Distributed Energy Storage Roadmap

Final Report

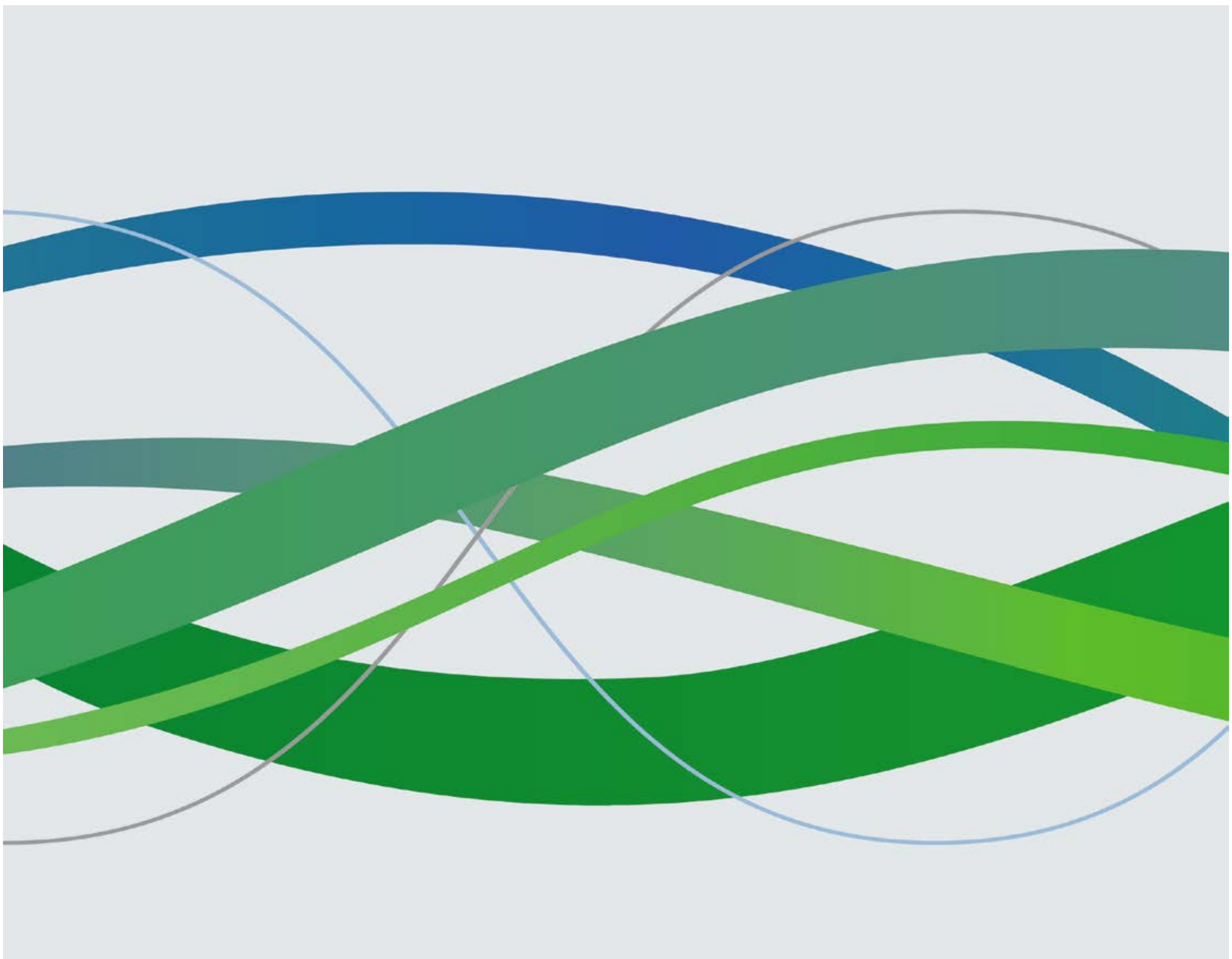
Sandia National Laboratories

Purchase Order #1367482

Prepared by DNV GL for

The National Alliance for Advanced Technology Batteries (“NAATBatt”)

February 17, 2014



Executive Summary

The purpose of this project was to survey electric utilities, storage vendors and other stakeholders of the electricity grid concerning their views about the optimal use of DES technology and the principal barriers that prevent widespread deployment of that technology on the grid today. It is intended that that data provided by this report be used to design a program of related and coordinated DES demonstration projects that can most effectively address the issues identified in this report.

In order to achieve these objectives, DNV GL recommended and executed the following process and methodology:

1. Identify DES applications that are most likely to provide the greatest value
2. Design survey questions and review the whole methodology with EPRI
3. Survey utilities and other stakeholders with a follow-up based on their feedback
4. Analyze the Survey Results and review them with the NAATBatt Advisory Team
5. Establish a subset of viable projects from the above survey and the Advisory Team comments
6. Design a method for utilities to share deployment information

The survey results are presented in section 3, the subsequent analysis in section 4, a list of some noteworthy DES projects and project focus recommendations are provided in section 5, and recommended protocols for sharing project information amongst utilities are provided in section 6.

