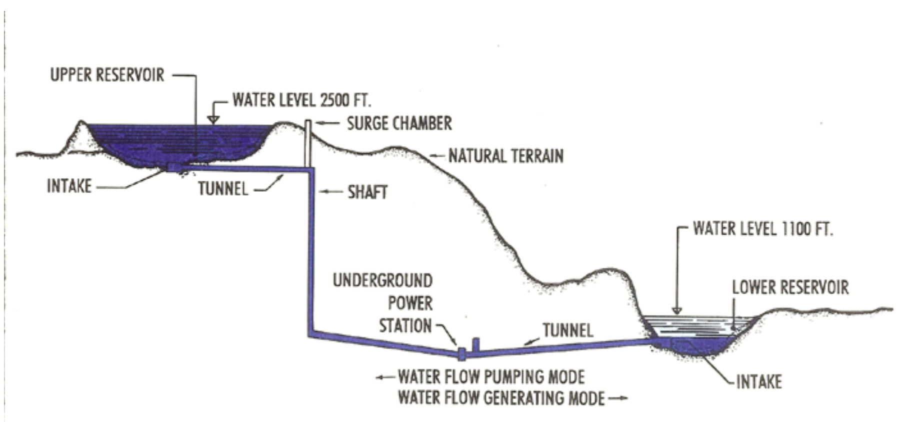
**Figure 11: A Tehachapi Wind Field**

*Source: U.S. DOE*[38]

Pacific Gas and Electric (PG&E), with ARRA support, is constructing a Compressed Air Energy Storage (CAES) plant in Kern County near Tehachapi, California, which could provide 300 MW of electric power for up to 10 hours. The Tehachapi area has one of California's largest wind resources. This demonstration project will validate the design, performance, and reliability of an advanced, underground CAES plant using a saline porous rock formation as the storage reservoir.

### *Eagle Mountain Hydro-Electric Pumped Storage Project*

**Figure 12: Eagle Mountain Pumped Hydro Project Schematic**




*Source: Electric Power Group*[39]

---

[38] *Progress in Grid Energy Storage*. Accessed August 8, 2012 at http://www.doe.gov/sites/prod/files/Presentation%20to%20the%20EAC%20-%20Progress%20in%20Grid%20Energy%20Storage%20-%20Imre%20Gyuk.pdf.

The Eagle Crest Energy Company plans to construct a pumped hydro energy storage facility near Palm Springs, California with an initial project capacity of 1,300 MW and a potential expansion to over 4,000 MW total, which would make it the largest in U.S.[40] This firm, stable, and dispatchable electric power will have a cycle efficiency of 80%. The Eagle Mountain project is located 65 miles east of Palm Springs, California, in a very arid area; and the closed loop water system will not involve any streams. The initial water fill and replenishment will come from non-potable ground water sources. The electric power will be drawn from nearby solar and wind power installations as well as baseload nuclear and fossil fuel power plants. It will be delivered to the electric grid at a 500-kV substation via two new 46-mile transmission lines or to a new closer collector substation under consideration by Southern California Edison on a major transmission line less than 10 miles away.

#### *AES 400 MW Energy Storage Plant*

The Long Island Power Authority (LIPA) is reviewing proposals from 16 companies to provide electric capacity, energy, and ancillary services to LIPA for up to 2,500 MW of new and/or repowered generation[41]. LIPA plans to announce project awards in the fall of 2012, with the first projected commercial operation date being in May 2016. AES Corporation (Arlington, Virginia) has announced that it has submitted a proposal to construct a grid-scale energy storage facility using batteries to produce up to 400 MW of electric power that would be connected to the LIPA electric grid[42]. AES anticipates that the batteries would return to the grid about 90% of the energy that is stored. The batteries would be charged at night using power generated at the more efficient power plants and would be drained during the peak hours to reduce the amount of electric power generated by the most inefficient power plants, which would bring economic and environmental benefits to Long Island. As this report is written, this is still an open proceeding.

## 3.3 Research & Development (R&D) Activity

Energy storage technologies offer many benefits, and are viewed as key enabling technologies that support national objectives, including increased adoption of renewable energy resources and improved grid operation from smart grid concepts. While the benefits are compelling, the penetration of energy storage technologies remains low. In the United States, only 2.3% of the electric generating capacity is delivered through energy storage facilities.[43] Pumped hydro

---

[39] *Eagle Mountain Hydro-Electric Pumped Storage Project*, Gil Tam, Electric Power Group, http://www.nwcouncil.org/energy/wind/meetings/2008/10/giltam.pdf.

[40] Bath County Pumped Storage Station Case Study. Accessed August 16, 2012 at http://www.cleanenergyactionproject.com/CleanEnergyActionProject/CS.Bath_County_Pumped_Storage_Station___Pumped_Storage_Hydropower_Case_Studies.html.

[41] *Request for Proposals to Provide Electric Capacity, Energy & Ancillary Services to the Long Island Power Authority*, Issued August 20, 2010. Accessed August 16, 2012 at http://www.lipower.org/company/proposals/electric.html.

[42] *LIPA Eyes World's Biggest Battery*. Accessed August 8, 2012 at http://www.aesenergystorage.com/news/libn-lipa-eyes-worlds-biggest-battery.html.

[43] Energy storage capacity from ESA data cited in EAC report, *Energy Storage Activities in the United States Electricity Grid*, May 2011 (www.doe.gov/sites/prod/files/oeprod/DocumentsandMedia/FINAL_DOE_Report-Storage_Activities_5-1-11.pdf), and net summer generating capacity is from *Electric Power Annual 2010*, U.S. Energy Information Agency, November 2011 (http://www.eia.gov/electricity/annual/pdf/epa.pdf).

represents over 95% of all storage capacity, and if pumped hydro is excluded, the capacity of storage technologies drops to only about 0.1% of the total electric power delivered in the United States[44].

The primary goals of R&D in storage technologies are to improve the functional performance of storage for the various applications, and to reduce the costs of storage – capital, installation, and operating costs. In some instances, R&D is "incremental" and is aimed at improving the characteristics of existing technologies. In others, R&D is innovative and is aimed at developing new technologies or variations that promise significant improvements over existing technologies. The energy storage field offers examples of both. Typically private industry conducts the bulk of incremental R&D. DOE as well as private industry – both large established firms as well as start-ups conduct innovative research. As the energy storage market currently exists, the most attractive approach for R&D is to engage both the government and the private sector in public-private partnerships.

In this section, R&D activities in the United States are discussed for a few key organizations, including:

- U.S. Department of Energy (DOE)
- Electric Power Research Institute (EPRI)
- State agencies

### 3.3.1 DOE

After years of limited federal funding, DOE's Energy Storage Program experienced a significant boost when American Recovery and Reinvestment Act (ARRA) funding provided $185 million to support energy storage projects. DOE used the ARRA funding to support several energy storage projects, and these projects are helping to accelerate technology advancements and demonstrate market benefits. In addition to high visibility ARRA demonstration projects, DOE continues to develop a wide range of tools and resources to assist energy storage stakeholders. Below we summarize key elements of DOE's support for large scale energy storage (divided into ARRA Projects and Other DOE Activities).

The goals for DOE in the storage sector that were identified in the 2008 EAC report were as follows, including an overall assessment of progress against these goals as of late 2012.

#### Near-Term Goals (3–5 years)

- Launch and accomplish the "materials genome project" for analysis of alternative materials for use in energy storage devices. This activity is being addressed by Arpa-e in a number of programs that are investigating new materials and structures which are currently not being addressed by the DOE OE roadmap. Examples include: the GRIDS program and the SBIR/STTR program. Complete detailed studies of the effects of higher penetration of renewable sources on grid operations and the permanent retirement of a

[44] If thermal energy storage (which does not produce electric power) is also excluded, only 0.02% of the total U.S. net summer electric generating capacity is produced by energy storage facilities.

large percentage of traditional generation. This is an ongoing area of work. The problem is too complex for any one study methodology to identify much less answer all issues. There is an ongoing need for more dynamic analysis, more models of investor and generation owner behavior, and more research on how best to use storage in a portfolio of integration technologies and methods.

- Complete at least three large-scale demonstration projects that examine the performance of Smart Grid technologies interacting with energy storage technologies on the grid. This goal is in process and is more than met today – multiple large scale storage demonstrations are under way, if not "complete" today.
- Establish the four Energy Storage Research Centers specified in the Energy Independence and Security Act of 2007. This goal is still open as of this writing. There is an open RFP process for a Storage "Hub" as of this writing.
- Provide funding for up to 30% of the cost of energy storage technology investments required to demonstrate the performance of the objectives cited above. This goal is more than satisfied – refer to Section 3 and Appendices. While the details of the financials of these projects are not contained in this report, most have at least 30% cost coverage from DOE under ARRA.

### Mid-Term Goals (6–12 years)

- Continue to fund (up to 30%) energy storage projects that expand the use of storage for grid performance enhancement and show benefits to increasing the use of renewable energy resources.
- Measure and report the impact of PHEVs and EVs on performance of the grid in terms of peak loading and any change in the need for ancillary services.
- Fund next-step R&D activities based on the results from the "materials genome projects" cited above.
- Fund larger-scale demonstrations of energy storage technologies for transportation to include large truck and rail applications.

### Long-Term Goals (2020 and beyond)

- Implement programs to test and analyze vehicle-to-grid (V2G) performance and the impact on grid operations.

### *ARRA Projects*

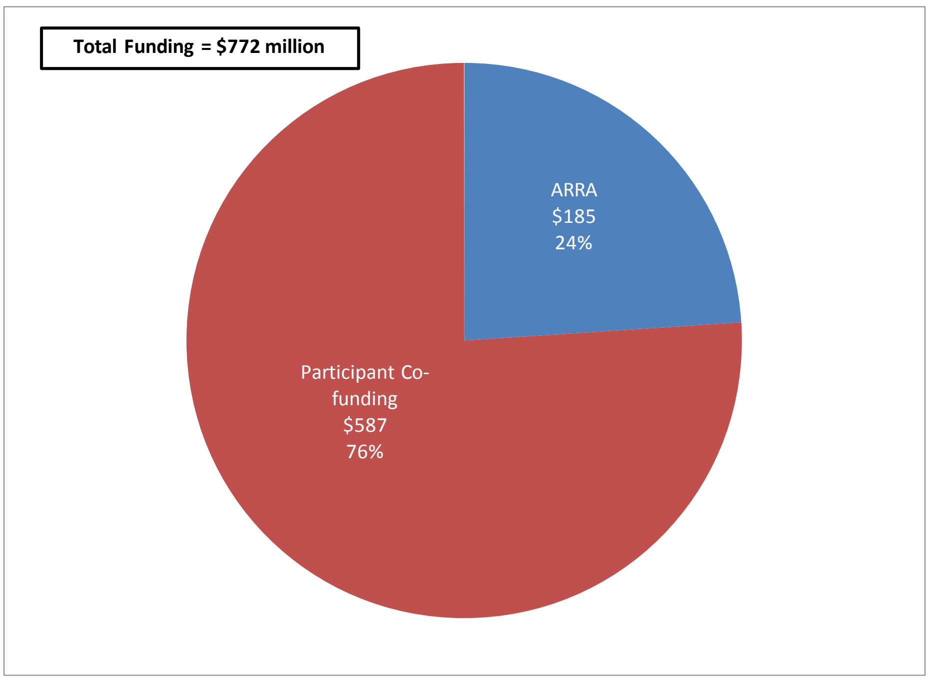
ARRA stimulus funding has supported 16 large-scale energy storage projects with a combined capacity of over 530 MW (see **Table 4**). As indicated in **Figure 13,** ARRA funding for all 16 projects totaled $185 million, and this funding was leveraged at over 3 to 1 with $585 million of cost sharing (total project value of $772 million). ARRA funding is an example of the important role that DOE plays as a catalyst for funding large-scale storage development, while also showing strong support from manufacturers and utilities.

**Table 4: ARRA Funded Energy Storage Projects**

| Project Type | Number of Projects | Capacity (MW) | Comments |
|---|---|---|---|
| Battery Storage for Utility Load Shifting or Wind Farm Integration | 3 | 57 | 3 battery projects ranging from 8 to 25 MW |
| Frequency Regulation Ancillary Services | 1 | 20 | 1 flywheel project |
| Distributed Storage for Grid Support | 5 | 8 | 4 battery systems and 1 ultracapacitor |
| Compressed Air Energy Storage | 2 | 450 | 300 and 150 MW projects |
| Demonstration of Promising Energy Storage Technologies | 5 | 1 | 3 battery systems, 1 flywheel, and 1 CAES |
| **Total** | **16** | **536** | **---** |

*Source: Sandia*[45]

**Figure 13: ARRA Funded Energy Storage Projects**




*Source: Sandia*[46]

[45] Sandia National Laboratory, http://www.sandia.gov/ess/docs/ARRA_StorDemos_4-22-11.pdf.
[46] Sandia National Laboratory, http://www.sandia.gov/ess/docs/ARRA_StorDemos_4-22-11.pdf.

### *Other DOE Activities*

In addition to high visibility ARRA projects, DOE is supporting energy storage with several other projects[47], including:

- **Energy Storage Project Database[48]**. The DOE Energy Storage Database is a publicly available database of worldwide projects, as well as state and federal legislation and policies. A beta version of the database was released in May 2012, and currently contains information on about 4% of the worldwide energy storage capacity (5.3 GW in database). More information on the database is provided in **Appendix A**.

- **DOE / EPRI Energy Storage Handbook[49]**. In partnership with EPRI and NRECA, DOE is developing an energy storage handbook scheduled to be released in the fourth quarter of 2012. This handbook will include details on commercially available energy storage technologies; information on applications, sizing, siting, and interconnecting; and a cost database. A previous energy storage handbook was released in 2003 (http://www.sandia.gov/ess/publications/ESHB%201001834%20reduced%20size.pdf ).

- **Energy Storage Selection Tool[50].** This tool is designed for high level decision makers to facilitate the planning process. The tool provides technical and economic information on technologies, sizing information, and information for business case development.

- **Storage Guidebook for Regulatory Officials** This guidebook, which is being developed with input from industry and government experts, is intended to help inform regulators on the benefits of storage. The guidebook provides technical information, regulatory challenges, and suggested approaches for addressing challenges.

- **Performance Protocol for Energy Storage Technologies**. DOE is leading an effort to develop an initial storage performance protocol (pre-standard). Goals for the protocol include: 1) form a representative stakeholder group, 2) clarify the anticipated applications and use of the protocol by industry, 3) develop a protocol with a reasonable consensus, 4) provide ongoing support as the technology evolves. Additional information on the protocol is discussed in the Standards section of Chapter 4.

## 3.3.2 EPRI Energy Storage Research & Development Activities

### EPRI Focus

EPRI's electric energy storage research and development activities are complimentary to DOE's. In fact, many projects are conducted collaboratively. Like DOE, EPRI believes that while

---

[47] *Progress in Grid Energy Storage*, Imre Gyuk, U.S. DOE. http://www.doe.gov/sites/prod/files/Presentation%20to%20the%20EAC%20-%20Progress%20in%20Grid%20Energy%20Storage%20-%20Imre%20Gyuk.pdf.
[48] Energy Storage Project Database. http://www.energystorageexchange.org/.
[49] DOE / EPRI Energy Storage Handbook. http://www.sandia.gov/ess/publications/ESHB%201001834%20reduced%20size.pdf.
[50] Energy Storage Selection Tool. http://www.sandia.gov/ess/esselect.html.

new storage technologies are rapidly maturing and are beginning to become practical in grid applications, there are still significant challenges to overcome:

- Understanding the performance characteristics, cost and expected service lifetime of various storage technologies.
- Defining the requirements specification for the various applications to facilitate the transformation of custom storage implementations to applications of predefined storage products.
- Understanding the possible impact on transmission and distribution system planning as well as construction and operations.
- Assessing the various uses of storage, including the performance requirements, cost breakeven points and valuation.
- Understanding the policy impacts, including market policy and/or regulation decision, on the adoption and cost-effectiveness of storage applications.
- Understanding the environmental impact of storage applications.
- Assessing the maturity of various storage technologies for grid applications.

Research projects that address these challenges can help to move this technology forward.

Current Year's Objectives

In the coming year, EPRI's research program has these objectives:

- To develop an updated Energy Storage Cost Database
- To complete EPRI's Energy Storage Benefit and Cost Analysis Tool
- To continue a series of Energy Storage System Tests and Evaluations

EPRI's current key research efforts include seven projects:

1. Strategic Intelligence and Technology Assessments of Energy Storage and Distributed Generation
2. Distributed Energy Storage Options for Power Delivery and End Use
3. Bulk Power Energy Storage Solutions
4. Substation-Sized Lithium Ion Energy Storage System Demonstration: Phase I
5. Substation-Sized Lithium ion Energy Storage System Demonstration: Phase II
6. Advanced Compressed Air Energy Storage

2013 and Beyond

Over the next three to five years, EPRI plans to continue facilitation of development of standard energy storage products supported by testing and demonstration of storage products in the laboratory and in the field. This will continue to be coupled with an understanding of grid integration of storage products (distribution effects and bulk system analysis).

Facilitating storage productization entails three elements:

1. Characterizing storage technologies by defining duty cycle and expectations for life and efficiency and characterizing performance in different regimes.
2. Improving power conditioning systems by defining critical functions and performance levels using test capabilities to understand optimal performance.
3. Facilitating product integration by developing guidelines for integration of components to ensure proper performance and sustain the ability to test and evaluate the product as a whole.

These activities are intended to guide the development of grid-ready products that meet the actual needs of the utility industry.

### 3.3.3 State Agencies

Two state agencies that have well developed energy storage R&D programs are the California Energy Commission (CEC) and the New York Research and Development Authority (NYSERDA).

#### *CEC*

A significant portion of CEC's energy storage program is currently aligned with projects that have received DOE ARRA awards. In fact, eight ARRA energy storage projects involve CEC Public Interest Energy Research (PIER) co-funding, as listed in **Table 5**. These eight projects represent $614 million, or 80%, of the total project funding allocated for ARRA energy storage projects ($772 million total). The CEC funding for these projects, as indicated in **Figure 14**, is highly leveraged against ARRA funding and participant co-funding. The CEC funding amount is $5.7 million compared to a total project cost of $614 million.