It is the opinion of this report that future government-funded DES projects should focus on demonstrating command and control technologies that will permit the owners and operators of DES systems to optimize the value of the multiple applications that those systems can provide to the grid. Demonstrating the maximization of the economic value of DES storage systems (or their value to the grid, whether or not capable of monetization due to regulatory restrictions) is the most important function that future, government-funded DES demonstration projects can serve.

More demonstration projects of existing storage technology are necessary to move DES technology from theory to reality on the grid. Future demonstration projects should focus on optimizing the economic benefits (or grid benefits) of DES systems. Until utilities can see specific examples of how DES systems can maximize benefits and generate an acceptable return on investment, incenting additional voluntary utility investments in DES systems will be challenging.

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List of Exhibits

1. Purpose

The purpose of this project was to design a master list of DES demonstration projects that address stated industry and market challenges for grid-scale electrical energy storage delivery system with a focus on the distribution aspect of the electricity grid, and recommend potential demonstration projects to advance the maturity level of DES systems deployment.

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2. Scope

To satisfy the scope of this project, DNV GL conducted a survey of representatives from EPRI, 18 utilities, 11 energy storage vendors, 8 consultant or analysts, and 2 other types of stakeholders. The results from this survey were instrumental in producing the following deliverables:

- Identify most valuable applications and benefits of DES
- Create a Master DES Projects List of DES demonstration projects addressing industry and market challenges
- Create a list of highly feasible and useful DES Projects from the Master DES Projects List identifying the technical basis for conducting the project, and technical analysis done to define risks and solutions
- Design a method and checklist for utilities to share deployment information and practical experiences to overcome technical challenges and improve the cost-effectiveness of grid-scale DES systems.

3. Survey Results

The survey respondents consisted of representatives from EPRI, various electric utilities, Energy Storage (ES) vendors and manufacturers, consultants, analysts, the Underwriter Lab and a Public Service Commission. The survey effort was conducted in two phases; there were 45 respondents to the first survey, and 14 to the follow-up survey. The results presented in this report will clearly state which survey they relate to.

The initial survey prompted respondents to rank various DES project drivers and applications identified by DNV GL on a scale of 1 to 10 (i.e. least desirable to most desirable or feasible). Additionally, respondents were encouraged to suggest additional drivers and applications, and provide comments. A sample of this survey is attached in Appendix A1.

The follow-up survey presented the preliminary aggregated results from the initial survey to the respondents, and prompted the respondents to rank five new drivers and one new application suggested by the respondents of the initial survey. It also inquired about the respondents' preferred energy storage technology and deployment location, the nature of the barriers to DES adoption, interconnection issues, and opinion on the most viable mechanism to share best practices throughout the industry. A sample of this survey is attached in Appendix A2 – Follow-up Survey.

3.1 Survey Respondents

The initial survey respondents consisted of 43 representatives from utilities either interested or already deploying DES systems, energy storage vendors or manufacturers, consultants and analysts, and other stakeholders. The breakdown of these participants is illustrated in Figure 1.

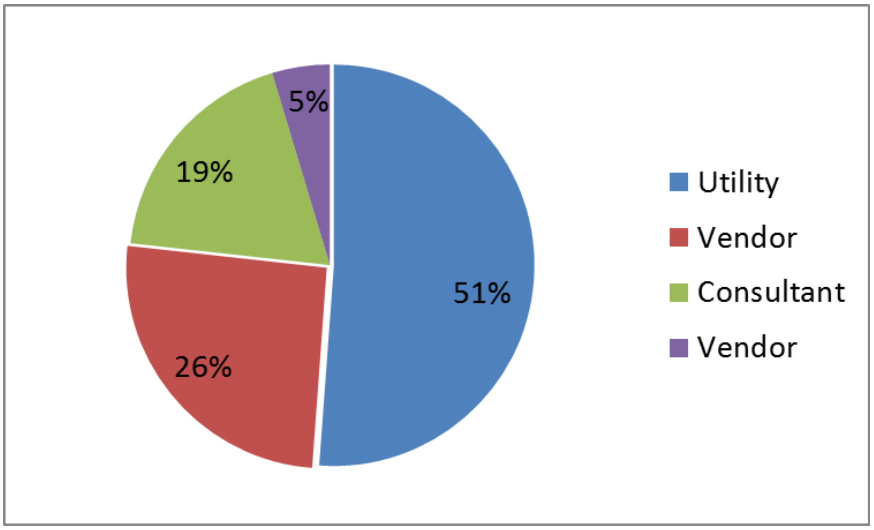


Figure 1 – Initial Survey Respondents Breakdown

The initial survey respondents represented 18 utilities, 11 energy storage vendors, 8 consultant or analysts, and 2 other types of stakeholders; they are listed in Table 1.