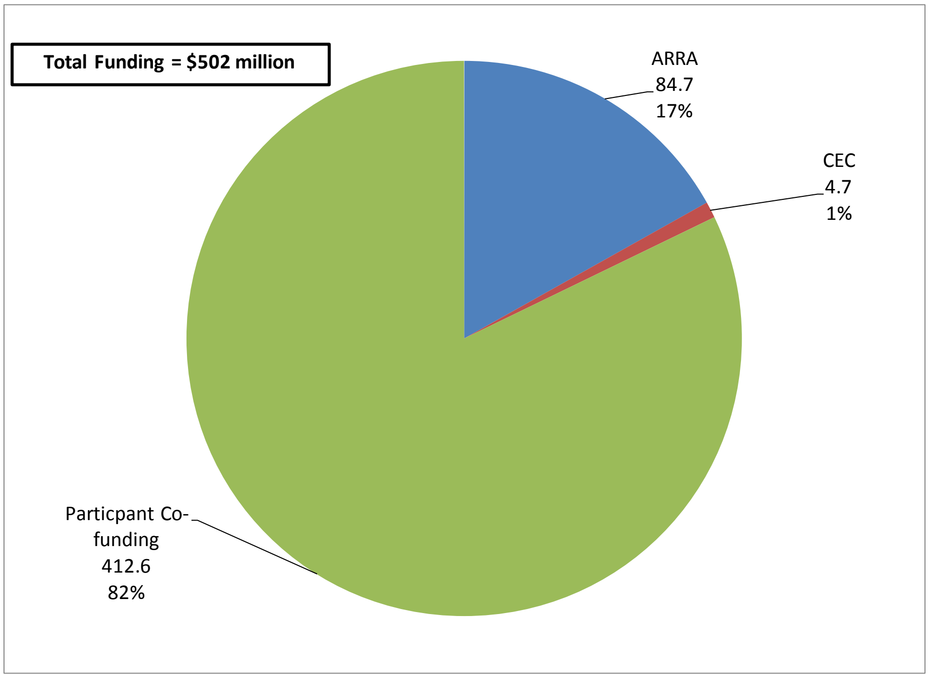
**Table 5: ARRA Funded Energy Storage Projects with CEC PIER Funding, 2010-2011**

| **Awardee** | **Project Title** | **Technology** | **Funding ($ Million)** | | |
|---|---|---|---|---|---|
| | | | PIER | DOE + Match | Total |
| Southern California Edison | Tehachapi Wind Energy Storage Project | Li-ion battery | 1.0 | 52.5 | 53.5 |
| Primus Power Corporation | Wind Firming Energy Farm | Zinc flow battery | 1.0 | 45.7 | 46.7 |
| Seeo Inc. | Solid State Batteries for Grid-Scale Energy Storage | Li-ion battery with nano-structured polymer electrolytes. | 0.6 | 11.8 | 12.4 |
| Sacramento Municipal Utility District | Premium Power Distributed Energy Storage Systems Demonstration | Zinc Bromine flow battery | 0.2 | 5.2 | 5.4 |
| Amber Kinetics, Inc | Utility-Scale Flywheel Energy Storage Demonstration | Advanced technology utility-scale flywheel energy storage | 0.4 | 9.6 | 10.0 |
| EnerVault Corporation | Flow Battery Solution to Smart Grid Renewable Energy Applications | Novel iron-chromium redox flow battery (BESS) | 0.5 | 9.0 | 9.5 |
| Los Angeles Department of Water and Power | Smart Grid Demonstration Project | Involves battery energy storage systems for electric vehicles | 1.0 | 119.6 | 120.6 |
| Pacific Gas and Electric Company | Advanced Underground Compressed Air Energy Storage Demonstration Project | "Second generation" compressed air energy storage (CAES) | 1.0 | 354.9 | 355.9 |
| Totals | | | **5.7** | **608.3** | **614.0** |

*Source: California Energy Commission*[51]

[51] 2020 Strategic Analysis of Energy Storage in California, by J. Intrator, et al., for California Energy Commission, Publication Number: CEC-500-2011-047. http://www.law.berkeley.edu/files/bccj/CEC-500-2011-047.pdf.

**Figure 14: CEC Participation in ARRA Projects**




In addition to the seven ARRA projects, CEC has funded seven other energy storage projects recently, and these projects are listed in **Table 6**. With the ARRA projects ($4.7 million) and the additional projects ($9.0 million), CEC has invested nearly $13.7 million in energy storage projects.

**Table 6: CEC Energy Storage Projects, 2010-2011 (not including ARRA funding)**

| Awardee | Project Title | Technology | Funding ($ Million) | | |
|---|---|---|---|---|---|
| | | | PIER | Match | Total |
| Transportation Power, Inc. | Grid-Saver Fast Energy Storage Demonstration | Li-ion battery | 2.0 | 0.5 | 2.5 |
| Satcon Technology Corporation | Grid-Interactive PV System with DC-Link Battery Storage Integration | PV plus battery | 2.0 | 1.3 | 3.3 |
| KEMA | Evaluation and Optimization of Concentrated Solar Power Coupled with Thermal Energy Storage | CSP and thermal storage | 0.4 | 0.2 | 0.6 |
| PG&E | CAES Demonstration and Analytical Study | Na-S battery and CAES study | 2.8 | 0.0 | 2.8 |
| Lawrence Livermore National Laboratory | Analysis of ADR and Energy Storage | ADR and energy storage | 1.8 | 0.0 | 1.8 |
| Pacific Northwest National Laboratory | Wide-Area Energy Storage and Management System – Phase 2 - to Balance Intermittent Resources in the California ISO | Flywheels and Hydro | 0.2 | 0.0 | 0.2 |
| California Institute for Energy and Environment | 2020 Strategic Analysis of Energy Storage | All | 0.3 | 0.0 | 0.3 |
| | | | **9.5** | **2.0** | **11.5** |

### *NYSERDA*

From battery storage to CAES, the New York Research and Development Authority (NYSERDA) is supporting a diverse range of energy storage projects. In 2011, New York State Electric & Gas (NYSEG), a subsidiary of Iberdrola USA, received $1 million from NYSERDA to explore applications of CAES. Partly funded by DOE ARRA funding and smart grid grants, the project uses a depleted underground salt cavern near Watkins Glen, New York to store up to 15 MW (2-8 hours or more) of compressed air energy for peak load and other applications. The facility could be operational and grid-connected by late 2014 or early 2015.

With support from NYSERDA, Beacon Power's 20-MW flywheel energy storage plant in Stephentown, NY, exemplifies how storage performance can excel over traditional generation assets, providing rapid-response frequency regulation service to New York's grid. Beacon's plant has increased grid reliability and cut carbon emissions by reducing dependence on fossil fuels.

## 3.4 Market Perspective

Certain applications are gaining traction in the wholesale, transmission, and end use markets depending upon the economics, end user motivations, and particular circumstances.

- Regulation services in wholesale market environments have been attracting interest for several years. Regulation services offered an opportunity for relatively low duration (1 hour or less) storage systems to participate in a potentially lucrative market, especially where high peak energy prices resulted in high ancillaries prices. Early research[52] demonstrated the effectiveness or leveraging multiplier of fast resources (as compared to conventional thermal generation) and FERC recognized this in Order 755 which ordered the market operators to "pay for performance" – meaning to pay regulation resources not only for the regulation capacity but also for the actual amount of regulation up and down provided. The various market operators have developed different adaptations to this order, including computation of the accuracy or precision of the regulating resource response to signals. In some cases the markets continue to have one regulation capacity market; in others separate markets for "fast" and "slow" resources are contemplated. Some of the operators allow the storage resource to specify a state of charge schedule that the regulation signal must conform to on an hourly basis; others make it the responsibility of the operator, and some devise a fast regulation signal that guarantees zero net energy over a determined period of time[53][54]. Over time the market operators and the storage industry will be able to identify the actual benefits and costs of these different approaches. FERC has an open Notice of Proposed Rule Making (NOPR)[56] which would require non-market control areas to open themselves to third parties providing ancillary services. This, if it results in a final Order, would in time expand the market for regulation services. Today regulation capacity is procured at about 1% of peak load by the market operators. High renewable penetrations are forecast to increase this to as much as double, depending upon the particular renewable characteristics. On the other hand, faster resources such as batteries and flywheels may reduce the total requirement once grid operators become comfortable with that effect. One aspect of this effect determined by PJM in their filing is that at short time periods for zero energy in the signal (5 minutes) there is a point of diminishing return in the penetration of fast resources as a share of total regulation capacity. Today regulation is a "thin" market at 1% of load, and a single large new plant or hydro facility can react to too much storage penetration in the regulation market and lower the price. And at higher penetrations of storage, it is not clear whether competing operators may end up pushing the price down as there are no production costs to create a floor. On the other hand, high renewable penetrations are forecast to reduce

52 Cost Comparison for a 20 MW Flywheel-based Frequency Regulation Power Plant Beacon Power Corporation, KEMA Project: BPCC.0003.002 ,September, 2007, Final Report
53 139 FERC, 61,130, FEDERAL ENERGY REGULATORY COMMISSION, WASHINGTON, D.C. 20426, Before Commissioners: Jon Wellinghoff, Chairman; Philip D. Moeller, John R. Norris, and Cheryl A. LaFleur.PJM Interconnection, L.L.C. Docket No. ER12-1204-000
54 PJM Interconnection, L.L.C. Docket No. ER12-1204-000
56 139 FERC 61.245 Docket RM11-24-000 and AD10-13-000 Third Party Provision of Ancillary Services

conventional plant revenues, resulting retirements and higher prices when the plants are on line – which may maintain or increase today's regulation prices. The price level of regulation in the future may reflect additional performance requirements that are not specified today. A similar argument obtains for spinning reserves. Finally, smart grid technologies create the potential for increased Demand Response participation in ancillary markets and this may act to depress prices.

- The AEP/Electric Transmission Texas (ETT) Presidio project is replicable as a way to defer / resolve transmission upgrade costs. ETT, a joint venture between MidAmerican Energy Holdings Company and AEP, owns the transmission batteries to support load served in Presidio, Texas by AEP's transmission and distribution system. The transmission substation storage system at Presidio is a template for improving reliability at the end of long single circuit radial transmission lines. The cost of adding a circuit or additional line to a remote substation is usually high and well understood, and the station battery provides backup for a period of hours – enough to address many outages. This is a circumstance with numerous examples nationally so the project is of great interest to utilities. This is an application immune to the effects of low natural gas prices in locales where pipeline access is non-existent, which correlates well with the remoteness hypothesized.

- Wind farms especially in island or remote locations. Large wind farms on island systems are one instance where market forces act in favor of storage today. Islands benefit greatly from wind power – it substitutes for expensive oil fired generation. However, island grids are typically small and at high penetrations maintaining grid stability requires that the wind power be firmed and be controllable. Local battery storage is cost effective in these situations when the alternative is firming by oil fired flexible generation. Similarly, when the growth of wind farms outpaces the growth of transmission to interconnect them, the wind farms may suffer curtailment due to transmission congestion. This means lost revenues and lost production tax credits which are usually tied to project financing. Storage can be economical in these cases depending upon the frequency and duration of curtailment and the applicable congestion costs. This application is also immune to the effects of low natural gas prices, although in the future increased LNG capacity may enable gas peakers to be used in island systems. Conversely, mainland wind farms in large interconnections and where transmission congestion is not an issue are as easily firmed with gas fired peaking generation if only economics are at issue. The Spanish grid operator has been quoted as saying that for every MW of wind capacity, a MW of gas capacity is needed, and for every MW of wind production in real time, a quarter or third as much on line gas generation is needed. This requirement is less expensive than ever and out-competes storage for the purpose unless emissions are factored in.

- Large commercial customers are considering / embracing storage for their own reasons

    - Internal renewable / zero net energy (zne) goals that spur combining renewable energy procurement with storage to firm the energy. As noted earlier, some large

Internet or data center firms are shifting from diesel backup to battery back up at data centers. Other commercial organizations consider microgrids with storage as way to achieve zero net energy / zero emissions goals.

  - Reliability and power quality in applications with stringent requirements concerns and a recognition that storage is an alternative to back up generation (example – data centers)

- University campuses, hospitals, and city / state government facilities are considering the adoption of microgrids incorporating renewable and conventional distributed generation and energy storage. Here, the need for high reliability for critical infrastructure or laboratory facilities couples with (possible) zne or zero emissions objectives. Economically, storage as part of the portfolio may be better than relying strictly on conventional distributed generation or combined heat and power, especially if large amounts of PV are in the design.

- DOD SPIDERS, ESTCP, and SRDP programs and public ambitious plans for base energy security. The requirement that bases incorporate renewable energy supplies and that they are capable of sustained off-grid operations leads to storage in the design portfolio.

Developing countries with inadequate or poorly performing electric power infrastructure are a market for microgrids. In some countries even though there is an existing pervasive T&D infrastructure, the growth of demand tied to economic growth (and use of air conditioning) outpaces infrastructure development resulting in poor reliability and/or frequent load curtailment. Factories, offices, hospitals, universities – all need reliable power and microgrids become a self-actuated and grid independent way to achieve this. For the same reasons as cited above, storage makes sense in the design portfolio rather than sizing and operating fuel derived DG alone. The mix of photovoltaic, gas or diesel fired generation, Liquid Propane fired generation, and storage depends upon the supply chains and availability of each as well as the weather.

In countries without a well-developed T&D infrastructure, microgrids (even at low power levels by Western standards) are the only means of rural electrification. Cell phones have become essential tools of commerce in many of these economics, substituting for unavailable banking and market services, and the citizenry need to be able to charge their phones. PV based chargers are an effective solution. But a second critical development aspect is the availability of clean cheap lighting so that students can study in the evening and other work can go on. LED lamps with batteries charging from the PV are a solution; so is a village level microgrid achieving scale efficiencies with PV and storage. There are organizations actively pursuing UN and other aid agency funded efforts to deploy these[55]. Such developments represent an export opportunity for US firms.

[55] http://www.generalmicrogrids.com

## 3.5 Energy Storage Manufacturing Capacity

In support of this study, DNV KEMA attempted to survey firms that are manufacturing various energy storage technologies and prepare a summary of existing and planned manufacturing capacity.

Status of Global Manufacturing Capacity Relative to Anticipated Demand for Storage

The storage market is in a state of active development and change. Manufacturers are in various stages of technology commercialization and are seeking to understand and build business cases and markets for their technologies. Achieving economies in scale in combination with R&D to further improve technology performance and manufacturing efficiencies will help bring down technology prices that are currently limiting market development. Growth in market demand is also limited in the near-term until regulatory, policy and market conditions align and better support the full scope of storage technology benefits. Demand for particular storage technologies is highly driven by regional/country-specific factors as well as site-specific factors. Specific application needs ultimately will drive demand for best-fit technologies.

Global storage manufacturing capacity is currently in the process of build up at varying rates depending on the storage technology. Most storage producers are in the pre-commercialization R&D and demonstration phase and have not yet scaled up their manufacturing capacities for high volume production. Storage producers with commercially-ready technologies and established manufacturing plants are reticent to share specific data on their current versus total potential manufacturing capacity due to competitive sensitivities. However, a number of reports and data available in the public domain provide baseline insight into storage manufacturing capacity relative to projected demand at the macro level.

Based on an April 2012 Lux Research report, annual global demand for grid storage in 2012 is projected at 2,500 MWh.[56] Annual global demand for grid storage technologies is forecasted to grow at more than 230 percent year-over-year (yoy) in the years 2012 through 2015. Demand growth is expected to slow down to 43 percent yoy in 2016 and 2017, with a total annual demand of 185,400 MWh in grid storage in 2017. Top-demand markets are the U.S., China, Japan, Germany and the UK, representing over two-thirds of the total storage global market by 2017.

The current and near-term storage market development focus has been on lithium-ion (li-ion) storage technologies. For example, in the U.S. about one-half of the 230 MWh in planned grid battery storage projects are based on li-ion technologies.[57] Globally, li-ion storage accounts for upwards of 80 percent of total demand for grid storage.[58] This market share represents a total world-wide demand of 2,000 MWh for li-ion grid storage batteries in 2012. An estimated three-

[56] Lux Research, *Grid Storage under the Microscope: Using Local Knowledge to Forecast Global Demand*, April 2012
[57] IHS Emerging Energy Research, US Utility-Scale Battery Storage Market Surges Forward, September 2011
[58] IDC Energy Insights, *Lithium Ion Manufacturing Global Buildout — Supply and Demand Forecasts*, December 2011

fold surplus of li-ion manufacturing capacity is currently on-line, with global total 2012 annual manufacturing capacity amounting to 6,700 MWh[59].

Annual li-ion manufacturing capacity is projected to expand to 30,000 MWh world-wide by 2017. At the same time, the total global grid storage market demand for li-ion storage technology is forecasted at 24,100 MWh in 2017[60] – 5,900 MWh below total global supply. By 2015, more than 60 percent of this capacity will be located in Asia (China, Japan, and Korea), one-third in the U.S., and just over 5 percent in the EU.[61] Much of this li-ion battery manufacturing capacity is being built out in anticipation of growth in the global EV market and so growth forecasts must be considered in the light of that linkage, i.e., they are skewed by EV market growth projections which have been overly optimistic. Because EV market development has been slow to gain traction, li-ion storage technology manufacturers increasingly see the grid storage market as a strategic opportunity – even necessity – to diversify the market base and absorb excess manufacturing capacity.

Japan and Korea together account for 47 percent of the 2015 global li-ion battery capacity. With domestic demand for EVs well below domestic supply of li-ion batteries, these nations are positioning as net exporters of li-ion battery technology – with upward of 24,000 MWh in export capacity by 2015. However, China may face a shortfall of 100 MWh of li-ion battery capacity relative to domestic EV demand by 2015 and this may offer an import market opportunity, albeit limited, both due to size and intrinsic barriers that importers face in penetrating the China market. Similar to Japan and Korea, domestic demand for EVs in the U.S. is projected to be lower relative to domestic li-ion battery manufacturing capacity, facing upward of 15,200 MWh in li-ion storage overcapacity. The EU, however, will be a net importer of li-ion battery technology, with regional demand for EVs outstripping li-ion storage manufacturing capacity by up to 3,200 MWh.

While the near-term grid storage market demand is focused on li-ion technologies, over the next 5 years other storage technologies will gain market share as price, performance, experience and market conditions become more favorable for grid storage applications. The annual global grid storage demand of 185,400 MWh will become more technologically diversified, expanding market share for Vanadium Redox flow batteries (33%), Sodium Sulfur (NaS) (19%), Sodium Nickel Chloride batteries (15%), Zinc Bromide flow batteries (19%), and flywheels (2%). With the exception of NaS battery technology, which already has a well-established manufacturing base, a significant manufacturing capacity build out of storage technologies beyond li-ion will be needed over next several years to meet this expected growth in global demand for grid-scale storage.

Developments in adiabatic compressed air energy storage (CAES), concentrated solar power-thermal energy storage (CSP-TES), and cold thermal storage portend future market presence of these emerging technologies.

---

[59] IDC
[60] Lux
[61] Roland Berger Strategy Consultants, *Powertrain 2020: Li-ion batteries – the next bubble ahead?*, February 2010

The current commercial maturity of various energy storage technologies has an impact on current and future manufacturing capacity build out. A summary of the development stage and 5-year outlook is shown in **Table 7**for key storage technologies as context on the global storage supply picture.

**Table 7: Technology Status**

| Technology | Commercial Position | Global Annual Manufacturing Capacity (2012) | 5-Year Outlook | Key Stakeholders |
|---|---|---|---|---|
| Lithium-ion | Mature | 6,700 MWh | Large established players and early-stage market entrants vying for market share; continued price improvements as chemistries diversify and production increases; multitude of producers to consolidate. | • A123 Systems<br>• Boston Power<br>• BYD Company Ltd.<br>• Demand Energy<br>• Dow Kokam<br>• Electrovaya<br>• Enerdel, Inc.<br>• EnerSys<br>• Exide<br>• Greensmith<br>• GS Battery<br>• Ionex (including CalBattery)<br>• Johnson Controls Power Solutions<br>• Mitsubishi International Corporation<br>• Onyx Lithium Power<br>• Panasonic<br>• Quallion Inc.<br>• ReStore Energy Systems<br>• RONGKE Power<br>• SAFT<br>• Samsung SDIA<br>• Sanyo<br>• Seeo, Inc.<br>• Siemens Corporation<br>• Sony<br>• Toshiba<br>• UltraLife<br>• Valence Technology<br>• Multiple system integrators, including ABB, Beckett Energy Systems, PowerHub, S&C Electric |
| Vanadium Redox | Early Stage | In demonstration phase | Limited projects in operation. Market development dependent on lessons learned from demonstration projects. | • Cellstrom<br>• Prudent Energy<br>• RONGKE Power |
| Sodium Sulfur (NaS) | Mature | 150,000 MWh. Production on hold until 2013. | Many NaS battery projects on hold in light of recent NaS battery fire incidents; grid market demand may shift to competing technologies. | • NGK |
| Sodium Nickel Chloride | Emerging, but has a decade of history being used for transportation in Europe. | 1,000 MWh | Very promising. | • GE Transportation (currently entering a strategic alliance with Xtreme Power)<br>• Fiamm |
| Zinc Bromine | Emerging, in demonstration phase | est. 300 MWh | Limited projects in operation. Market development dependent on lessons learned from demonstration projects. | • Premium Power<br>• PrimusPower<br>• RedFlow<br>• ZBB Energy Corporation |
| Flywheel | Emerging | est. 15 MWh | Several projects in operation. Demand for large format flywheels could emerge if sufficiently high payments for storage-based regulation are secured. | • Beacon Power<br>• Temporal Power |

### *GE Battery Manufacturing Facility*

In recent news reports, General Electric Company (GE) said that it is investing $170 million to expand its advanced sodium battery plant in downtown Schenectady, New York[62]. GE considers the plant to be central to its effort to bring to market the next generation of industrial batteries. GE also received $15 million in funding from New York State authorities and $5 million from the Schenectady County Metroplex Development Authority for the plant [63]. The Durathon batteries produced at the plant use a sodium halide chemistry to store energy. The company is developing three different battery models: for cell phone towers, for data centers, and for utility grids. In the next few years, it plans to move toward mobile storage applications such as hybrid locomotives, forklift trucks, and mining vehicles. At full capacity the plant site will employ about 450 people. GE has received its first order for Durathon batteries to be manufactured at the new plant. The South African engineering company Megatron Federal said their order for 6,000 batteries to be used as backup power supplies at telecommunications sites in Nigeria is worth some $60 million[64].