18 Utilities (22 respondents)	**11 Vendors** (11 respondents)	**8 Consultants / Analysts** (8 respondents)	**2 Others** (2 respondents)
AEP (2)	1EnergySystems, Inc.	Customized Energy Solutions, LLC	Kentucky PSC
AES Energy Storage	ABB, Inc.	EPRI	UL, LLC
ComEd	Amperex Technology, Ltd.	G Nicholas and Associates, LLC	
Con Edison of New York	Becket Energy Systems	Good Company Associates, Inc.	
CPS Energy	EaglePicher Technologies, LLC	Navigant Consulting, Inc.	
DTE Energy	Enerdel, Inc.	Renewable Energy Ventures, LLC	
Duke Energy (2)	GE	Strategen Consulting, LLC (CESA)	
FirstEnergy Service Company	Kokam, LLC	Technology Insights, LLC	
HECO	S&C Electric Company, Inc.		
National Grid	Saft America, Inc.		
North East Utilities	UniEnergy Technologies, LLC		
Orange and Rockland Utilities			
PNM (2)			
SCE (2)			
SDGE			
Snohomish PUD			
Tri-State G&T			
Xcel Energy			

Table 1 - Stakeholders Represented in Initial Survey

The follow-up survey respondents consisted of 13 representatives from utilities either interested or already deploying DES systems, energy storage vendors or manufacturers, consultants and analysts. The breakdown of these participants is illustrated in Figure 2.

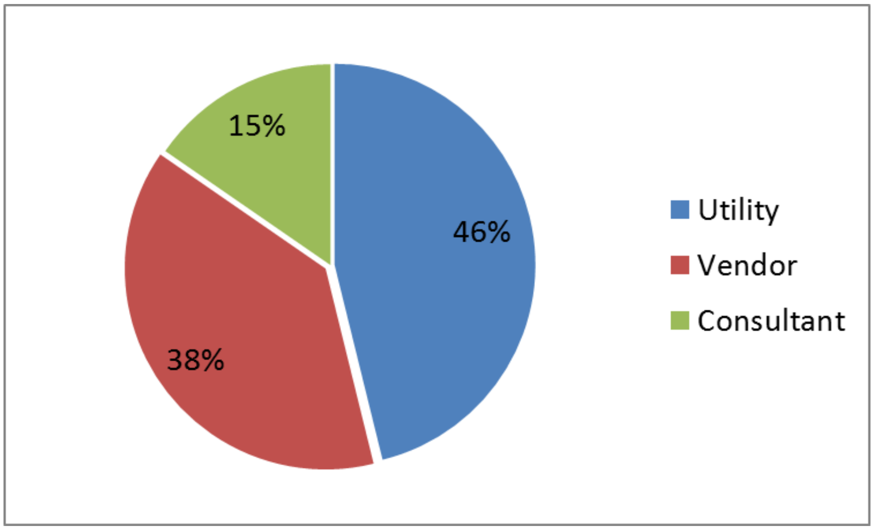


Figure 2 – Follow-up Survey Respondents Breakdown

The follow-up survey respondents represented 6 utilities, 5 energy storage vendors, and 2 consultant or analysts; they are listed in Table 2.

6 Utilities (6 respondents)	5 Vendors (5 respondents)	2 Consultants / Analysts (2 respondents)
Con Edison of New York	Amperex Technology, Ltd.	G Nicholas and Associates, LLC
National Grid	Becket Energy Systems	Technology Insights, LLC
PNM	EaglePicher Technologies, LLC	
SCE	Kokam, LLC	
SDGE	S&C Electric Company, Inc.	
Snohomish PUD		

Table 2 - Stakeholders Represented in Follow-up Survey

3.2 Preferred Storage Technologies

The results presented in Figure 3 were gathered from the follow-up survey. Taking into account all respondents, there is equal preference for no specific technology or lithium-ion batteries.

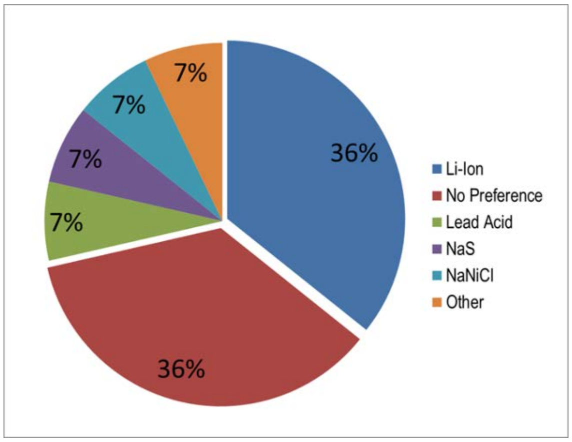


Figure 3 - Preferred ES Technologies

3.3 Preferred Deployment Locations

The results presented in this section were gathered from the follow-up survey. The responses from six utilities, five energy storage vendors, and two consultants are represented in Figure 4.

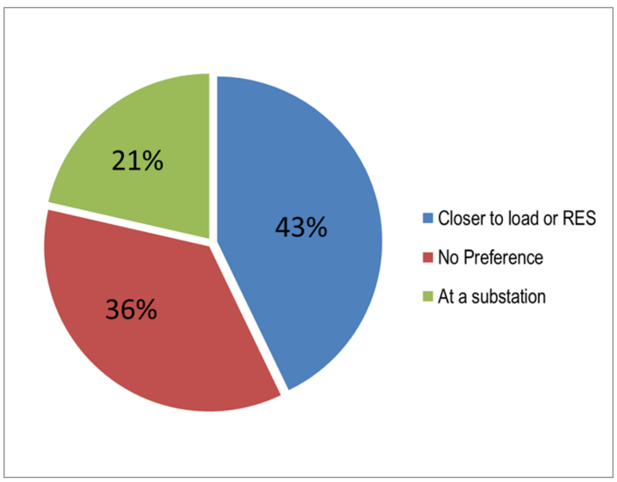


Figure 4 - Preferred Deployment Location

3.4 DES Deployment Barriers

The results presented in this section were gathered from the follow-up survey. The respondents were prompted to identify and rank the top three barriers to DES deployment. The responses from six utilities, five energy storage vendors, and two consultants are represented in Figure 5.

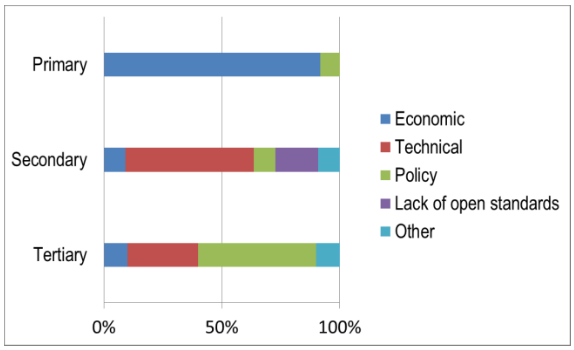


Figure 5 - Deployment Barriers Survey Ranking

3.5 DES Project Drivers

The results in this section were weighed with respect to the number of respondents from each stakeholder type. The semi-transparent bars represent opinions gathered solely from the follow-up survey, and consist of responses from six utilities, five energy storage vendors, and two consultants. The ranking of key drivers for a successful DES project is presented in Figure 6.

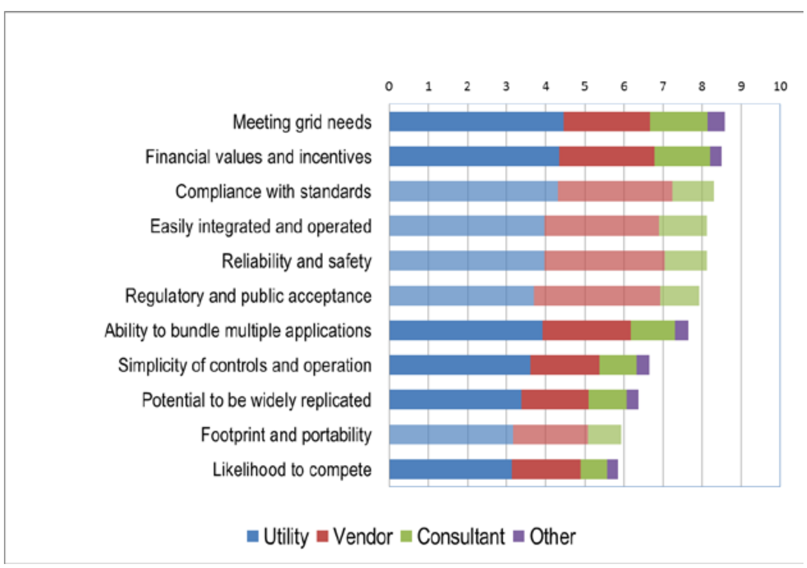


Figure 6 - Project Drivers Survey Ranking

3.6 DES Applications

The results in this section were weighed with respect to the number of respondents from each stakeholder type. The applications labeled with an asterisk (*) were gathered from the follow-up survey, and consist of responses from six utilities, five energy storage vendors, and two consultants.

The applications considered were evaluated for primary usage, where the application is the DES device dispatch priority and secondary usage, where the application is bundled with another primary application to provide additional benefits. The primary applications ranking is presented in Figure 7 and the secondary applications ranking is presented in Figure 8.