**Additional technologies in development**

<u>CAES</u> – The traditional form of CAES – adiabatic or diabatic systems – requires large areas in which to store compressed air. Traditional adiabatic or diabatic CAES systems use underground cavities such as a depleted oil field or salt caverns. These CAES systems can store large amount of energy and are well-suited when sited in combination with large renewable energy plants. However, geographic limitations and competition with natural gas for underground caverns likely limit the mass adoption of traditional CAES. Isothermal CAES technology in development offers more siting flexibility and more distributed-based applications. SustainX has developed isothermal technology that incorporates a mechanical drivetrain and uses an electric machine. A crankshaft stores compressed air at near-ambient temperature versus traditional CEAS pre-heating cool high-pressure air and cavern-based storage. SustainX is planning on demonstrating 1-2 MW ICAES systems in 2013 and begin system deployments in 2014—with early field demonstrators in the 5-10 MW range and future commercial systems scaled up to 100 MW.

<u>Molten Salt Thermal Energy Storage</u> – Thermal energy storage (TES) is a relatively inexpensive storage technology and can provide several hours of stored energy when combined with a thermal energy source such as concentrating solar power (CSP). A CSP system collects solar energy with a mirror field or a trough design and the heat is transferred through the CSP-TES system using a heat transfer fluid (HTF), typically oil or molten salt. Molten salt storage in a two tank system is the leading thermal energy storage (TES) technology to support emerging CSP plants. The molten salt circulates through the receiver, collecting thermal energy collected by

---

[62] *GE CEO to tour new advanced battery plant in Schenectady*, Accessed August 16, 2012 at http://www.news10.com/story/18988885/ge-ceo-to-tour-new-advanced-battery-plant-in-schenectady.

[63] *GE Expands New York Advanced Battery Plant*, Matthew Van Dusen, July 10, 2012. Accessed August 16, 2012 at http://www.ecomagination.com/ge-gets-charged-up-at-new-upstate-new-york-advanced-battery-plant.

[64] *GE Sees $1 Billion Potential in Industrial Batteries*. Accessed August 8, 2012 at http://news.yahoo.com/ge-sees-1-billion-potential-industrial-batteries-190636249--sector.html.

the solar field. The hot fluid is then stored in the 'hot' tank or used to produce steam for the generator. Molten salt-based TES is commercialized, but currently limited to large-scale CSP plants and is expected to be limited in the near-term to a few high-profile projects. CSP-TES plants in operation today are 30-350 MW and located in California, North Africa and Spain. CSP plants of 1-10 GW are being planned worldwide, including in Australia, China, South Africa and India and a distributed market for CSP plants of less than 10MW is in development.

Cold thermal storage – Thermal storage is a proven technology that is being advanced in chilled water or ice as well as heat systems. The cold thermal technology includes a thermal reservoir that is maintained at a temperature or colder that of the ambient location temperature. The applications today include the production of ice, chilled water, or eutectic solution (chemical compounds that solidify at lower temperatures) at night that is then used cool locations during the day. ICE Energy is advancing the concept of using its ICE Bear system to reduce air conditioning load. Over the past two years, ICE energy has been constructing the largest ice-based energy storage projects for several Southern California municipal utilities, installing 6,000 devices at 1,500 locations with a total storage capacity 53 MW.

The point of this information on manufacturing capacity is that it is far from certain that manufacturing capacity will be developed at a pace to support the storage market and deployment projections reported earlier in this report. Market conditions for storage and the investment environment will dictate that outcome. The market development for electric vehicles has not lived up to the expectations that drove some firms to invest in manufacturing capacity in recent years. Some may have planned on the electric power market as providing a bridge until the EV sector demand fully materialized. A concern[65] in California is that when the mandated renewable production in 2020 is realized there may not be sufficient domestic supply of energy storage to fulfill the resulting needs for storage. The data available to us today is insufficient to make a clear decision much less a recommendation that DOE explore avenues to support storage manufacturing in the near term. We recommend that DOE undertake more in depth analysis of scenarios for storage manufacturing in the US and the world, and also examine the possible future of domestic vs. imported supply.

## 3.6 Conclusions

The overall picture of RD&D on energy storage today as compared with four years ago is one of tremendous growth and early signs of successful examples. Even so, by looking at which applications have gained "traction" with private investors, we can see that more remains to be done.

Cost and performance improvement is a continuing focus, especially for T&D and community energy storage applications where the number of potential deployments will increase dramatically as costs come down. Improved analytic modeling tools and methods are key to enabling utilities and regulators to proceed with "business as usual" deployment of storage. As noted above, the successful application areas to date are ones that are transparent, easily

[65] Lessons Learned from Managing Public Interest Energy Storage Projects over the Last Ten Years, Mike Gravely, Deputy Division Chief, California Energy Commission, May 2012Smart Grid Applications Virtual Summit

assessed, and subject to risk taking investor decisions, not utility/regulatory evaluation and decision making. The lack of such methods and tools is discussed at length in section 4 below.

Much of the focus on the cost of storage has been on the storage media and the battery system – the format, materials science, packaging, and controls of cells within the battery. However, the inverter electronics, cooling/ heating systems (where applicable), and overall integration are significant costs as well – perhaps 50% of overall installed cost. Research on power electronics especially, including topics of cost reduction, achieving higher junction voltages / larger current capacity, and improving efficiency/reducing losses are as important as storage technologies and tend to be overlooked. Inverter-rectifier losses are a significant fraction of storage system losses, especially for the more efficient technologies.

A roadmap from DOE that shows the path from ARPA-E research (TRL 1-2-3) to demonstration and commercial viability (TRL 8-9) including time frames is needed in 2013 to guide future demonstration and incremental R&D activities. Signposts and checkpoints along the way to measure success and probability of commercial success are needed.

# 4 Government Activities

## 4.1 State Legislative and Regulatory Activities Related to Electricity Storage

States frequently are the laboratories of change and innovation in the realm of public policy-making. Generally closer to problems and opportunities than is the federal government, their decision-making processes are often simpler and more nimble.

Unfortunately, state governments have been reluctant to promote investments in electricity storage. While some reasons for this reluctance and recommendations for federal officials to consider are made below, the limited nature of the states' forays into storage follow.

Legislatures: Several states have introduced bills to provide tax credits or exemptions from tax liabilities for individuals and businesses to invest in renewable energy with energy storage being a "tag along" to the primary intent (e.g., HI Senate Bill 1479; NY Assembly Bill 5643). Other state legislative initiatives have focused on directing their Public Utility Commission to take action to require public utilities to purchase ancillary services that include energy storage and demand management (e.g., HI House Bill 1519) and addressing the treatment of energy storage for cost recovery and rate-making purposes (e.g., KS House Bill 2445). A few states have taken the approach of addressing energy storage as an ancillary part of an economic development package (e.g. AL House Bill 518; CA Assembly Bill 724).

The above failed efforts are indicative of at least three factors: a) the condition of state and national economies with the result that any efforts to reduce state revenues are summarily rejected, b) the reluctance of utilities to strongly support the legislative proposals, thereby leaving the sponsors with less effective political allies, and c) the necessity to increase utility or other fees to support research or investments.

The few legislative initiatives that have passed, or appear likely to do so as this report is drafted, either encourages a voluntary action or is largely symbolic. For example, recommend that energy storage be evaluated by utilities and the PUC if cost-effective and practical (e.g., CA Assembly Bill 2227); including within the statutory definition of renewable energy, energy from wind, solar or other renewable source that is inserted into an energy storage device and then recovered (e.g., KS Senate Sub. for House Bill 2526); or provides a sales tax exemption for off-peak residential electricity used for water and space heating in the context of those devices providing thermal storage (e.g., ME Senate Bill 554).

Public Utility Commissions: As with state legislatures, commissions have also largely been silent on energy/electricity storage policies. While most states are silent on the issue because of a general lack of interest by stakeholders, a few deliberately choose not to engage (e.g., KS Commission which declined to definitively answer a legislator's request to predetermine for ratemaking purposes whether electricity storage is a component of generation, transmission, distribution or the fourth element of the electric system).

Of the state commissions that do open and pursue dockets or workshops related to storage, most remain in fact finding modes (e.g., TX docket 39764 to determine which rules need to be changed to promote storage; CA workshops on March 9 and June 28, 2011). Anecdotally, individual Commissioners are interested in the potential value of electricity storage and press their regulated utilities to conduct their own research (e.g., WA requires utilities to look at storage in their next resource study).

States do remain laboratories for innovation, but those initiatives tend to be driven by individuals. For example, a Kansas Legislator brought a renewable energy development company, Electricity Storage Association representatives, the nation's leading retailer, state economic development agencies, the PUC, the state's largest IOU, and the Governor's staff together to explore the feasibility of integrating wind and solar generation with electricity storage. The objective is to meet the retailer's corporate objective of having all stores lighted by renewable energy and for the utility to deliver capacity and not just energy.

Non-disclosure agreements have been signed to permit exchange of load, generation performance, ancillary and other costs. Storage will provide the "shoulder" power to smooth the variability of the renewable generators. Whether or not the project moves to construction and operations, it reflects the need for rewarding first adopters/innovation by the DOE and the power of an individual. This is an example of the value of DOE outreach and education efforts through NARUC, NCSL, CSG, and other organizations.

## 4.2 Energy Storage Standards

### 4.2.1 Introduction

Standardization provides a solid foundation upon which to develop, demonstrate and deploy technologies as well as to provide a consistent pathway to enhance existing practices regarding the application and operation of technology. Standardized technologies are more apt to be safe, environmentally benign, secure and reliable. In the case of technologies potentially applied to the electric power system, like electric energy storage devices, they are more apt to be able to interoperate with other components of the system. Standardization also usually leads to better cost-effectiveness for a technology, through economies of scale, replaceability and learning curve effects. Typically, some standardization is a key requirement for the widespread adoption of a technology. The standardization can be "official" (promulgated by a recognized industry standards organization such as the International Electrotechnical Commission) or it can be unofficial and developed by a consensus between developers, suppliers and users.

Both official and unofficial standards are effective provided there is common agreement on key issues such as terminology; areas of application; common specifications; performance criteria; safety; operational procedures; test protocols; and interoperability with the power system. Interoperability is key to technology adoption. Safety, security, and cyber security are given requirements in the standards process.

The primary focus of energy storage standards has been in battery technology. While several standards exist for the battery (comprising the cell and module/pack interconnection) by itself, until relatively recently, there has not been much standardization at a storage system level (that is, system including the battery or other storage technology, the power electronics, and the balance of plant required for the product to function as a grid appliance). The absence of system standards is a significant obstacle to the widespread use of storage. Without generally accepted standards, it is difficult enough for users and vendors to agree on the critical technical parameters related to a single storage project, let along develop standard products through which cost reduction through volume manufacture can be actualized. At a minimum, it would be highly useful to the entire industry to agree on a common understanding of terminology, applications, specifications and performance criteria, dispatch algorithms, test and validation procedures, and safety.

### 4.2.2 Standards Development

While standardization is normally thought of as a formal (de jure) process through a standards body such as IEEE and IEC, standardization can also be achieved through an informal de facto process in which the energy storage community agrees on key issues. It should be noted that standards that are developed purely from a technology angle, without strong input from the application viewpoint, may not reflect the actual uses of storage, and may end up being wasted effort. For this reason, we suggest that a standards process is best done from an applications viewpoint, with storage owners and operators leading the way, and with input from technology vendors. The Department of Energy can facilitate this process continuing to convene workshops of the relevant stakeholders.

Recognizing the importance of standardization, several collaborative efforts are currently underway. These efforts are being led by several important bodies, including the U.S. Department of Energy, the Electric Power Research Institute, the Electricity Storage Association, and other industry trade groups, with support from utilities, national labs, leading consultants, energy storage manufacturers, and system integrators. Some of these representative efforts are described below.

**Table 8** lists most of the organizations engaged in supporting and developing technical standards related to electricity storage.

**Table 8: Organizations Engaged in Energy Storage Standards**

| Organization | Activity | Standards Area |
|---|---|---|
| American National Standards Institute (ANSI) | Standards Development | • ANSI C12 – Revenue Metering |
| American Society of Heating Refrigeration & Air Conditioning Engineers (ASHRAE) | Standards Development | • ASHRAE/ANSI 135 – Building Automation |
| Electric Power Research Institute (EPRI) | Supporting Role | • See text |
| Electricity Storage Association (ESA) | Supporting Role | • See text |
| Institute of Electrical & Electronics Engineers (IEEE) | Standards Development | • IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems<br>• IEEE P37.118 – Phasor Measurement Units<br>• IEEE 2030 – Standards for Electric Vehicles as Storage Devices<br>IEEE 802 – Communications Protocol for Personal Area Networks on Which ZigBee is based |
| International Electrotechnology Commission (IEC) | Standards Development | • IEC 61850 – Interoperability<br>• IEC 61724 Photovoltaic Modules and Panels<br>• IEC 61970 & 61968 – Enterprise IT Integration |
| International Society for Automation (ISA) | Standards Development | • ISA 99 & ISA 100 – Manufacturing and Control Systems for Security and Automation |
| National Fire Protection Association (NFPA) | Standards Development | • NFPA 70 – Community Energy Storage and Electric Vehicle Charging<br>• The National Electrical Code® Provisions for Service Interface and Control of Storage Devices |
| National Institute of Standards & Technology (NIST) | Standards Coordination | • Sponsors the Smart Grid Interoperability Panel (SGIP) – see text |
| Society of Automotive Engineers (SAE) | Standards Development | • J1772 & J1773 – Electric Vehicle Charging |
| U.S. Department of Energy (USDOE) | Supporting Role through Sandia & Pacific Northwest National Laboratories | See text |
| Underwriters Laboratory (UL) | Safety-related Standards for customer-side devices | • UL 1741 – Inverters, Converters, Controllers and Interconnection, System Equipment for Use with Energy Resources<br>UL 1703 Flat Plate Photovoltaic Modules and Panels |

| Organization | Activity | Standards Area |
|---|---|---|
| Canadian Standards Association (CSA) | Standards Development | • C22 – Canadian Electrical Code |
| National Electrical Manufacturers Association (NEMA) | Standards Development | • Network Roaming and Communications Standards for Plug-In Electric Vehicles Under Development |

The following paragraphs provide a blueprint for standards development in storage by describing common requirements, specifications, terminology, test protocols, duty cycles, communications approaches, and interconnection standards as well as standards coordination. Each is discussed in the context of the many organizations involved in coordinating, supporting and developing standards.

**Common Requirements:** In 2011, the Electric Power Research Institute (EPRI) initiated development of a common requirements document for the application of energy storage in the electrical grid. The outcome was a Functional Requirements Document for utility storage that outlined the four key energy storage applications: substation-based storage, distributed energy storage systems, customer premises energy storage systems, and energy storage to integrate renewables. The requirements for each application include details related to specific use cases and operating modes, power output and duration, system ratings and effectiveness, physical requirements, communications and data flow, and operational and safety issues. This document was developed through a public, open-source approach by bringing together high-level energy storage stakeholders, including representatives from utilities, renewable energy project developers, equipment developers and manufacturers, regulatory bodies, independent system operators, power pools, and government and educational institutions. The document's primary purpose is to gain consensus in the procurement of energy storage devices and appurtenances. By steering procurement and development efforts so that they are consistent with these requirements, utilities and developers can work with a common understanding to develop the most effective storage solutions to utility problems.

**Common Specifications:** A common set of specifications across all owners and operators of utility - scale power systems will help vendors understand performance targets and relative importance of performance parameters (performance, operating conditions, and life). Individual utilities will use these specifications as the basis for customized specifications that match their own needs. EPRI is collaborating with member utilities to develop a reference specification for substation batteries, building on previous work bringing together a number of utilities and other users of storage to develop a guideline that could be used as a standard specification for a lithium ion battery system for grid applications.

**Common Terminology:** It is essential that a common set of terminology be used across the energy storage industry to define product requirements and applications. This terminology must be in conformance with common engineering practice and terminology used in the utility industry. This is presently being addressed under the auspices of the Electricity Storage Association Technical Working Group which currently is comprised of utilities, storage developers, and other interested parties, including EPRI and Sandia National Labs. This collaboration can be extended to other stakeholders.

**Common Test Protocols:** It is crucial to develop common test protocols that allow utilities and vendors to quickly assess technologies and products for viability in various applications. Several collaborative efforts are underway in this area.

- Energy Storage System Performance Metrics and Tests: The U.S. Department of Energy (USDOE) Energy Storage Systems (ESS) Program, through the support of the Pacific Northwest National Laboratory (PNNL) and Sandia National Laboratories (SNL) facilitated the development of this protocol for use in measuring and quantifying the performance of energy storage system applications. The availability of a suite of uniform, application-specific protocols to outline integration criteria and performance metrics will allow technology developers, power grid operators and other end users to evaluate the performance of energy storage technologies. This test protocol is slated for completion by the end of 2012. To date, cycling stability, roundtrip efficiency, response time, and ramp rate parameters are being developed in the context of frequency regulation and peak shaving applications. A compilation of definitions have also been agreed upon. Further work will be taken up to increase commercialization by applying the same methodology comprehensively to more parameters in more applications.
- EPRI, USDOE and SNL are also collaborating in the development of test protocols for storage in other applications.
- While the above test protocols focus on the system evaluation and benchmarking, EPRI is also working with its member utilities to develop common test protocols for factor acceptance testing, commissioning, and in-field evaluation.

**Common Duty Cycles:** Test protocols for energy storage systems must be based on pre-defined duty cycles for important utility applications. These duty cycles must be vetted by the utility industry. A collaborative effort between USDOE and Sandia National Labs is underway for developing standard duty cycles for storage applications.

**Common Communication Approaches:** The foundation for all electric power system communication standardization stems from the work of the Utility Communications Architecture (UCA) effort managed by EPRI in the 1980’s. UCA eventually led to the International Electrotechnical Commission (IEC) standard IEC 61850, a standard for the design of electrical substation automation. IEC 61850 subsequently evolved to include the first standard to support the communication integration of smart distributed photovoltaic and storage systems – the Distributed Network Protocol (DNP3) Application Note AN2011-001, Profile for Basic Photovoltaic Generation and Storage. This standard builds upon a compilation of well-defined “functions” that were collaboratively developed by the EPRI-led “Smart Inverter Communication Initiative” and later adopted by the IEC in the 61850-90-7 Technical Report. The DNP3 standard provides a mapping of a beginning set of these smart inverter functions into the DNP3 protocol, making it possible for multiple types, sizes, and brands of Distributed Energy Resources (DERs) to be interoperable. This activity, which has been conducted as an open industry project (i.e., anyone may participate), has engaged over 500 individuals including utilities, inverter manufacturers, PV and storage integrators, communication system providers, and researchers. In the first phase of the project, a set of seven priority functions were selected, and a common means identified for how each may work. Although it is a limited first revision, the content is suitable to cover the majority of the present functions of pad-mount storage systems. Preparation work is currently in process to develop a second version which will go further to support the full needs of pad-mount units.