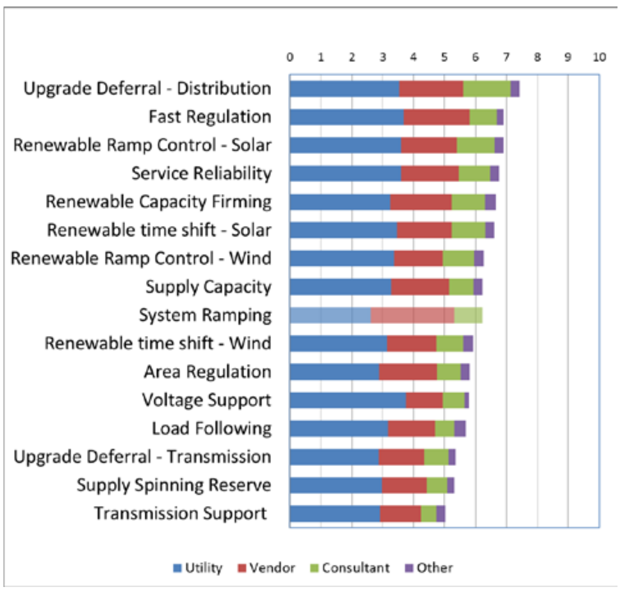


Figure 7 - Primary Applications Ranking

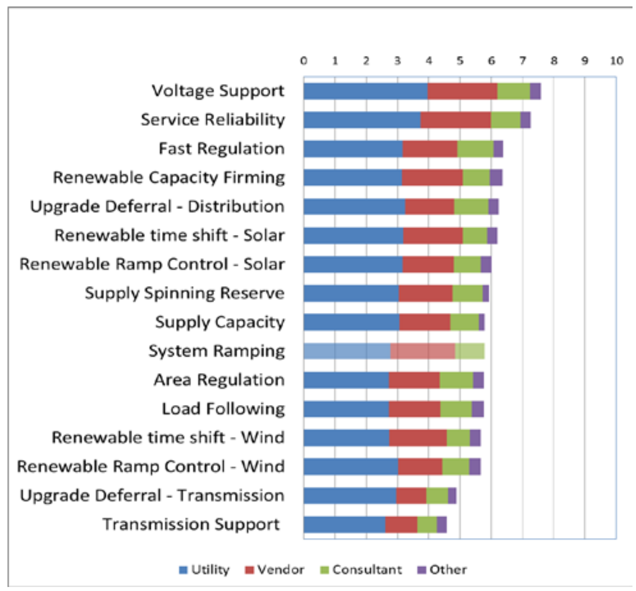


Figure 8 - Secondary Applications Ranking

4. Analysis of Survey Results

Considering that the purpose of this study focuses on distributed energy storage systems to be deployed by utilities, the responses from the utilities, storage vendors, and other contributors were analyzed independently, and compared. Energy storage vendors' opinion could be biased towards the specific capabilities of their products. Consultants, analysts, and governmental agencies are likely unbiased in their responses. The order of importance for each item populating the charts in this section was kept the same as the aggregated results.

4.1 Drivers

The survey results presented in Figure 9 suggest that meeting the grid needs and financial values and incentives of DES deployment are important drivers as seen by all stakeholders. Additionally, utilities care about DES systems compliance with standards due to the limitations a non-compliant system would pose. Ease of integration and operation, and reliability and safety are also considered important drivers.

The likelihood of DES systems to compete with other technologies seemed of relatively little importance to survey respondents. Also, the potential to be widely replicated, the footprint and portability, and the simplicity of controls and operation appeared to be secondary concerns for utilities.

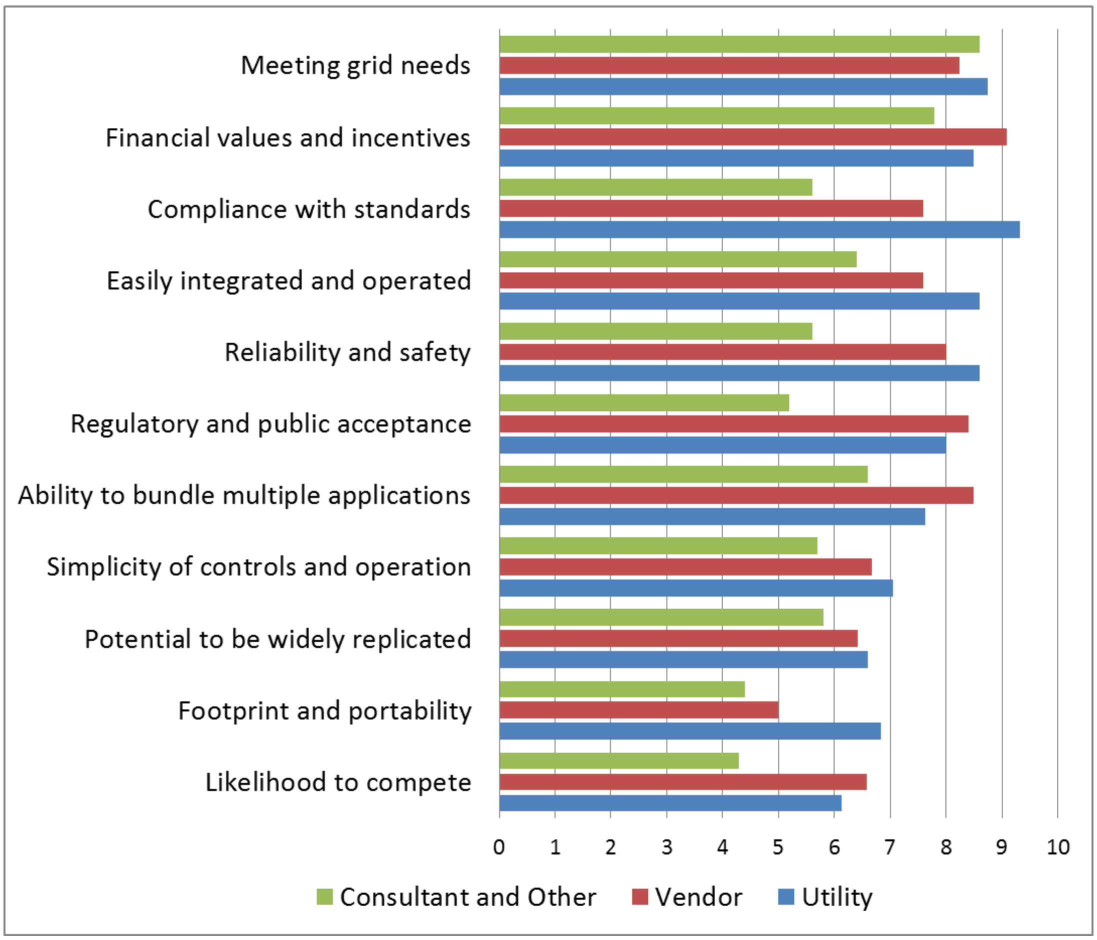


Figure 9 - Drivers Categorized Ranking

4.2 Barriers

The barriers ranking are presented by respondent category in Figure 10, Figure 11, and Figure 12. All parties agree that economic barriers are a primary factor hindering the deployment of DES systems. There is a general consensus that the technical barriers are an important, but secondary concern. The utilities are generally concerned about the lack of open standards, where the rest of the industry is more concerned with policy being a major barrier to the widespread adoption of DES systems.

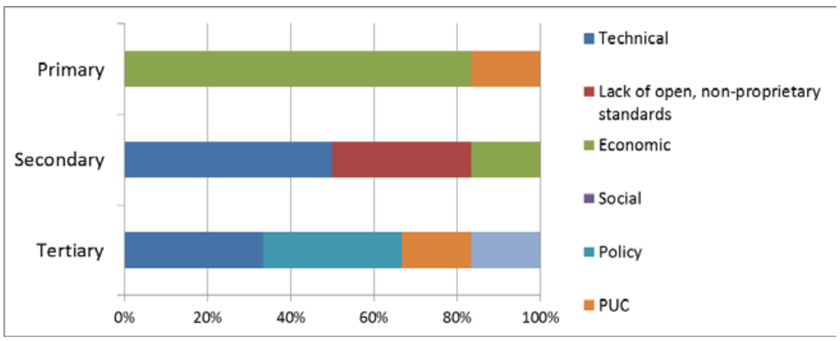


Figure 10 - Utilities Barriers Ranking

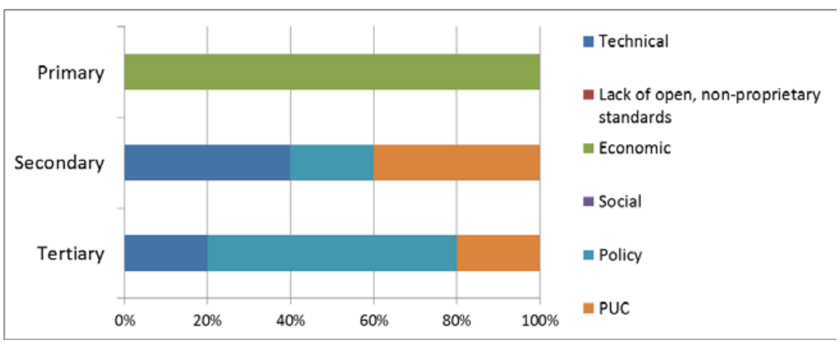


Figure 11 - Vendors Barriers Ranking

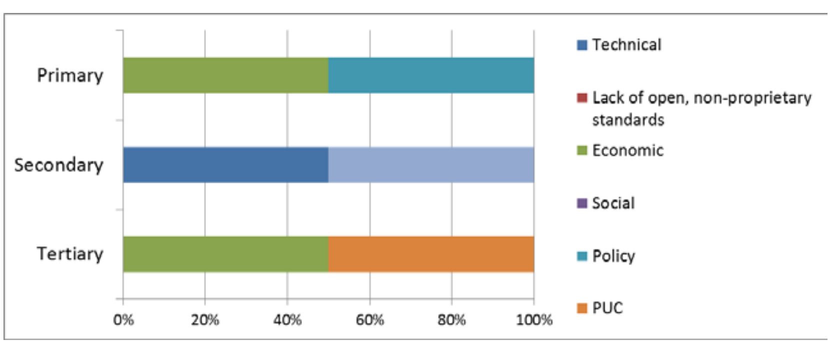


Figure 12 - Consultants and Others Barriers Ranking

4.3 Preferred Technologies

The results presented in Figure 13, Figure 14, and Figure 15 were gathered from five utilities, five vendors, and two consultants in the follow-up survey. Lithium-ion technology seems to be of most interest to vendors, and some utilities. However, most utilities do not have a preference as to which technology is being used.