**Interconnection Standards:** While the Institute of Electrical and Electronics Engineers (IEEE) Standard IEEE 1547 has been in existence for a number of years, recognizing the growing importance of addressing energy storage as a Distributed Energy Resource (DER), work is presently underway on two important standards the IEEE P1547.8 *Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Standard 1547*, and the P2030 *Smart Grid Interoperability Draft Guide for Smart Grid Interoperability of Energy Technology & Information Technology Operation with the Electric Power System (EPS) & End Use Applications & Loads*.

The purpose of the IEEE 1547.8 methods and procedures provided in this recommended practice is to provide more flexibility in determining the design and processes used in expanding the implementation strategies used for interconnecting distributed resources with the electric power systems. Further, based on IEEE Standard 1547 requirements, the purpose of this recommended practice is to provide the knowledge base, experience, and opportunities for greater utilization of the interconnection and its applications.

IEEE P2030 is sponsored by IEEE Standards Coordinating Committee 21 (SCC21). This standard provides guidelines in understanding and defining smart grid interoperability of the electric power system with end-use applications and loads. Integration of energy technology and information and communications technology is necessary to achieve seamless operation for electric generation, delivery, and end-use benefits to permit two-way power flows with communication and control. Interconnection and interfacing frameworks and strategies with design definitions are addressed in this standard, providing guidance in expanding the current knowledge base.

### 4.2.3 Standards Coordination

**Smart Grid Interoperability Panel (SGIP)**: The National Institute of Standards and Technology (NIST) initiated the Smart Grid Interoperability Panel (SGIP) to support NIST in fulfilling its responsibility, under the Energy Independence and Security Act of 2007 (Title XIII, Section 1305), to coordinate standards development for the Smart Grid. The SGIP is a vehicle for NIST to solicit input and cooperation from private and public sector stakeholders in developing the Smart Grid standards framework. Established in late 2009, the SGIP is a public/private partnership that defines requirements for essential communication protocols and other common specifications and coordinates development of these standards by collaborating organizations. The SGIP does not develop standards directly, but rather it provides an open process for stakeholders, including NIST, to interact and drive progress in the ongoing

The SGIP has three primary functions:

- To oversee activities intended to expedite the development of interoperability and cyber security specifications within standards-setting organizations (SSOs);
- To provide technical guidance to facilitate the development of standards for a secure, interoperable Smart Grid; and
- To specify testing and certification requirements necessary to assess the interoperability of Smart Grid-related equipment.

In January 2010, NIST produced its Framework and Roadmap (F&R) for Smart Grid Interoperability Standards (NIST Special Publication 1108) which included “Energy Storage” as one of eight critical application areas for Smart Grid. Building on a July 2009 order by the Federal Energy Regulatory Commission that listed energy storage as one of its four critical applications, the NIST F&R, updated in January 2012 as Special Publication 1108R2, identifies a variety of U.S. standards dealing with storage including the IEC IEEE 1547 and IEEE 2031.

NIST also established a “Priority Action Plan” (PAP) for “Energy Storage Interconnection Guidelines” calling for the engagement of a broad set of stakeholders to address interconnection issues and operational interface requirements.

In 2012, the SGIP also established a Distributed Renewables, Generation, and Storage Domain Expert Working Group (DRGS DEWG) to provide “a forum within SGIP to identify and define standards and interoperability issues and gaps related to Smart Grid integration of distributed renewable/clean energy generators and electric storage.” Part of the charter for this DEWG is also to evaluate gaps and potentially initiate additional priority action plans and task groups to address them. According to the DEWG collaboration site (http://collaborate.nist.gov/twidi-sggrid/bin/view/SmartGrid/DRGS), “Significant technical challenges exist in this area and resolution of these issues and gaps is essential to enable high penetrations of distributed renewable/clean generator and storage devices while also enhancing rather than degrading grid stability, resiliency, power quality, and safety.”

**International Electrotechnical Commission (IEC)**: In October 2010, the IEC’s Market Strategy Board established a project team to plan future energy storage activities within IEC. Their future activities include the development of an energy storage fundamental architecture, which may serve as the basis for future standardization; the development of control, interconnection, and installation standards detailing the interface of storage with other grid elements and the data models for exchange of the information necessary to do so; and the development of standards to use energy storage to relieve transmission congestion and safety standards to decrease risk and cost associated with implementation.

In line with these recommendations, in June 2012, the U.S. National Committee (USNC) of the IEC requested comment and approval regarding the creation of a new Technical Committee – “Electrical Energy Storage.”

## 4.3 Other

Many existing standards that are reflected in electrical codes today were developed with lead acid battery technology in mind. As new standards are developed around specific application duty cycles and “use case” definitions for storage applications, these existing electrical and building standards need to be adapted to recognize the new technologies. This is particularly true for end use and consumer applications.

Just as the National Renewable Energy Lab (NREL) has established the life cycle expectations for wind turbine blades and gearboxes, so too should the DOE sponsor development of the necessary testing protocols and equipment for energy storage devices. Such information (e.g., verification of life-time cycling capabilities) would benefit decision-makers, utilities, and vendors. As with NREL, testing costs are recoverable from vendors, but the data would be trustworthy because of the involvement of the National Lab(s) and DOE

## 4.4 Conclusions

Since the 2008 EAC report was written a great deal of work has been accomplished, as evinced by the listed activities above. Standards need to address not only technology but applications of technology. The Energy Storage System Performance Metrics and Tests effort is salutary for proceeding down this path and its plans to continue developing common terminology and definitions that lead to standards for particular applications should be continued, expanded. DOE should facilitate the engagement of storage owners and operators in this process.

While not unique to storage, it is the case that coordination between smart grid interoperability, power electronics, interconnection, and storage standards is required. An example is the potential for unacceptably large inrush current and demand upon system restoration if all storage charging resumed instantaneously on a given element of the power system.

# 5 Potential Barriers to Widespread Storage Deployment and Policy Alternatives

“Barriers” to widespread storage deployment include, to varying degrees

1. Cost of the technology
2. Risk of cost recovery in centrally planned, cost-of-service regulatory constructs
3. Potential inconsistency in, or lack of adequate, market rules in the restructured wholesale markets (regulated by the FERC, or in Texas, by the Texas PUC), that allow storage to provide wholesale market services on a comparable basis to other market resources
4. Lack of understanding the value of the technology
5. Understanding of how to assess the value of the technology in a given application
6. Accepted planning and operational methodologies to deal with storage – analytical methods, training, and readily available software tools

1) Cost of storage technology

Some storage technologies (flywheels, large scale grid connected batteries, etc) are still novel to the electric power sector and consequently a number of barriers to more widespread adoption exist in terms of lack of understanding, lack of easy tools / methods for evaluating and planning applications, and practices and methods for implementation and operation of storage, and a lack of specific regulatory and policy measures that speak to storage. There are additionally ongoing uncertainties about the technical and economic performance of storage that are to be expected of any new technology trying to gain a foothold in an established industry.

The single biggest barrier to widespread storage deployment in many potential applications today is the cost of storage technology relative to other technologies. This barrier exists in both the organized (restructured) wholesale markets regulated by the FERC and the traditional, vertically integrated, cost of service utilities that are regulated by state regulators. For the most part, this is either because the intrinsic technology has not yet reached cost parity with other market (generation/demand response) resources or transmission/distribution assets, or economies of scale have not yet been achieved because of low market penetration. This problem will be addressed over time as the industry continues to innovate and lower the costs of the technology – but this is likely to take some time. Cost reduction comes from three dimensions: economies of scale as volumes grow; “learning” economies as manufacturers learn how to improve processes and incrementally improve design (this is usually linked closely to scale growth); and innovation economics wherein newer technologies outperform the previous generation. Government could play a role in accelerating this maturation process through efforts such as the ARRA investments, via explicit subsidies and incentives such as those currently provided at either the federal or state level for renewable generation technologies, or via mandatory targets for penetration as exist in some state portfolio standards for renewables today and as are being considered for storage in California today. ARRA investments and ARPA-E investments can help the “innovation” dimension of cost and performance improvement but are unlikely to address the scale and learning dimensions. These only come with time and increased volumes.

It is important for policy makers to consider whether additional subsidies for storage are warranted and what the best mechanisms are. This is a complex question which requires a discussion of the policy objective before deciding on an implementation strategy. As storage does not “produce” energy a production tax credit is unlikely to be effective. An investment tax credit that is readily transferable in project finance to institutions able to utilize it is more likely to be effective, and is a form of subsidy. Tailoring the availability of the tax credit to specific storage applications that themselves advance policy goals may pose real challenges. For instance, if the underlying policy goal is to facilitate the penetration of renewable resources in the energy portfolio, then somehow the application of storage in a particular instance has to be linked to and validated against the integration of renewable resources in comparison with other alternatives such as newly available more flexible gas fired generation or dispatchable demand response. If the policy goal is to increase the utilization factor of T&D infrastructure, then that application and benefit would have to be linked and validated and compared with, for instance, demand side management/peak shaving measures or other approaches to reducing post contingency congestion limits. These complexities are probably beyond workable incentive designs other than broadly defined. Another incentive design issue is whether to make the incentives completely technology neutral. For instance, should incentives recognize the round trip efficiency of the storage system or rely on energy market economics to correctly dictate that selection. The more technology neutral the incentives are, the less market distortions they will create.

Incentives to develop storage associated with renewables firming could take several forms:

- Requiring that the storage investment be associated with a renewable resource or investment directly or via an instrument such as a PPA. This certainly links storage to renewable development but limits investment flexibility.

- Requiring that renewable operators self-schedule in markets and are exposed to penalties for variability in terms of balancing energy. This acts to discourage renewable penetration of course, which may be an undesirable side effect, but acts to encourage the development of a market for firming services and technologies. To favor storage vs. natural gas firming the value/size of the REC associated with the renewable investment could be discounted to account for the emissions generated in firming, which would encourage storage. This opens the discussion to whether other causes of variability should be financially accountable – which may create other policy difficulties.

- Establishing, at either the federal or state level, financial incentives for storage technologies that are paired with variable renewable generation projects, e.g. a storage energy credit, similar to the RECs provided by many states. Another example is incenting storage as a means to achieve higher reliability. Alternatives could include:

  - Providing direct or tax credit incentives to utilities for storage investments linked to T&D reliability.

  - Granting tax credits to end user investments in storage

- Allowing utilities to offer storage as a reliability enhancer to customers at incremental rates – creating a market for utility reliability.

- Recognizing the emissions impacts of increased ancillary services from conventional fossil fueled generation and providing incentives for “green ancillaries” from storage systems whose energy is provided by renewable energy – an example being Concentrating Solar Thermal with thermal storage.

All of these have implications in terms of rate payer costs and in some cases differentiating among rate payers in ways that are foreign to the regulatory paradigm today.

The EAC does not advocate a particular incentive structure. We do recommend that the unintended consequences of incentive design be thoroughly considered and that incentives be linked as best possible to the underlying policy goal. The unintended consequences and market impacts of incentives are not always well understood or quantified. DOE can contribute by improving the state of knowledge and analytic methodologies for assessing how these (and other) potential policy decisions may play out.

2) Risk of cost recovery in centrally planned, cost of service environments

Storage resources have the ability to provide both reliability and economic benefits when deployed on the distribution and transmission system. As described above, in a centrally planned system, planners, and state regulators have the ability to substitute storage resources for more traditional generation or wires solutions. Setting aside the cost issue described above, another factor that influences technology choices is the reality that utility system planners, and their regulators, are typically risk averse and will tend to choose proven technologies (particularly if they appear to initially be lower cost solutions). In particular, a utility would want to ensure that it does not make investments today that could be deemed ‘imprudent’ by future regulators. There are two ways of addressing this potential barrier:

i. Education of utility planners and state regulators on the potential applications and benefits of storage. The DOE could potentially be a provider of education on storage applications.
ii. A willingness on the part of regulators to share new technology risks and adoption costs with the regulated entities on some basis. This can take the form of incentives, direct subsidies, acceptance of premature failure (accelerated depreciation), or allowance for insurance costs against premature failures (assuming such insurance can be made commercially available). Regulatory risk sharing inevitably transfers to rate payer cost increases for the failures, unless incentives or subsidies are created for this cost outside the rate setting process and which shift these costs to taxpayers rather than ratepayers.

3) Potential inconsistencies or inadequate, wholesale market rules in the restructured wholesale markets.

The restructured markets are for the most part under FERC’s jurisdiction (the exception being Texas), therefore, these issues are outside of DOE’s jurisdiction. Currently, there are multiple opportunities for storage resources to earn revenues by providing services in the ISO energy and ancillary services markets, however the reality is that each of the ISO wholesale market designs are different and reflect the power system needs and political realities of the regions that they serve.  The result is that the various market designs have features that are more or less 'friendly' to storage resources. For example, in New England, pumped storage resources are able to provide operating reserves either as a generator (when generating) or as a dispatchable DR asset (when pumping). This feature may be unique to the New England region. New England was also the first region to provide market resources with 'mileage' payments when providing regulation services – this later became the basis for the mileage payment in FERC Order 755. There are a number of other examples; New York ISO has developed rules that give preference to the dispatch of certain storage technologies and PJM allows storage resources to participate in their ancillary services markets. MISO and CA ISO also have new tariffs or market products. SPP will shortly.

DOE could provide a useful research role if it chose to analyze the various wholesale market designs with the objective of identifying any potential barriers or favorable biases to entry for storage resources that are inherent in the market design (as opposed to whether there are sufficient market revenues to justify investing in storage).  As noted above, an open FERC NOPR would expand the ancillary services markets by requiring non-market control areas / balancing authorities to open the provision of ancillary services to 3rd parties. However, if all these new potential customers for services provided by storage develop unique application definitions and protocols, significant barriers to entry just in the cost of adaption (to smaller markets than the existing ISOs) will result. The sooner some of these definitions can be standardized and standard procurement and scheduling protocols, as with OASIS for transmission reservations, can be established, the better. DOE can contribute in this regard by leading / facilitating the process to reach consensus on a limited set of definitions.

Another market design dilemma which is worth researching is the intersection between a high penetration of limited energy resources, and the market design features needed to ensure reliable system operations in this environment. The grid of the future will consist of many limited energy resources. Current EMS applications are based on the presumption that market resources are able to produce (or reduce) energy in accordance with the dispatch signal issued by the system operator. There are currently three notable exceptions; storage resources, certain renewable energy resources and demand resources. These exceptions are easily accommodated when they are a relatively small percentage of the overall resource base. However, as the penetration of these resources increases, it will require changes to market designs and the EMS applications that are the primary tools utilized by system operators to manage system reliability. It is likely to drive a need for significant investment in the EMS architecture and technology.  The EAC has separately prepared a white paper for DOE on the broad need for investments in EMS technology including the issues raised here.   In the area of market design, the ISO's are already contemplating the next steps in the evolution of their market designs to deal with the variability and uncertainty created by limited energy resources (e.g. the CA ISO flexible ramping product design[66] and the ISO New England[67] discussion on differentiating the capacity market based on operating requirements).

4) Lack of understanding of the technology
The Electricity Storage Association (ESA) conducted a survey of selected PUC Commissioners and State Legislators to determine how much information about electricity storage these decision-makers have, the most trusted sources of information, their highest information needs, and their preferred means of "learning" or receiving educational information. The Commissioners and Legislators were primarily selected because they are engaged in professional association committees (e.g., NARUC Electricity Committee, NCSL Energy Supply Task Force) that help develop energy policies for their colleagues. Thus, the selected survey respondents reflect the "upper" levels of subject knowledge and interest, thereby establishing knowledge thresholds. The ESA has shared the survey results with the EAC's Electricity Storage Subcommittee and will do the same with NARUC, NCSL, and other appropriate organizations.

While the full survey results are contained in Appendix B of this report, the results indicate that there is little in-depth knowledge about electricity storage and its potential to improve grid performance because there have been few regulatory filings or legislative bills introduced. This lack of formal opportunities for decision-maker education and action reflects the classic "chicken or egg" condition. Do utilities fail to bring storage issues to policy-makers because of projected project costs and regulatory/legislative uncertainty or is there regulatory/legislative uncertainty because utilities fail to bring initiatives forward?

The survey's results clearly indicate a potential role for the DOE. Both PUC and Legislative respondents indicate strongly that they trust information provided by National Laboratories and federal agencies more than data/information provided by other sources (e.g., utilities, vendors). Furthermore, the survey's respondents clearly indicated their preferred means of receiving information includes direct electronic communications and presentations by trusted sources at workshops and professional association meetings. That information provides opportunities for the DOE to expand its partnerships with NARUC, NCSL, CSG, and other professional organizations, as well as identify, educate, and cultivate individual policy-makers at the state level.

The DOE can provide great assistance by supporting advanced model development to quantify the roles and benefits of storage options in concert with or as replacement for "traditional" generation, transmission, and distribution solutions to operational problems. Among the more desired information sought by Commissioners and Legislators are cost allocation models, cost-benefit models for ancillary services, life cycle cost comparisons. These are all within the capabilities of the DOE and National Laboratories to facilitate development and distribution.

[66] California ISO Stakeholder Initiatives Catalog, Sept 19, 2012, 3.3. Flexi-ramp Product, pg 13.

[67] http://www.iso-ne.com/committees/comm_wkgrps/strategic_planning_discussion/materials/fcm_whitepaper_final_may_11_2012.pdf

More importantly, meeting these and other information needs are tasks that are cost-effectively within the DOE’s mission.

The analysis of the responses to the specific questions show that there is a real need for outreach and education to state commissions and legislative groups, and that these groups place DOE and the National Labs first as trusted sources of information. Given that in the T&D space these are the groups that will have to adjust policies and regulatory practice to enable storage applications to be deployed, this outreach should be a priority for DOE in 2013.

5) Understanding of how to assess the value of the technology in a given application

Because storage is “new” and for most applications in a demonstration phase, there are few cases where there are accepted methods for valuing storage in a given application. As one example, the use of storage (and other fast resources) in system regulation has been under discussion since 2008 and has been piloted since then, with several merchant projects built for the purpose. Nonetheless, FERC Order 755 only addressed compensation issues for fast regulation resources in 2012 and the ISO tariff filings in response are for the most part still under review.

There have been a number of regional and national studies on the integration of ever higher penetrations of renewable resources and on the costs of variability that are imposed on the grid[68][69]. As more and more is understood about the market and operating impacts of high renewables penetration, the need for firming and mitigating technologies becomes more and more clear. Today, these studies produce results in increased requirements for ancillary services and for balancing energy / flexibility. In most cases the market cost impact for these additional services in terms of direct procurement costs and increased energy prices are established via production cost/market simulations. Most of these studies, however, do not address storage as a potential resource to mitigate renewable variability nor do they examine what mix of storage and conventional firming resources might be suitable for a given set of technology and fuel costs.

**Midwest ISO (MISO) Transmission Plan - Example**

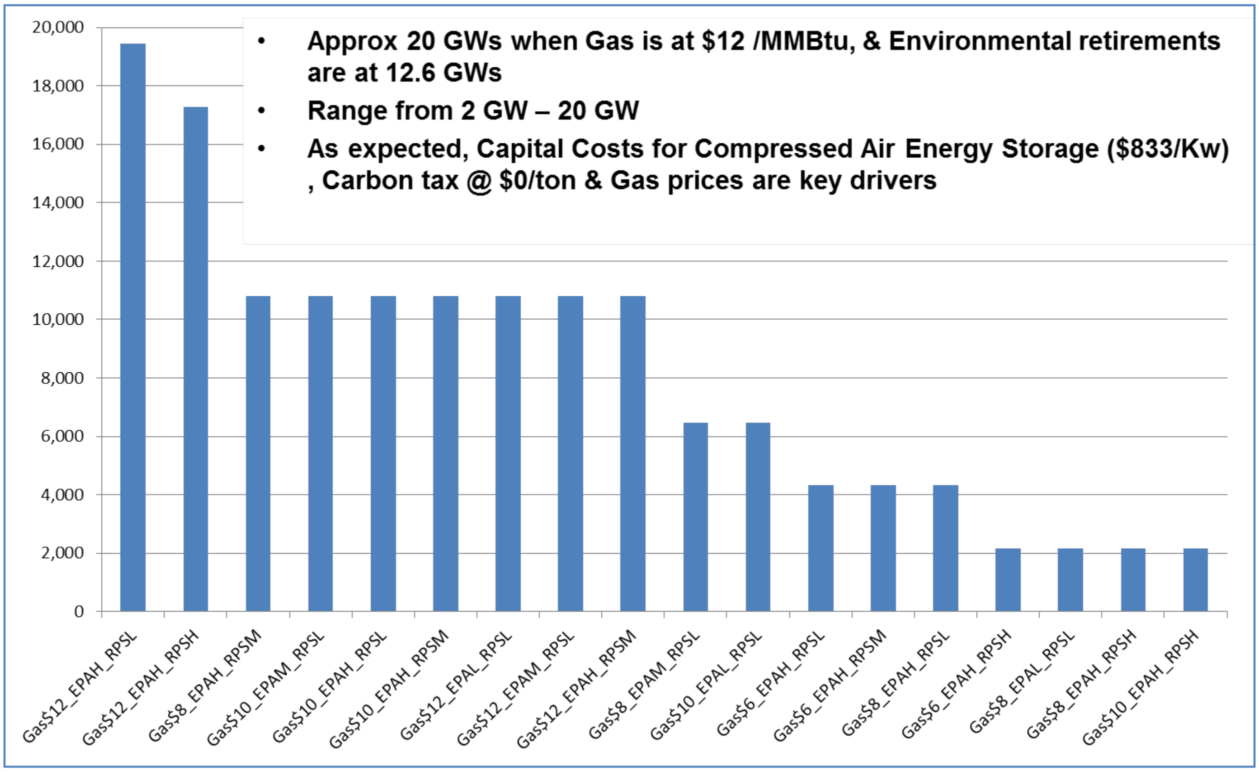
One example of a regional resource planning effort that has made an effort to incorporate storage as a major resource in integrating renewables is the MidWest ISO (MISO) in its Transmission Expansion Plan [1] The regional resource forecasting model EGEAS was used to provide insights into the economic potential for storage on a long term basis. The results showed storage penetration could be as high as 20,000 MWs when the gas price is highest ($12 per MMBTu), and the level of environmental retirements are at 12,600 MW with a $0 per ton carbon cost and capital costs of new storage unit lowest ($833 per kW). EGEAS chose storage as an economic alternative only in 18 cases out of the possible 405 simulations. Figure 15 shows a summary of these results for illustrative purposes; in general the economic

[68] http://www.nrel.gov/wind/systemsintegration/ewits.html

[69] http://www.nrel.gov/wind/systemsintegration/wwsis.html

penetrations of storage are very much a function of renewable penetration, gas costs, and the capital costs for energy storage.

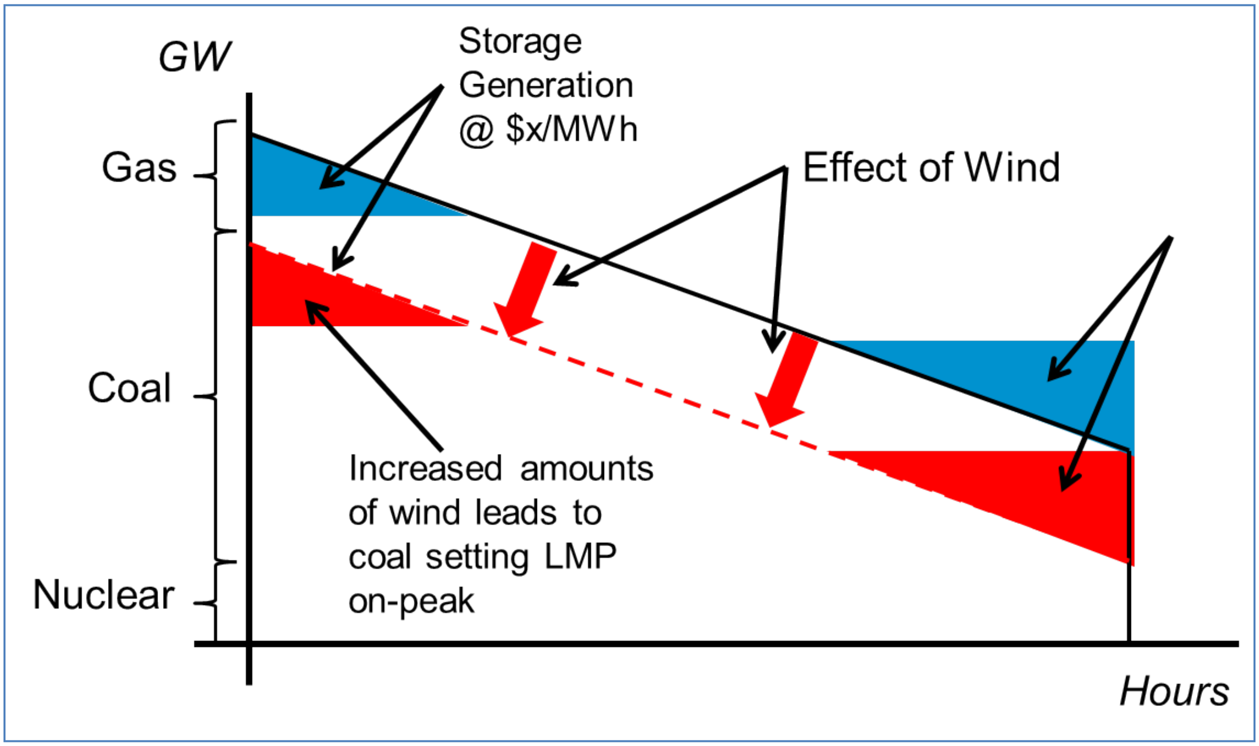
**Figure 15: Summary of EGEAS results Demonstrating Storage as Economic Alternative**




Going against conventional logic, EGEAS also showed lesser opportunity for storage (2,000 MW) when the wind penetration was at its highest (30% by 2025). However, the results confirm the scope of the economic valuation of storage providing a clear answer to the question - *what does it take to make energy storage economical for grid scale applications?*

Investigating further one of the key business case drivers for energy storage, namely peak versus off-peak price spread (also known as "arbitrage"), MISO staff discovered that in EGEAS when more wind was added to the system – it forced coal to be on the margin instead of gas during periods of peak demand leading to less price spread between the peak versus off-peak hours. This modeling aspect is further illustrated in 16.

**Figure 16: Peak Versus off-peak Price Spread**




MISO Transmission Expansion Plan (MTEP)
https://www.midwestiso.org/Planning/TransmissionExpansionPlanning/Pages/TransmissionExpansionPlanning.aspx

The results confirm the hypothesis around wind penetration, system cost, and the level of base load capacity available impacting the storage is valid. MISO's results should only be looked at from a long term economic potential for storage perspective. Detailed analysis especially related to the operational (e.g. regulation requirements) and transmission (e.g. congestion trade-off) oriented drivers is warranted to fully delineate the storage value drivers.

Some applications and especially combinations or bundling of applications are much less well understood and accepted methodologies and mathematics for valuing them still under development. Even after there is a library of engineering and cost benefit analyses for these applications, it will take some time before operational data is available to validate them.

6) Accepted planning and operational methodologies to deal with storage – analytical methods, training, and readily available software tools

Utilities and their supporting organizations (engineering consultants, example) as well as regulatory staff are accustomed to developing and assessing capital investment plans using long accepted engineering planning software tools. For any given engineering problem, there are typically 2 -4 tools or platforms that are widely used, whose results are accepted, and which the workforce is readily able to use. These tools do not support storage today as a type of equipment – in their data bases, their models, or in the ability of their solution mathematics and code to incorporate them, optimize them, and simulate their operations. This is true of production cost simulation / unit commitment tools, of transmission analysis tools, and of distribution planning tools. Because the engineering fraternity cannot model and analyze storage in its many applications, it is not going to be considered as part of the solution. This restricts demand, and the lack of demand for storage not only depresses the overall market development but also provides little demand for the providers of software tools to incorporate storage.

### 5.1.1 Renewable Energy/Portfolio Standards versus Clean Capacity Standards; Redefining Policy Debate

Businesses have moved from maintaining a long-term inventory to “just in time” delivery of materials. The electric industry has always provided its product “on demand.” However, with the increasing reliance on variable generation sources, quality power, new types of demand (e.g., EVs), and more reliable power in the form of micro grids, operating the electric system is becoming more complex and difficult. The ability to technologically and cost-effectively store electricity at sites at any point from the generators to the customer to meet these new operational challenges/opportunities is a potential “game” changer.

The electric power sector has seen a decade long trend of decreasing capacity factor – the daily and seasonal load shape has become “peakier” meaning that the ratio of average utilization to peak utilization has been decreasing steadily[70]. Figure 17 shows capacity factor over time on a national basis.

This is due to a number of effects: the increasing penetration and usage of air conditioning is a large one, and in the near term increased renewables penetration will act to further decrease capacity factor of conventional generators – and as well distributed renewables generation will decrease T&D capacity factors. While nighttime charging of Electric Vehicles would act to counter this trend, day time charging in parking lots and parking garages will have the opposite effect, and some believe that consumers will rationally charge vehicles at every opportunity due to “range anxiety.”

–Electric industry infrastructure planning and investment follows peak demand because of the requirement to meet a 1 day in 10 year reliability standard. Peak demand is largely driven by air conditioning demand in the summer and heating and lighting demand in the winter. This leads to power system infrastructure that is underutilized in off-peak periods. There are a number of ways to address the problem of capacity utilization. One way is to create pricing incentives at the retail level so that consumers can choose whether they want to pay for the increased infrastructure caused by their on-peak demand and incent them to consume in off-peak periods. Another way is through the greater utilization of storage, since storage technologies effectively act as consumers during off-peak periods and producers during on-peak periods. Market incentives should be structured so as to allow demand response, storage and generation

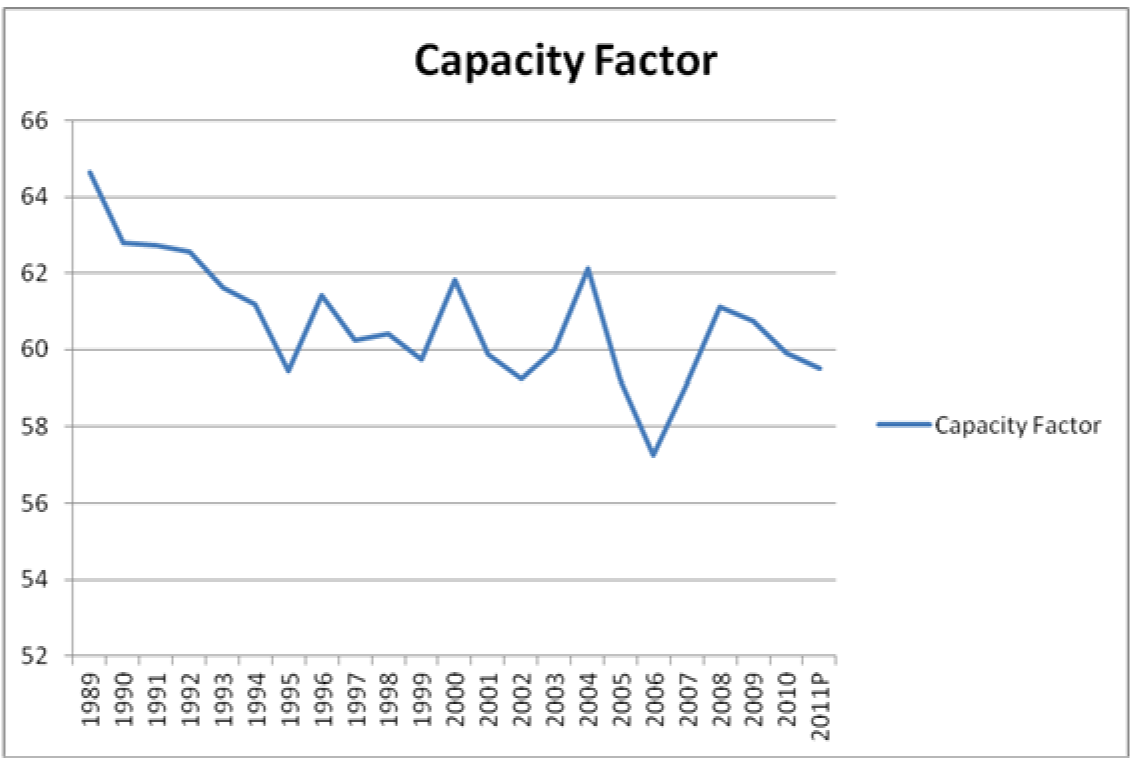
[70] U.S. Energy Information Agency.

technologies to compete on a level playing field. This will lead to the economically optimal level of infrastructure investment.

Storing electricity will allow the industry to optimize capacity factors throughout the supply chain – production, transmission, distribution, and end usage – if it is cost effective to do so. Economic studies that showed the total capital and operating benefits of substituting storage for increased peak capacity would be immensely useful in informing the policy debate and perhaps changing the terms and focus of the renewables integration and infrastructure investment discussion.

Storage, demand response and fast start/responsive generation can be used to mitigate the variability injected into the system by renewable generation technologies. Existing renewable penetration studies deal with future uncertainties by examining “scenarios” of portfolio development. The role that storage assets can play in balancing renewable resources should be considered in these scenario analyses.

**Figure 17: Capacity Factor**




Storing electricity will allow the industry to optimize capacity factors throughout the supply chain – production, transmission, distribution, and end usage. This dimension of the policy debate around renewables integration and long term infrastructure investment has not been phrased in such stark terms of overall supply chain optimization before. Economic studies that showed the total capital and operating benefits of substituting storage for increased peak capacity would be immensely useful in informing the policy debate and perhaps changing the terms and focus of the renewables integration and infrastructure investment discussion.

Storage is potentially a risk mitigator in the face of unknown variability in future renewables penetration, as well. Existing renewable penetration studies at best deal with future uncertainties by examining "scenarios" of portfolio development. The role that storage assets can play in reducing the risks inherent in forecasting future resource portfolios is not a factor in these studies today.

### 5.1.2 Mitigating Early Adopter Risk

As previously mentioned above, state utility regulators tend to be reluctant to approve new technologies that may, or may not, improve system reliability, stability, or performance due to concerns about the viability of the new technology. Pilot programs in other states with other utilities frequently are not accepted as being conclusive because the conditions may not be exactly equivalent. Regulatory uncertainty and hesitation mean that utilities are reluctant to propose innovative technology adoptions due to concerns over PUC rejection or, what would be even more problematic, a disallowance of costs already incurred for an investment if the new technology does not perform as expected.

It may well be that "unknown" technology risks such as asset longevity carry significantly higher "risk premiums" absent good data on the actual risk. Such an implicit risk premium raises the effective cost barrier to new technology penetration. Pilot programs for a few years may not fully mitigate this effect. Pilot programs serve to demonstrate that the technology works and to provide a real world data point on the problems encountered and the benefits realized over the duration of the project.

An investigation of how existing insurance, risk mitigation, performance guarantee, or other structures as used in energy or other domains would be useful. Some initial concepts are discussed below. The EAC is not recommending that a particular approach be taken, nor can we recommend explicitly that such a risk mitigation approach be adopted as policy absent an analysis of the costs; however, this is an important issue in achieving penetration of the new technology that would benefit from serious analysis and consideration.

Possible structures could include:

- Long term risk coverage as provided to the nuclear industry. (this example may not fit as the coverage is against very large risks associated with accidents and not premature end of life risk)
- Loan guarantees as provided to any number of startup industries but specifically to the energy industry examples such as photovoltaic and battery manufacture. These could be provided instead directly to utilities and tied to specific storage assets, or to investors that were leasing these assets to utilities.
- Incentives or tax credits against commercial insurance provided to and procured by electric utilities against asset failure. If backstopped by excess loss coverage to the

issuing underwriter to address their concerns over unknown quantifications of the risk, this might provide the desired risk mitigation.

- Incentives, tax credits, excess risk coverage, and back stop guarantees so that manufacturers can offer longer warranties for the assets. Another possibility is allowance for manufacturers to gain the tax benefits from early recognition of possibly higher warranty costs in the future without penalties they fail to materialize. Any path that considers warranties as a mechanism has to deal with the risks inherent in a start up business with no financial mass or track record as compared to a very large corporate entity.

A related aspect of this is to focus technology R&D on the longevity/performance issue as a way to provide more information to the entities assuming the risks or providing the financial risk mitigations. The better information that is available, the better decisions that can be made, and the lower the excessive risk premiums implicit in the perceived costs of the technologies will be.

# 6 Recommendations

## Near-Term Goals (3–5 years)

- The EAC strongly encourages that DOE continue basic electrochemical research aimed at exposing the "genome of the periodic table" over time – exploring the potential for energy storage based on new electrochemistries and their practical realization.
- Complete detailed studies of the effects of higher penetration of renewable sources on grid operations and the permanent retirement of a large percentage of traditional generation. As noted in section 4, this is an ongoing and open area due to the complexity of the problem and the continuing discovery of issues by researchers. The goals of RPS studies should be modified to consider changing end use penetrations, changing T&D infrastructure capacity utilization, and how these will affect storage economics. Work in assessing the role of storage as part of a portfolio of flexible generation, storage, and demand response for renewables integration is needed.
- Multiple large scale demonstration projects are underway. Additional projects should be planned following the update of DOE OE's storage plan identified above and as completed R&D and demonstration projects inform the checkpoints along that roadmap. Short-term progress on larger demonstration projects needs to continue.
- The Energy Independence and Security Act of 2007 required DOE to establish four Energy Storage Research Centers. An RFP for one storage "hub" was released in February 2012 with an award yet to be made (as of this writing). The EAC recommends that this storage hub should be funded and an award made.
- DOE should develop and make public for discussion and debate its roadmap for technology development for storage from TRL 1-2-3 to TRL 8-9, including checkpoints, signposts, and decision criteria.
- Provide funding for up to 30% of the cost of energy storage technology investments required to demonstrate the performance of the objectives cited above. More than satisfied – refer to sec 3 and appendices. This activity should be continued following the development of the technology roadmap and utilizing the decision points established in it to identify suitable demonstration projects and technologies.

## New Short Term & Mid-Term Goals

- Continue to fund (up to 30%) energy demonstration storage projects of new technologies arising from ARPA-E and other developments targeted at moving technology from TRL 3 to TRL 7-8 that expand the use of storage for grid performance enhancement and show benefits to increasing the use of renewable energy resources.
- Measure and report the impact of PEVs and on performance of the grid in terms of peak loading and any change in the need for ancillary services, and on the impacts of EV load and charging behavior on the T&D system and on methods to address issues identified.

Investigate the integration of EV charging with renewable generation. Consider the use of local energy storage as a way to mitigate the impacts of “fast charging” (Level 3 charging)  These measurements and analyses have to be performed in the context of local “pockets” of PEV adoption today as in general PEV penetration is not sufficient to exhibit any impacts on a national or regional basis.