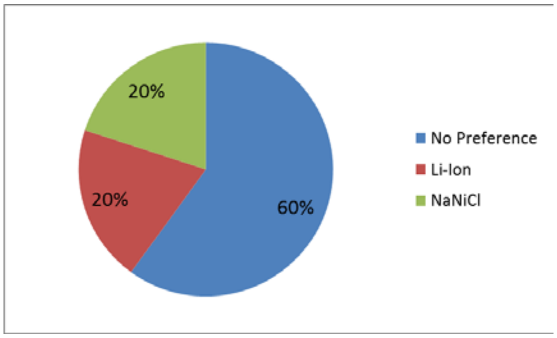


Figure 13 - Preferred Technologies by Utilities

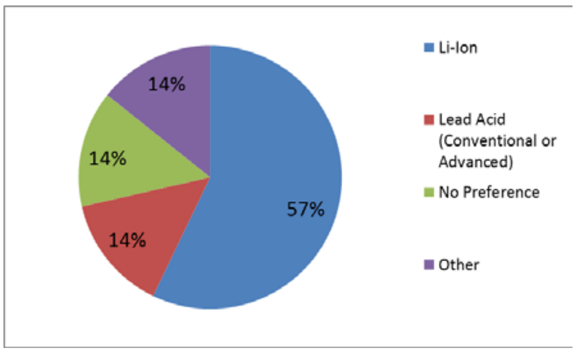


Figure 14 - Storage Technologies Preferred by Vendors

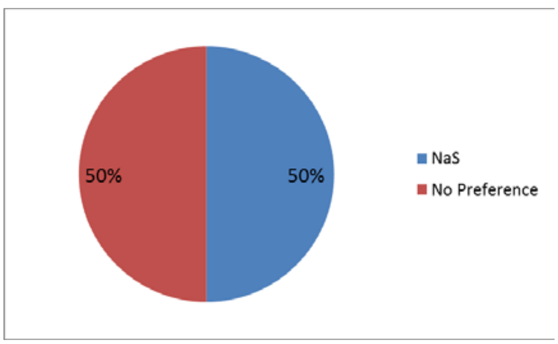


Figure 15 - Storage Technologies Preferred by Consultants

4.4 Applications and Benefits

The primary and secondary applications rankings were further broken down by respondent category, as was done with the other results analyzed in this section. These results are presented in Figure 16 and Figure 17 respectively.