- Continue Funding of next-step R&D activities based on the results from the “materials genome project” cited above.
- Develop R&D projects focused on better understanding of storage longevity in different applications for existing and new storage technologies.
- Evaluate ongoing larger-scale demonstrations of energy storage technologies for transportation to include large truck and rail applications and the effect on T&D systems and grid and market operations of such technologies at scale.
- Develop and conduct an educational outreach program to state regulators and legislators involved in energy issues. Conduct this in on site workshops per the preferences expressed by the ESA survey respondents rather than in webinars, publications, or national conferences. Focus especially on commission and legislative staff assigned to renewable integration, advanced energy technology, and other related areas.
- Consider research into better understanding how different incentive designs and longer term performance guarantees / risk mitigation will actually influence investment behavior and support (or not) underlying policy goals, including better anticipation of unintended consequences.
- Support studies to expose the emissions benefits of storage as a source of ancillary services and the impact this has on the net emissions benefits of variable renewable resources.

## Long-Term Goals (2020 and beyond)

- Implement programs to test and analyze vehicle-to-grid (V2G) performance and the impact on grid operations.

## Appendix A. DOE Large-Scale Energy Storage Project Database

DOE initiated development of the Energy Storage Database in August 2011, and released a beta version in May 2012.[71] Improvements and enhancements to the beta version are underway.

The goal of the DOE Energy Storage Database is to become the premiere "go to" source for information on large-scale energy storage projects in operation or under construction. To make the database as accessible and inclusive as possible, it is being delivered as a publicly available resource at no charge. The content is based on project information that users voluntarily provide. While the Energy Storage Database does not currently contain a comprehensive list of energy storage projects, it is expected that the database coverage will become significantly more extensive as additional projects are added by users.

To ensure data quality, all newly entered records are vetted by qualified individuals before the records go "live" and become accessible to the public. During the vetting process, the equity owner of the project is contacted and interviewed to ensure all project data are accurate and may be published. To help expand coverage of the Energy Storage Database, DOE collaborates with storage industry associations and stakeholders to identify and enter appropriate projects.

As of August 2012, the DOE Energy Storage Database contained 58 projects with a total capacity of 5.3 GW. **Figure 18** shows a breakdown of these projects grouped into four different size ranges. The smallest project is a 10 kW Amber Kinetics flywheel announced for installation in California. The largest is a 3 GW pumped hydro system operating in Virginia.

[71] The DOE Energy Storage Database is available on-line at http://www.energystorageexchange.org/ .

**Figure 18: Storage Projects by Size Range, DOE Database**

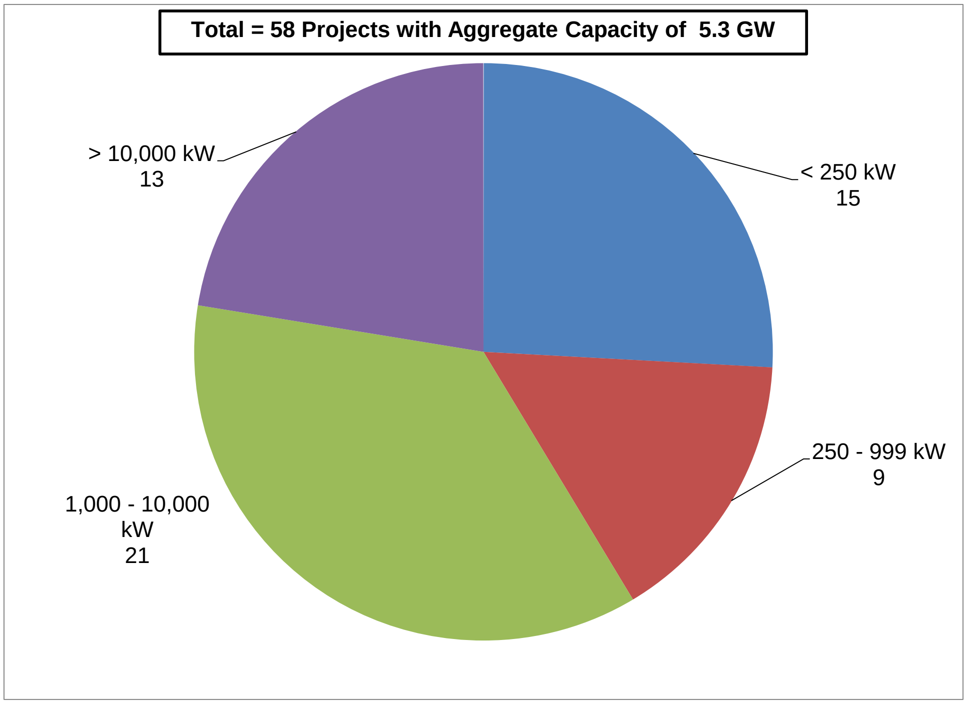



**Figure 19** shows the projects grouped by technology type that are represented in the DOE Energy Storage Database. Batteries are the most common (36 total), followed by thermal storage (14), compressed air (4), pumped hydro (3), and flywheels (1). From a capacity perspective, the three pumped hydro projects represent the largest fraction of power. As indicated in **Figure 20**, pumped hydro accounts for 83% of the power. These pumped hydro projects include a 3 GW operational system in Virginia, a 1.3 GW contracted plant in California, and a 40 MW project under construction in California.

**Figure 19: Storage Projects by Technology Type, DOE Database**

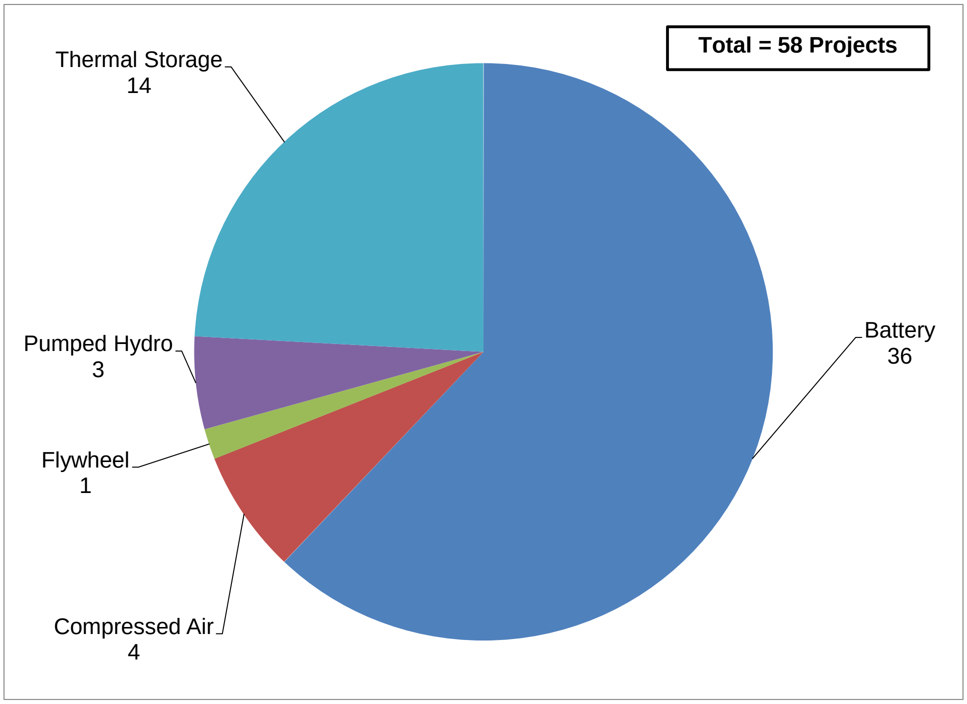
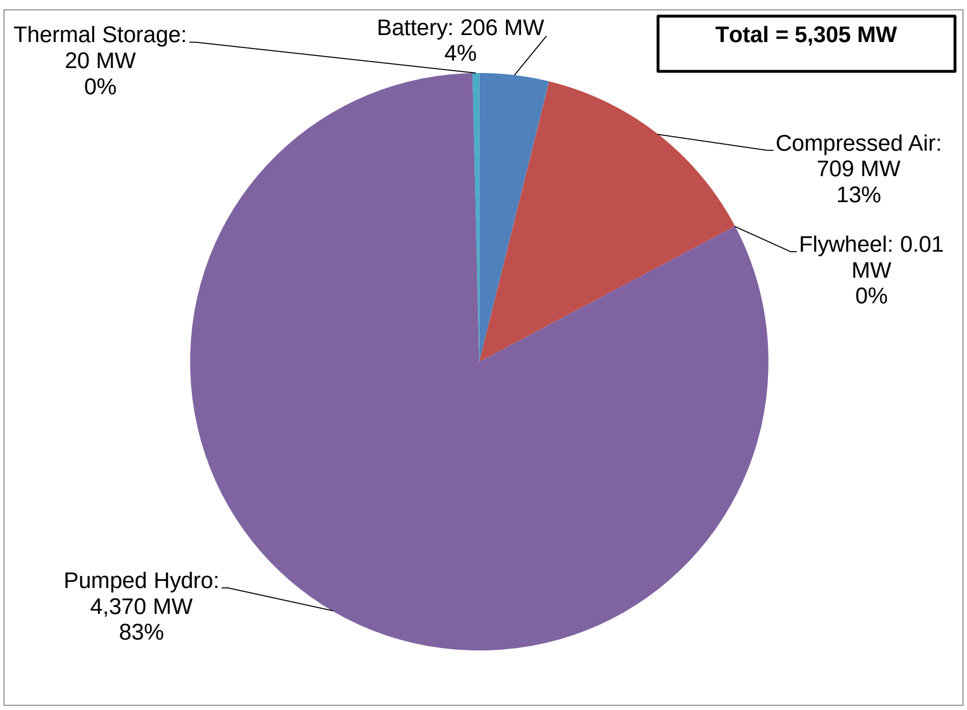


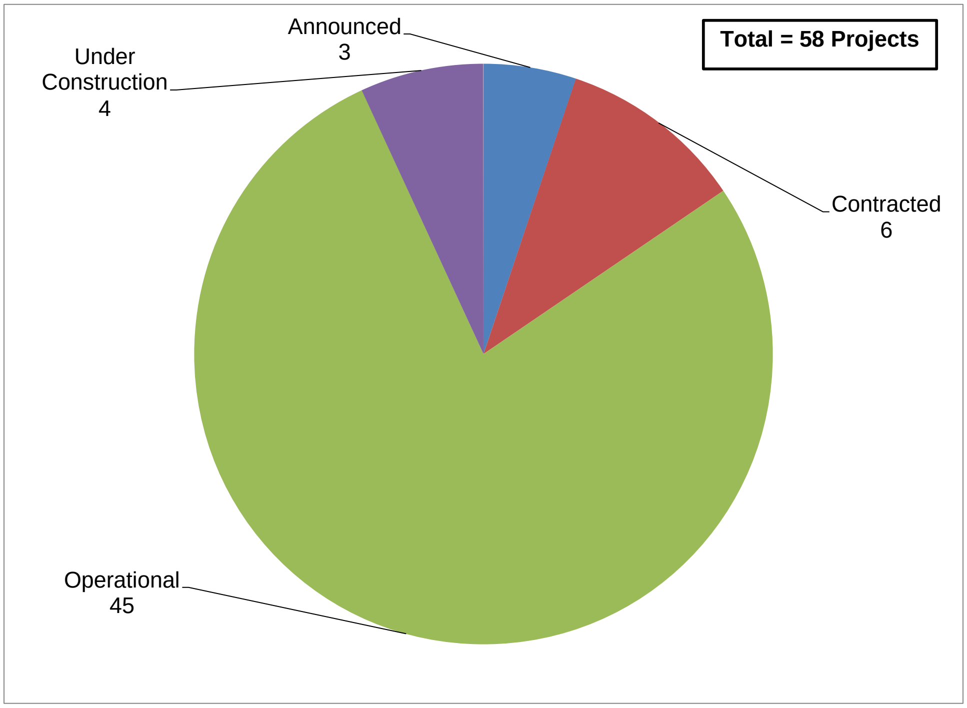

**Figure 20: Storage Capacity by Technology Type, DOE Database**



The majority of projects now entered in the DOE Energy Storage Database – 45 of 58 records – are operational systems (see

**Figure** 21). The other 13 projects have a status of announced (3), contracted (6), or under construction (4).

**Figure 21: Project Status, DOE Energy Storage Database, August 2012**



# Appendix B. ESA Survey of State Legislative and Regulatory Bodies

The Electricity Storage Association (ESA) conducted a survey of selected PUC Commissioners and State Legislators to determine how much information about electricity storage these decision-makers have, the most trusted sources of information, their highest information needs, and their preferred means of "learning" or receiving educational information. The Commissioners and Legislators were primarily selected because they are engaged in professional association committees (e.g., NARUC Electricity Committee, NCSL Energy Supply Task Force) that help develop energy policies for their colleagues. Thus, the selected survey respondents reflect the "upper" levels of subject knowledge and interest, thereby establishing knowledge thresholds. The ESA has shared the survey results with the EAC's Electricity Storage Subcommittee and will do the same with NARUC, NCSL, and other appropriate organizations.

The questions posed to legislators and to regulators were fine tuned slightly for the two different populations. The questions to legislators and an analysis of the responses follow:

1. The ESA is interested in the **level of knowledge and exposure the state legislative community has with energy storage technologies**. Please check the description that most closely describes your experience:

    ____ I have a very general awareness of energy storage.

    ____ I have read some information about energy storage but do not have first-hand experience.

    ____ I have studied energy storage and have a good understanding of these technologies and their benefits.

    ____ I have seen or proposed legislation involving energy storage and made a policy decision based on my knowledge of the technologies and their value.

**Figure 22: Legislators Knowledge of Storage**

2. Please order the following **sources of information on credibility and usefulness** in legislative policy decision-making on the prudence of an investment in new technology (with “1” being the most credible and trusted source):

   ____ Third party cost-effectiveness study, generic to the technology

   ____ Third party cost-effectiveness study, specific to a rate case or policy

   ____ Utility cost-effectiveness study

   ____ National laboratory reports

   ____ Federal agency (like Department of Energy or Department of Defense) report

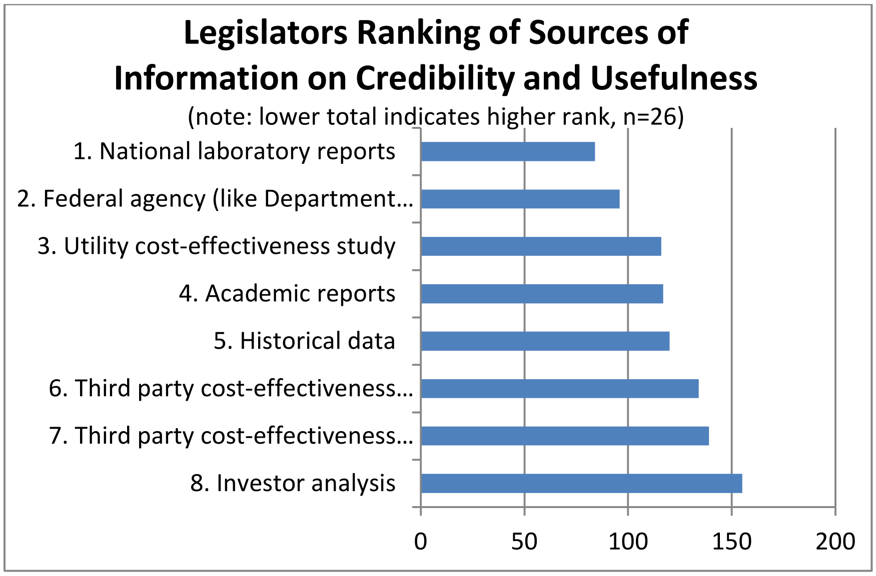
   ____ Academic reports

   ____ Historical data

   ____ Investor analysis

   ____ Other ____________________________________________

**Figure 23: Legislators Ranking of Sources of Information on Credibility and Usefulness**




3. Effectively communicating information between federal and state lawmakers, regulators, industry, and other stakeholders for the purpose of developing dialogues and consensus among all parties is frequently difficult to achieve. Please rank the following **communication tools** for conveying information to you and your staff about projects, policies, and other issues of importance to you (with “1” being the best):

    ____ Electronic (such as e-mail) notifications directly to you containing information with links or attachments

    ____ Electronic (such as e-mail) notifications to your staff containing information with links or attachments

    ____ Hard copies of report and other information mailed to you

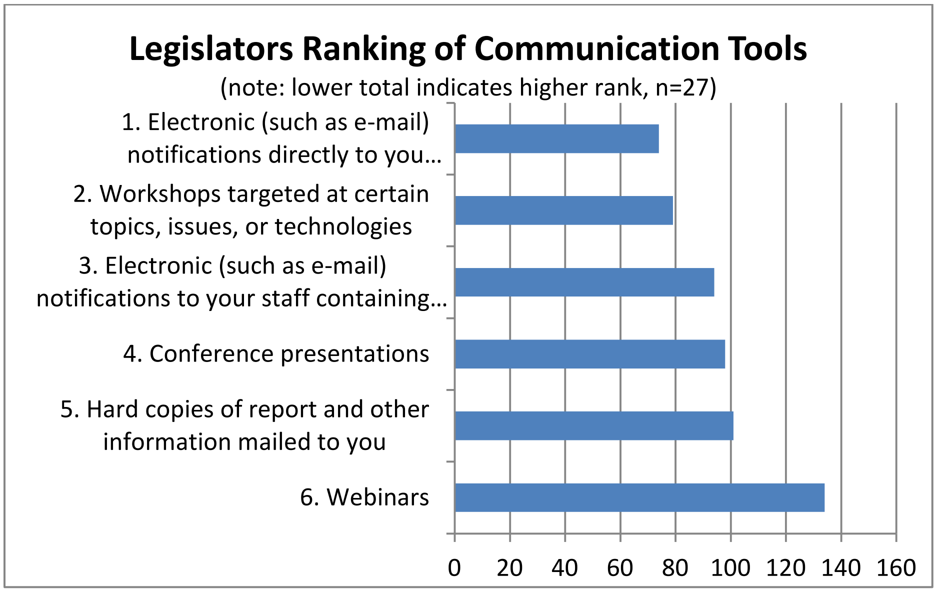
    ____ Webinars

    ____ Workshops targeted at certain topics, issues, or technologies

    ____ Conference presentations

    ____ Other______________________________________________________

**Figure 24: Legislators Ranking of Communication Tools**




4. Making smart public policy is key to the mission of state legislators; information from trusted resources is key to making policy decisions. Please rank order the **types of information that you would rely on** to make decisions and develop policy, assuming that the information came from a credible resource (with "1" being most valuable):

____ Cost allocation models that include electricity storage as a component

____ Information about the role of electricity storage plays in improving the performance of the electric grid and the conditions under which various types of storage may be appropriate

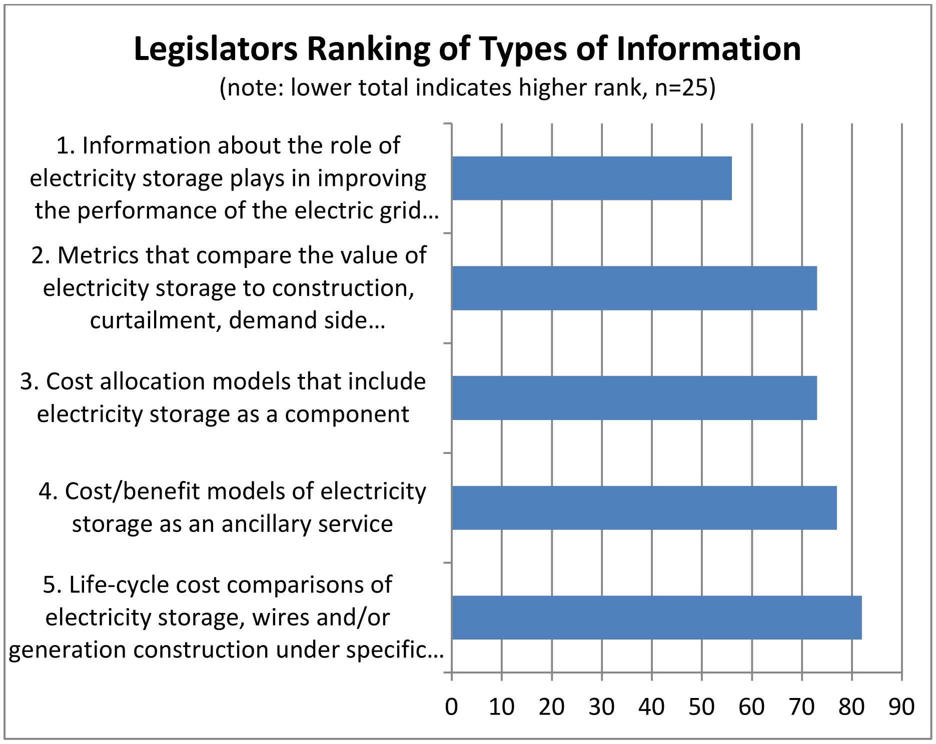
____ Metrics that compare the value of electricity storage to construction, curtailment, demand side management, and other options

____ Cost/benefit models of electricity storage as an ancillary service

____ Life-cycle cost comparisons of electricity storage, wires and/or generation construction under specific conditions and considerations

____ Other ____________________________________________

**Figure 25: Legislators Ranking of Types of Information**




5. Please order the following decision drivers when considering legislative proposals or policies (with "1" being the biggest driver):

____ Renewable Portfolio Standards and other state and local mandates or goals

____ Environmental regulations for traditional generation

____ Electric grid system reliability

____ Customer rates

____ Aging infrastructure

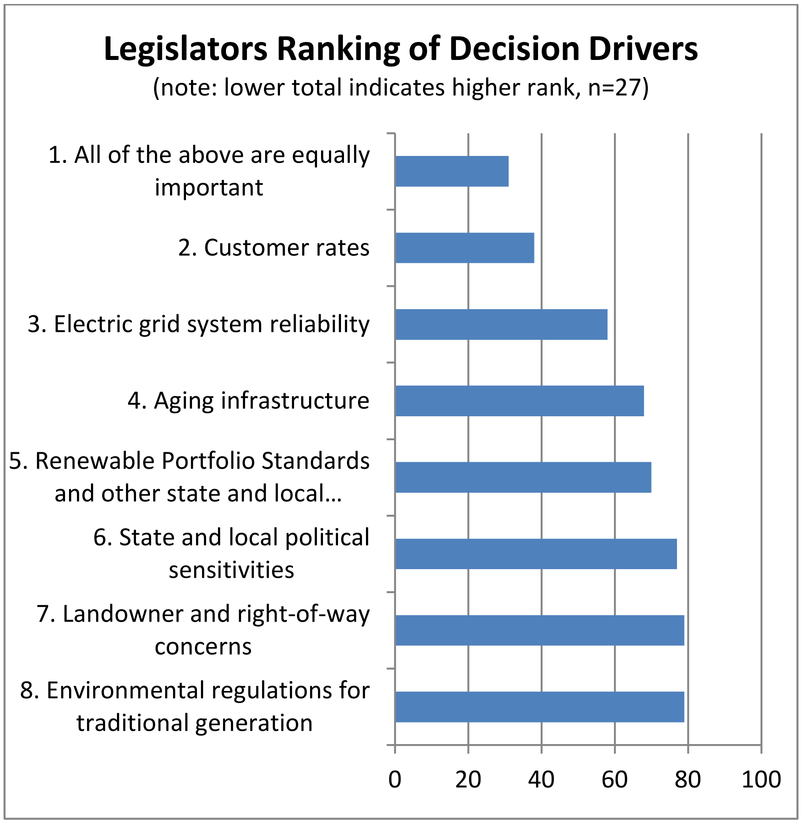
____ Landowner and right-of-way concerns

____ State and local political sensitivities

____ All of the above are equally important

____ Other ____________________________________________

**Figure 26: Legislators Ranking of Decision Drivers**




6. Please rate the following potential **discussion topics on interest and relevance** to you (with "1" being most useful):

____ Legislative initiatives in support of interoperability standards

____ Recognizing and rewarding the role of "first adopters" to advance innovations from the laboratory to pilot project to commercial application

____ Measuring and establishing the value of ancillary services to electric grid reliability and customer satisfaction

____ Consideration of alternative utility company revenue streams beyond commodity and customer charges (this would necessarily include alternative rate-making options)

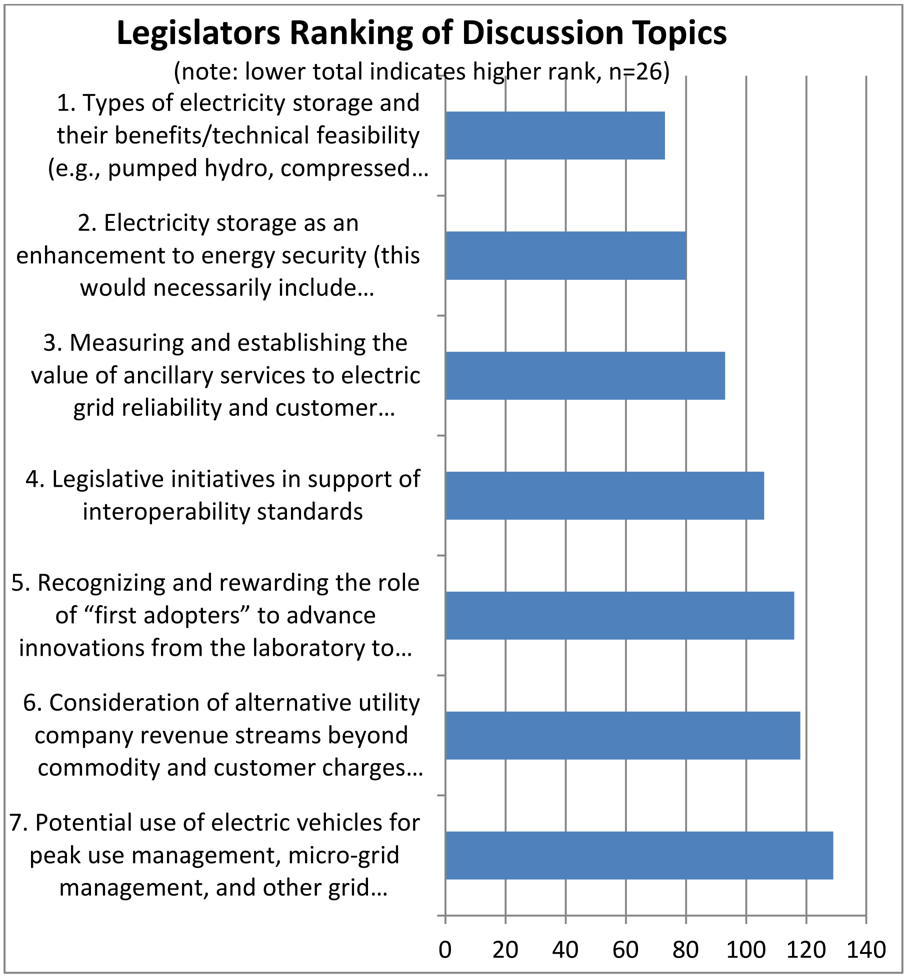
____ Potential use of electric vehicles for peak use management, micro-grid management, and other grid stabilization opportunities

____ Types of electricity storage and their benefits/technical feasibility (e.g., pumped hydro, compressed air, "storage" by transmission line, "storage" by natural gas pipeline, batteries, etc.)

____ Electricity storage as an enhancement to energy security (this would necessarily include discussions about storage capacity and duration of discharge)

____ Other ____________________________________________

**Figure 27: Legislators Ranking of Discussion Topics**




The specific questions posed to state regulators and their responses are as follows:

1. The ESA is interested in the **level of knowledge and exposure the regulatory community has with energy storage technologies**. Please check the description that most closely describes your experience:

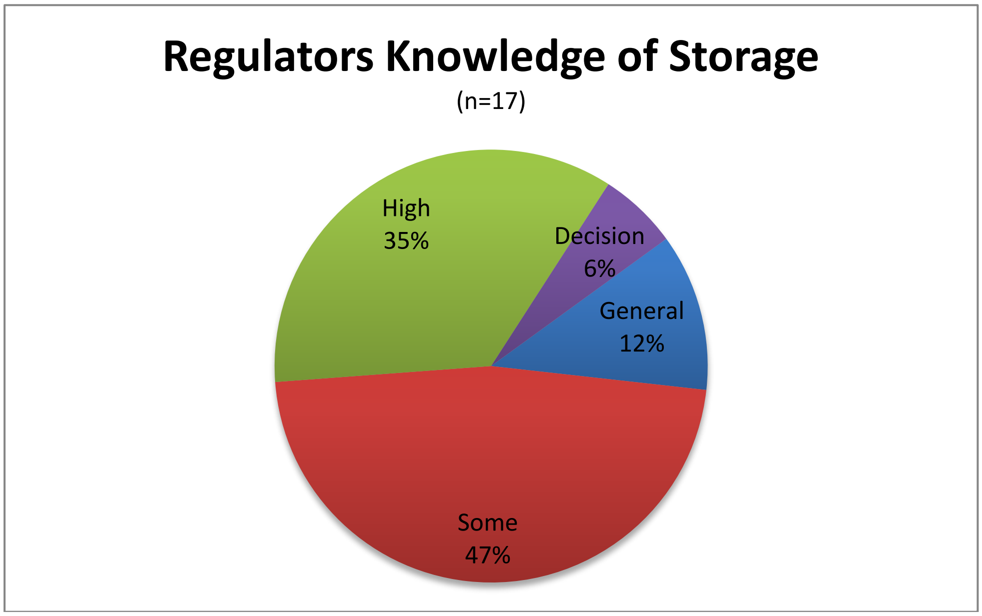
____ I have a very general awareness of energy storage.

____ I have read some information about energy storage but do not have first-hand experience.

____ I have studied energy storage and have a good understanding of these technologies and their benefits.

____ I have seen a rate case or other issue involving energy storage and made a policy decision based on my knowledge of the technologies and their value.

**Figure 28: Regulators Knowledge of Storage**




2. Please order the following **sources of information on credibility and usefulness** in rate case decision-making on the prudence of an investment in new technology (with "1" being the most credible and trusted source):

____ Third party cost-effectiveness study, generic to the technology

____ Third party cost-effectiveness study, specific to a rate case or policy

____ Utility cost-effectiveness study

____ National laboratory reports
____ Federal agency (like Department of Energy or Department of Defense) report

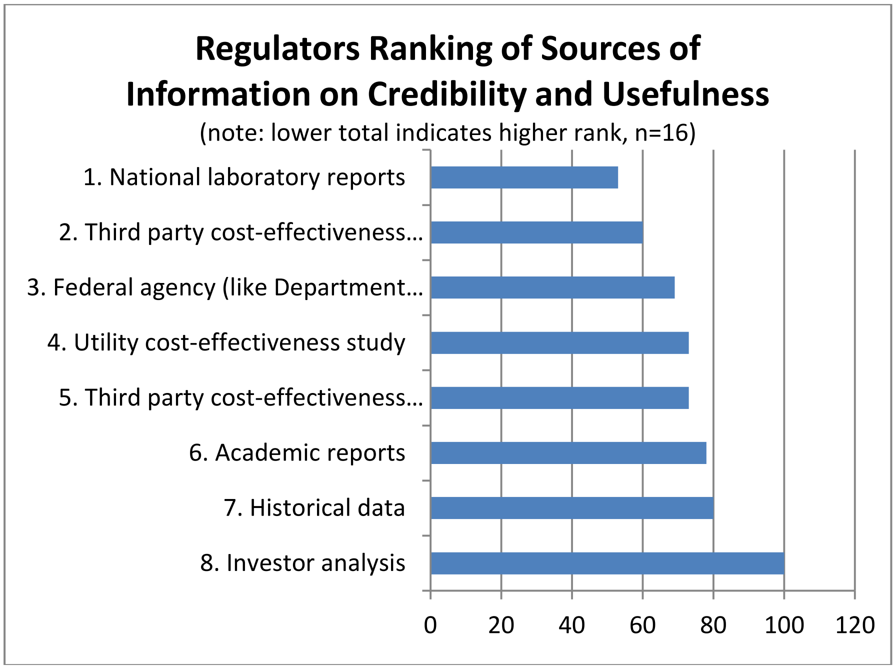
____ Academic reports

____ Historical data

____ Investor analysis

____ Other ____________________________________________

**Figure 29: Regulators Ranking of Sources of Information on Credibility and Usefulness**




3. Effectively communicating information between federal and state regulators, policy-makers, industry, and other stakeholders for the purpose of developing dialogues and consensus among all parties is frequently difficult to achieve. Please rank the following **communication tools** for conveying information to you and your staff about projects, policies, and other issues of importance to you (with "1" being the best):

____ Electronic (such as e-mail) notifications directly to you containing information with links or attachments

____ Electronic (such as e-mail) notifications to your staff containing information with links or attachments

____ Hard copies of report and other information mailed to you

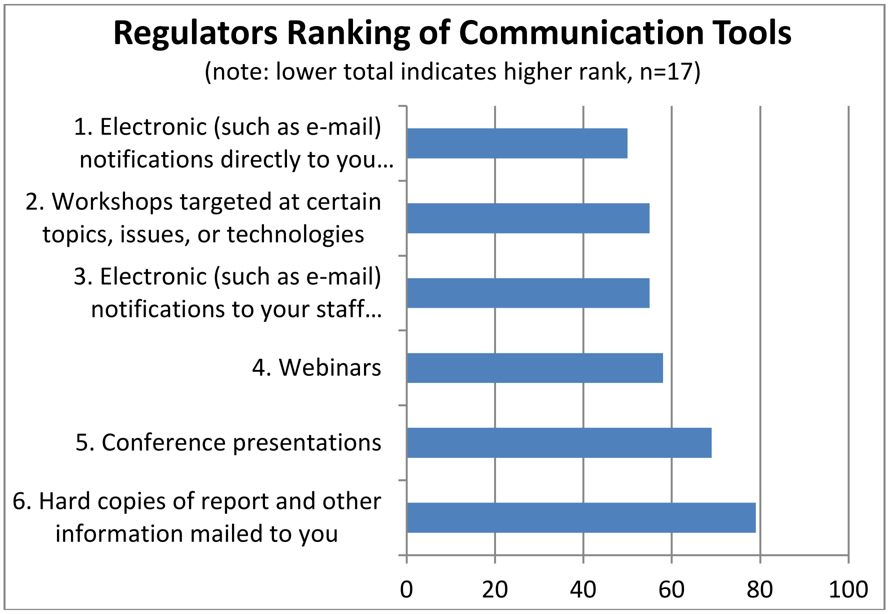
____ Webinars

____ Workshops targeted at certain topics, issues, or technologies

____ Conference presentations

____ Other________________________________________________

**Figure 30: Regulators Ranking of Communication Tools**




4. Managing risk is a critical aspect of the mission of both regulatory commissions and utilities; information from trusted resources is key managing decision-making and investment risks. Please rank order the **types of information that you would rely on** to make decisions, assuming that the information came from a credible resource(with "1" being most valuable):

____ Cost allocation models that include electricity storage as a component

____ Information about the role of electricity storage plays in improving the performance of the electric grid and the conditions under which various types of storage may be appropriate

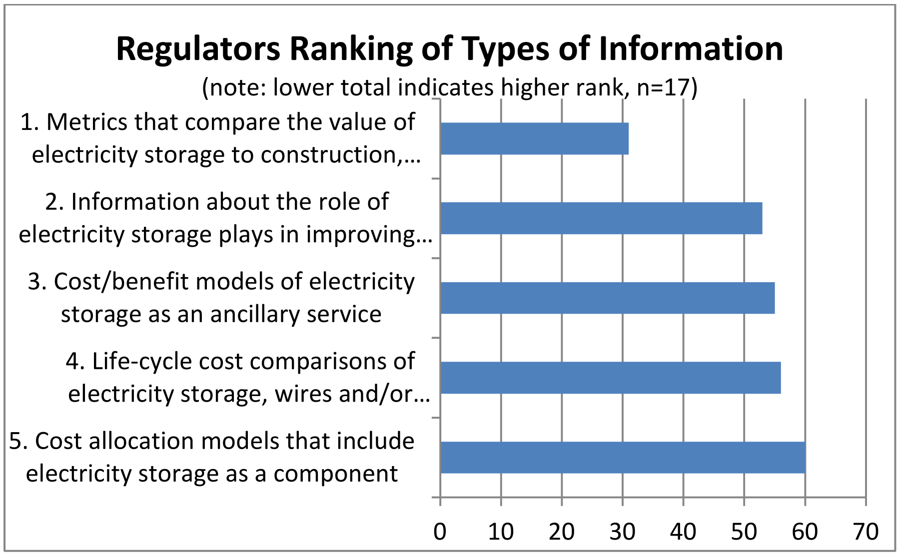
____ Metrics that compare the value of electricity storage to construction, curtailment, demand side management, and other options

____ Cost/benefit models of electricity storage as an ancillary service

____ Life-cycle cost comparisons of electricity storage, wires and/or generation construction under specific conditions and considerations

____ Other ____________________________________________

**Figure 31: Regulators Raking of Types of Information**




5. Please order the following decision drivers when considering utility company investments (with "1" being the biggest driver):

____ Renewable Portfolio Standards and other state and local mandates or goals

____ Environmental regulations for traditional generation

____ Electric grid system reliability

____ Customer rates

____ Aging infrastructure

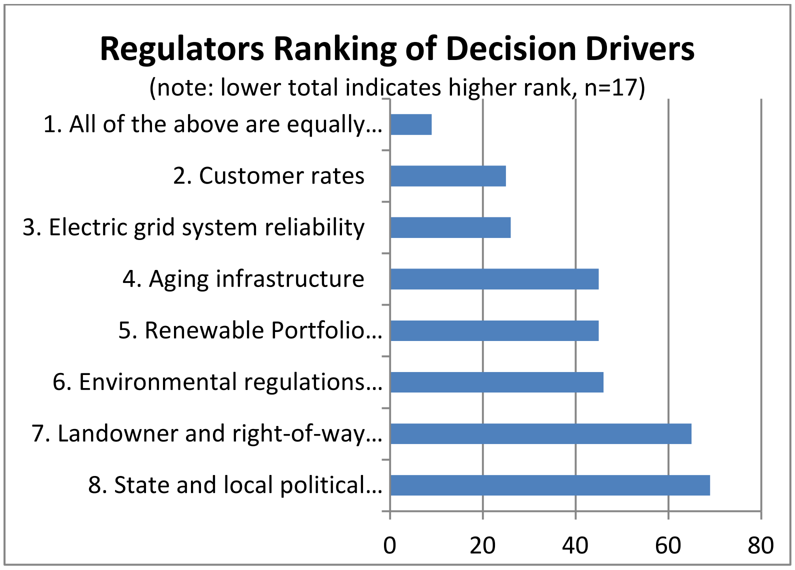
____ Landowner and right-of-way concerns

____ State and local political sensitivities

____ All of the above are equally important

____ Other ______________________________________________

**Figure 32: Regulators Ranking of Decision Drivers**




6. Please rate the following potential **discussion topics on interest and relevance** to you (with "1" being most useful):

____ Regulatory initiatives in support of interoperability standards

____ Recognizing and rewarding the role of "first adopters" to advance innovations from the laboratory to pilot project to commercial application

____ Measuring and establishing the value of ancillary services to electric grid reliability and customer satisfaction

____ Consideration of alternative utility company revenue streams beyond commodity and customer charges (this would necessarily include alternative rate-making options)

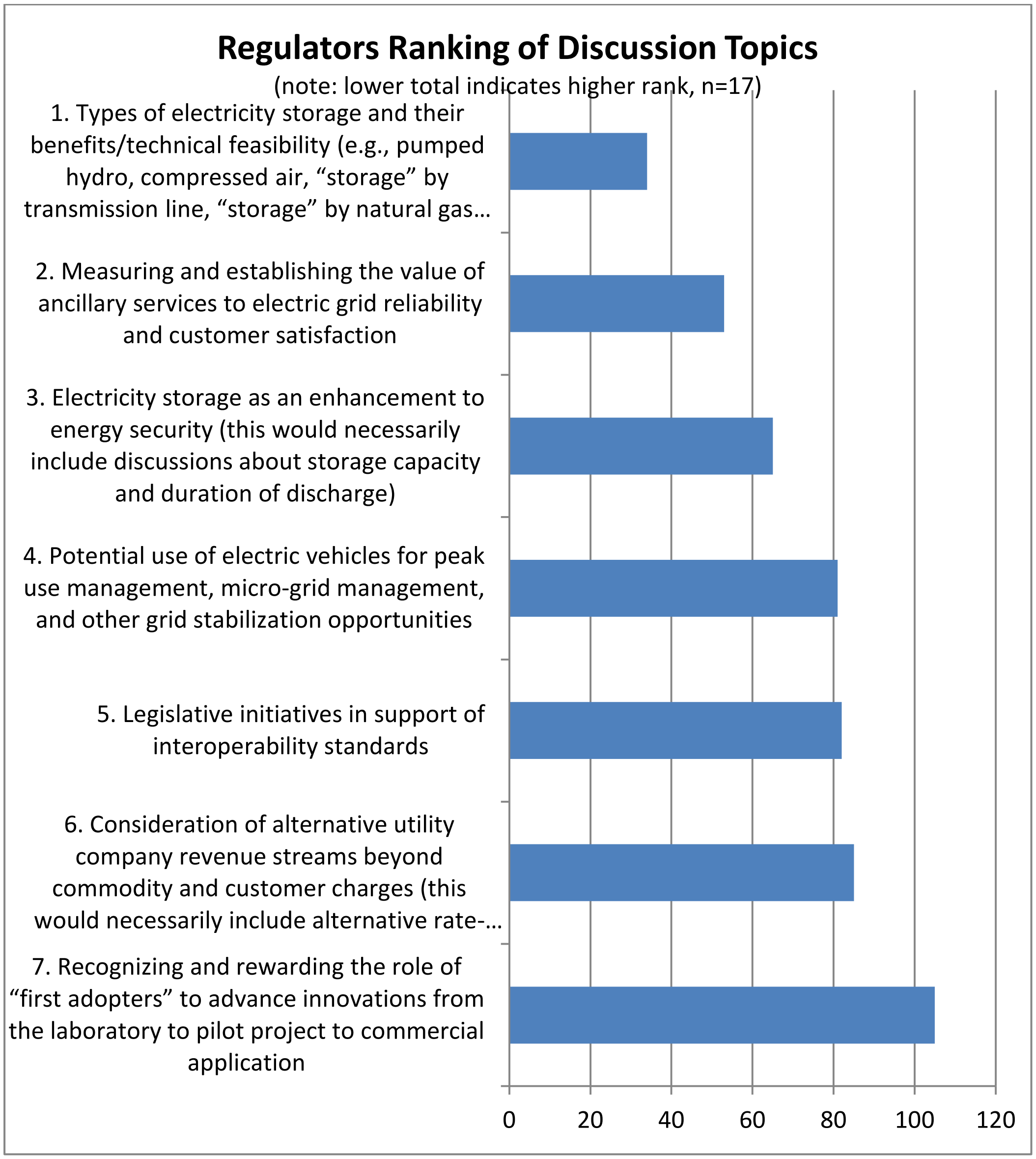
____ Potential use of electric vehicles for peak use management, micro-grid management, and other grid stabilization opportunities

____ Types of electricity storage and their benefits/technical feasibility (e.g., pumped hydro, compressed air, "storage" by transmission line, "storage" by natural gas pipeline, batteries, etc.)

____ Electricity storage as an enhancement to energy security (this would necessarily include discussions about storage capacity and duration of discharge)

____ Other ______________________________________________

## Figure 33: Regulators Ranking of Discussion Topics




On a combined basis the overall responses look like this:

**Figure 34: Combined Knowledge of Storage**

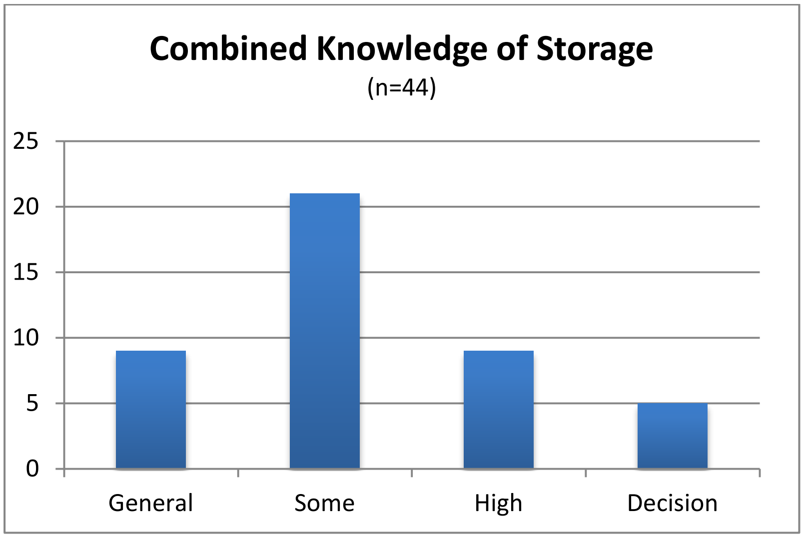



**Figure 35: Combined Ranking of Sources of Information on Credibility and Usefulness**

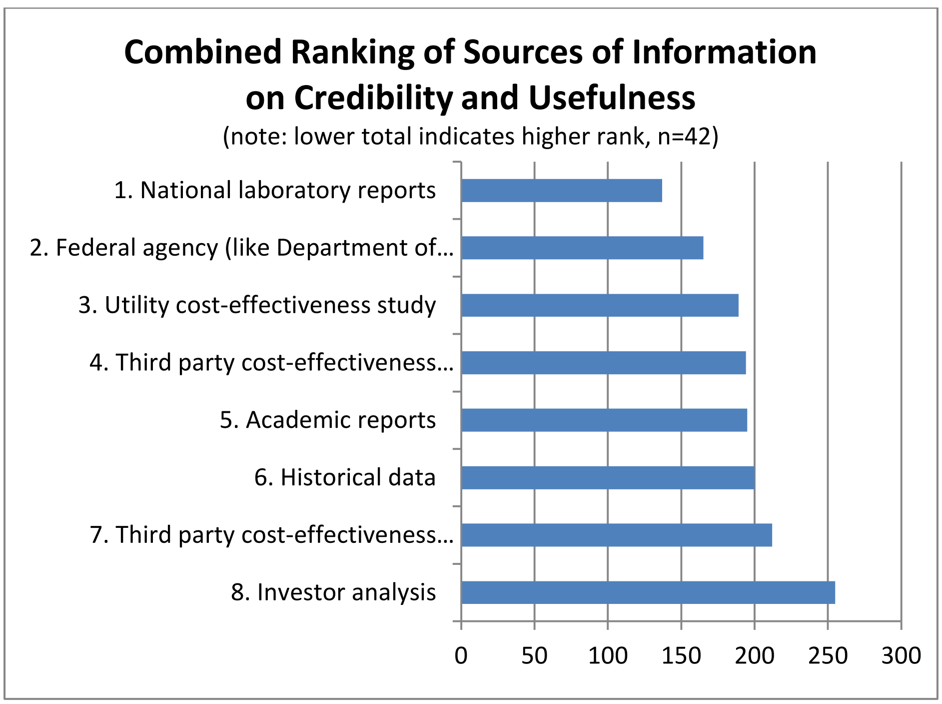


**Figure 36: Combined Ranking of Communication Tools**

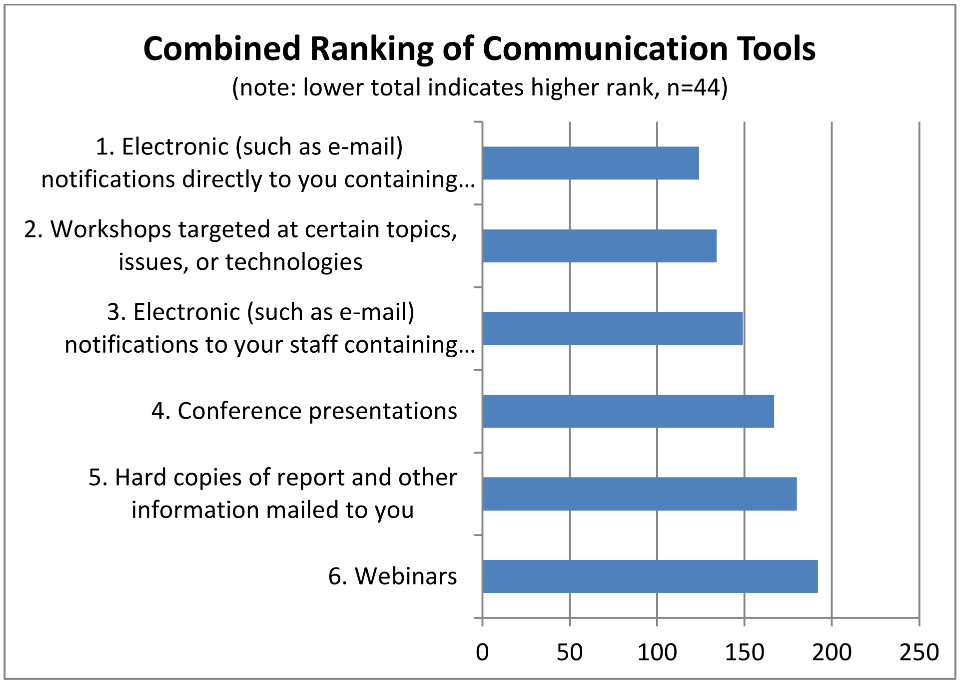
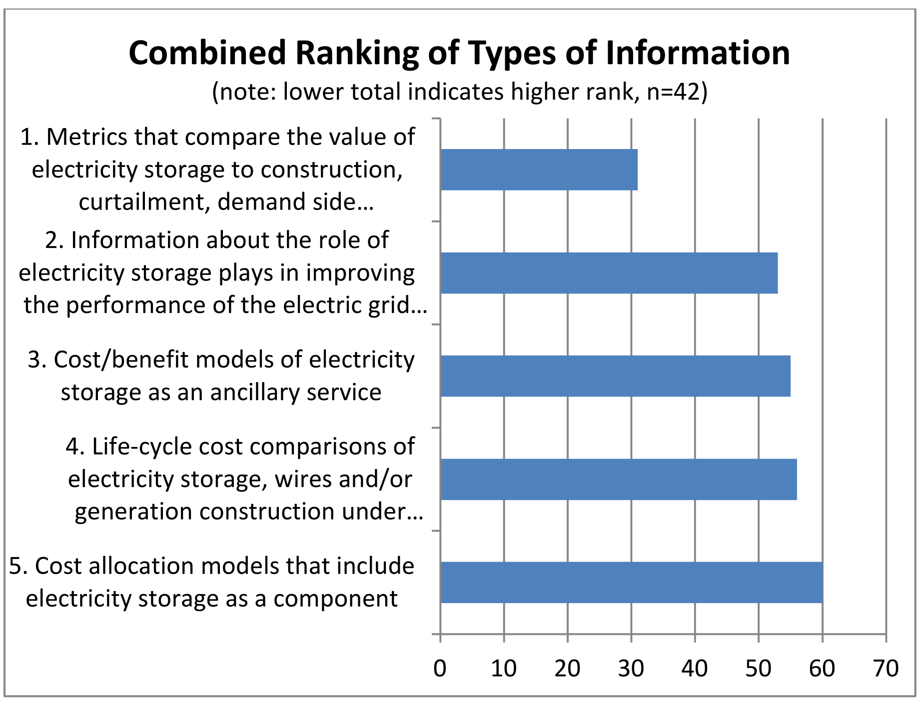



**Figure 37: Combined Ranking of Types of Information**




## Conclusions

In conclusion, based on these survey results, the ESA should be better equipped to develop more focused materials for the regulatory and legislative communities. The majority of regulators and legislators has some knowledge of energy storage but could certainly use additional information; national laboratories and the federal government are the most trusted sources of this information; and direct e-mail communications or targeted workshops are preferred.

Regulators consider comparisons between energy storage and other options of highest importance; legislators care more about how energy storage impacts the electric grid. Many issues--including customer rates, state mandates, grid reliability, aging infrastructure, environmental regulation, right-of-way concerns, and political sensitivities—are of equal importance to regulators and legislators. Both communities want to know more about energy storage benefits and applications.

Finally, while not listed specifically on the surveys, regulators and legislators called out their staff as of key importance to their understanding and decision-making ability on energy storage.

As ESA and the energy storage stakeholder industry continue outreach to state policymakers and their staff, these findings should be taken into consideration to ensure that communication methods and materials are effectively yielding the most informed decisions for energy storage applications.

**Acknowledgements**

Thank you to all survey respondents in the legislative and regulatory community. Special thanks go to Representative Tom Sloan of Kansas who spent untold hours convincing his peers to respond to the survey, and to Brad Roberts, Executive Director of the Electricity Storage Association, who rallied the industry to think through the survey content. Katherine Hamilton, policy director of the ESA's Advocacy Council, and Allyson Groff of 38 North Solutions tabulated the results and drafted the report.

**Figure 38: Combined Ranking of Decision Drivers**

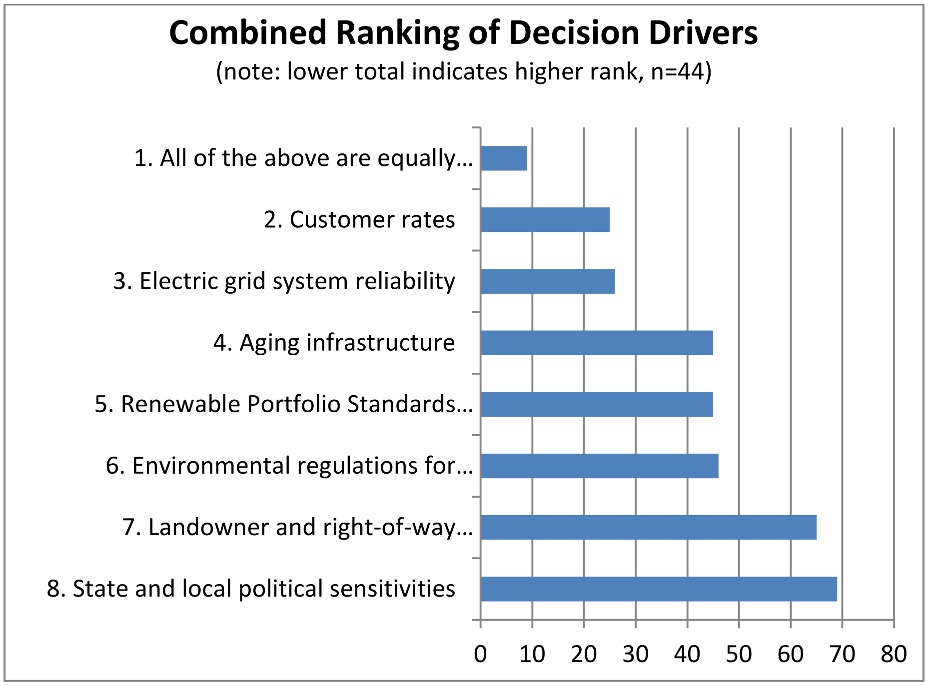
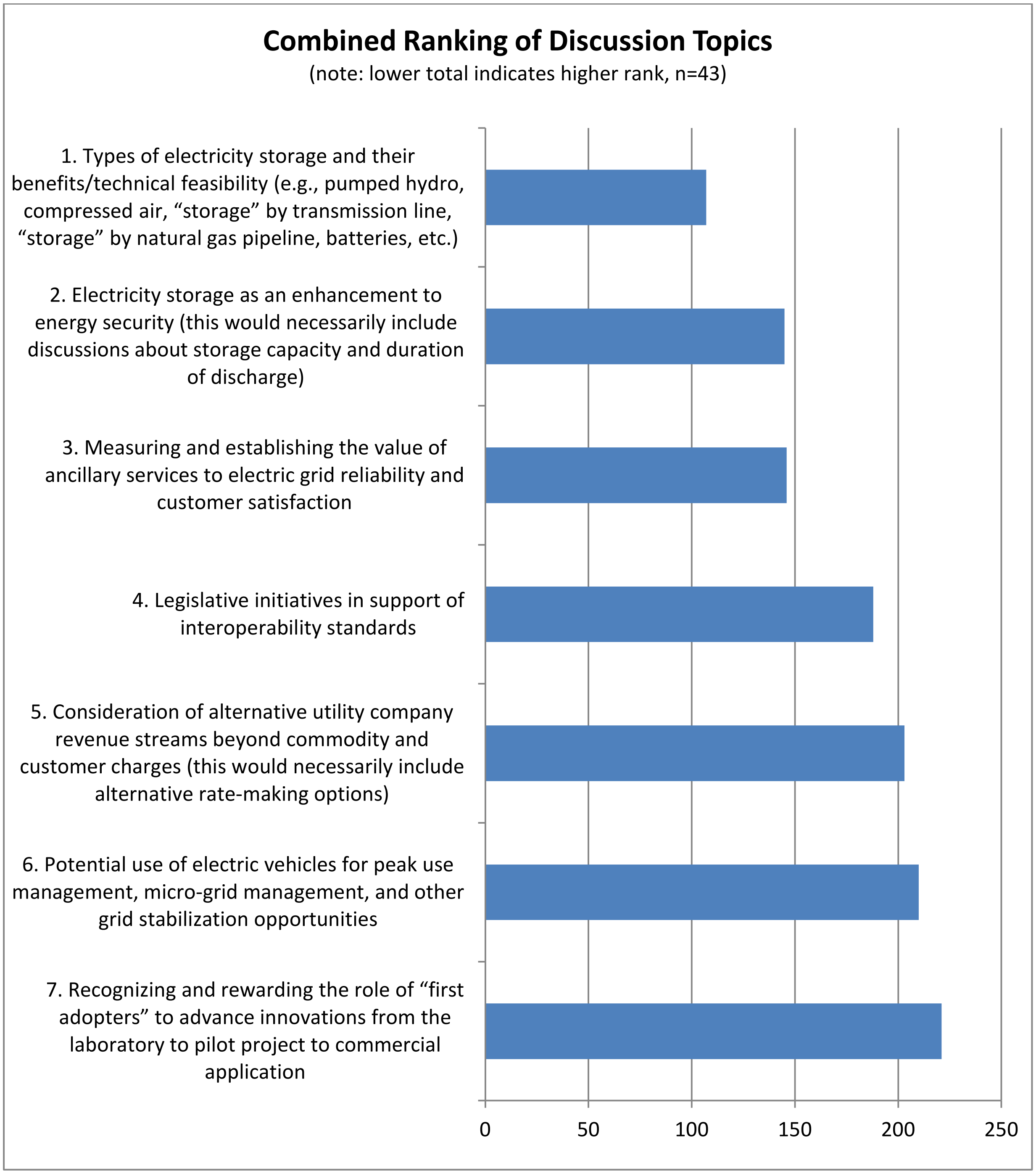


**Figure 39: Combined Ranking of Discussion Topics**



**Electricity Advisory Committee**

http://energy.gov/oe/services/electricity-advisory-committee-eac