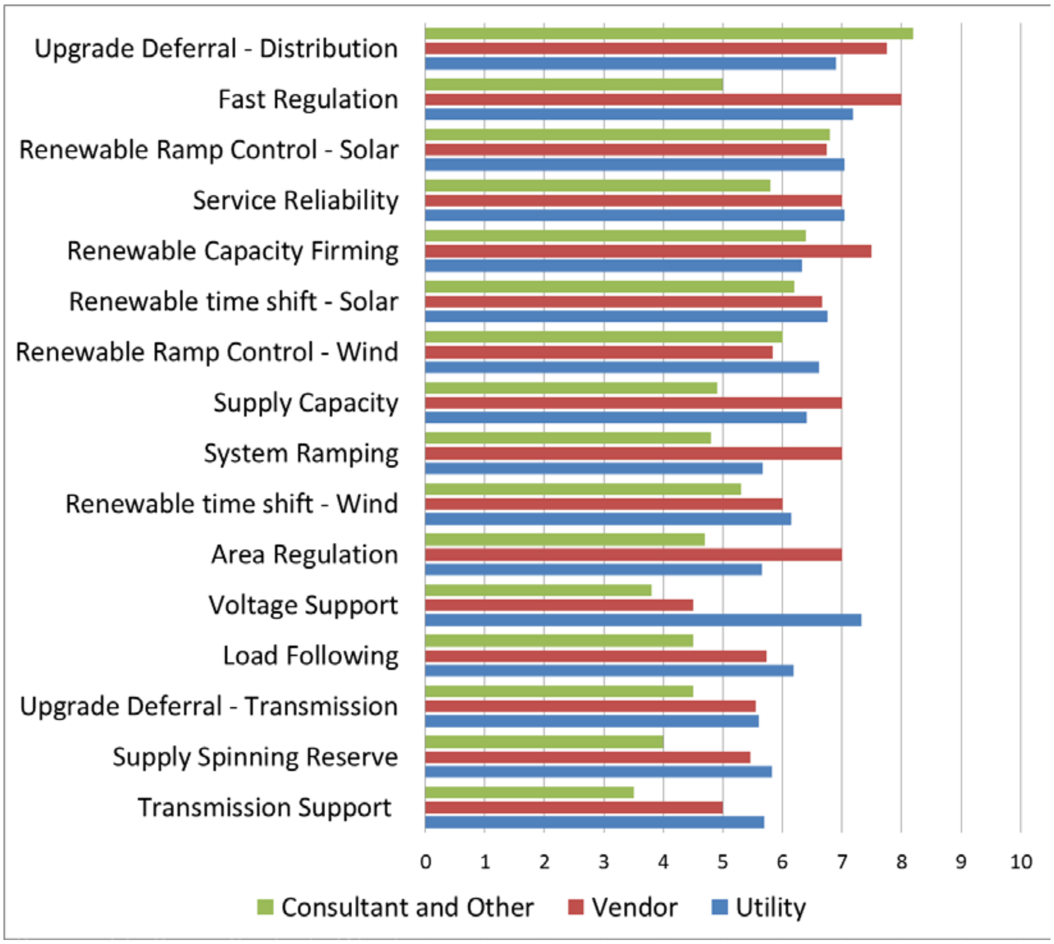


Figure 16 - Primary Applications Categorized Ranking

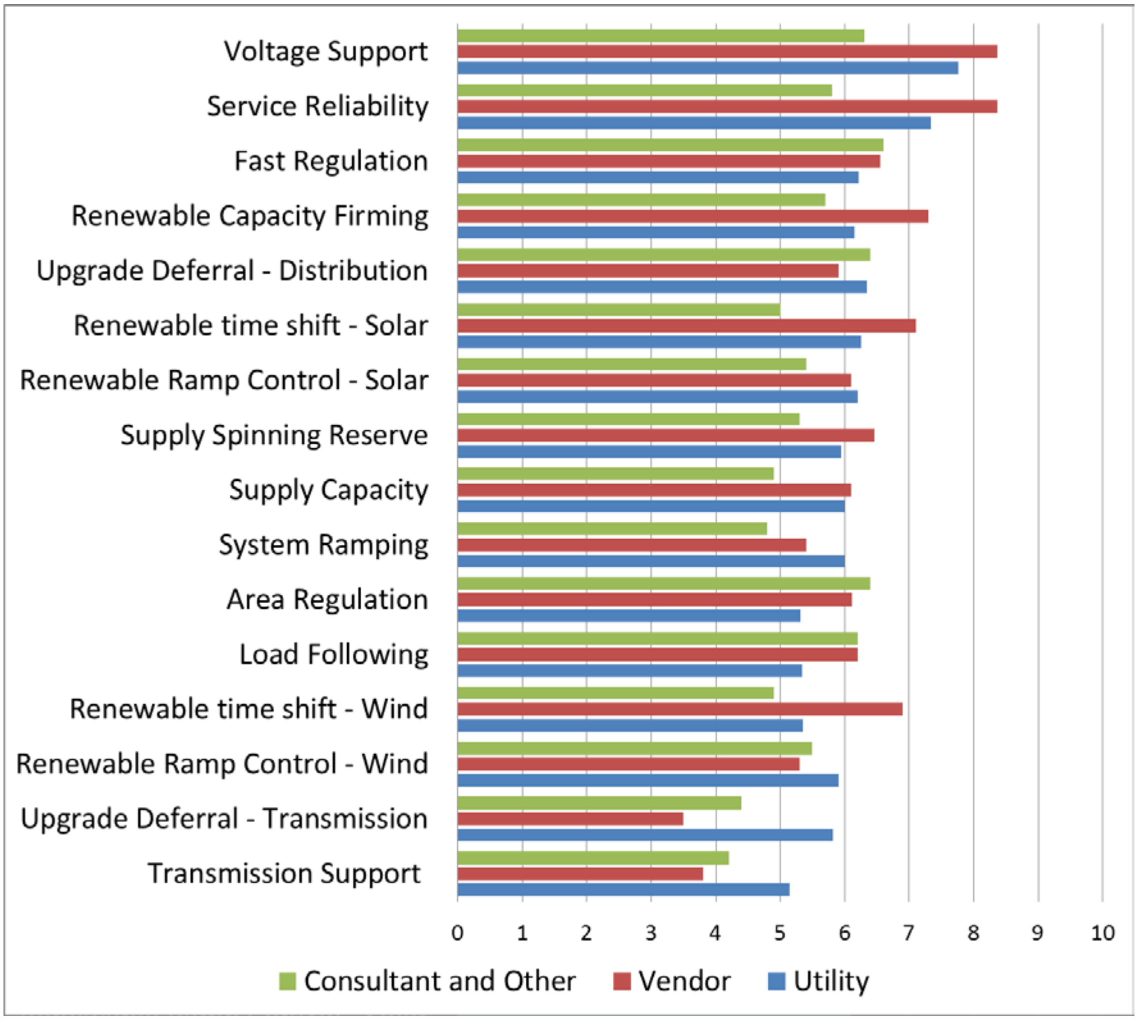


Figure 17 - Secondary Applications Categorized Ranking

4.4.1 Distribution upgrade deferral

Energy storage can be installed to defer the installation or upgrade of power lines and transformers. The value of this application may not necessarily be the cost of the alternatives but rather timing and feasibility. Siting power lines and substations are time-consuming challenges requiring sizeable capital expenditure. Storage can be utilized to defer the need for the additional lines and substation to a later time period.

4.4.2 Service reliability

This application focuses on the need for back-up power systems located on the utility side of the electric meter. Alternatively, it focuses on the need for back-up power systems at Commercial and Industrial facilities. These facilities typically use a combination of batteries for ride-through of momentary outages and a diesel generator for longer duration outages.

4.4.3 Fast regulation

This application is similar to "Area Regulation", with specific reference to FERC 755 for area regulation compensation. Energy storage units provide a faster response than conventional generation, and can be used both as an energy source and sink to achieve a finer generation to load balance.

4.4.4 Voltage support

The power conversion systems complementing battery systems are capable of providing dynamic, bi-directional VAR support to maintain line voltages within defined limits.

4.4.5 Solar RES ramp control

Shading caused by terrestrial obstructions such as clouds and trees can cause the power output from affected solar generation systems to drop quite rapidly. Solar farms are subject to specific ramping requirements in order to interconnect to the grid. Solar farm operators are contractually obligated to meet these ramping requirements, which vary by utilities, as stated in Power Purchase Agreements. Storage can be applied to smooth solar output and off-set these requirements.

4.4.6 Solar RES time shift

This is a subset of Energy Time Shift (arbitrage). Renewable resources are unpredictable and may not align with peak load patterns. Solar production tends to peak at or before noon when load is typically at a low and ebbs during the afternoon hours when load is at a maximum. Having a storage device with durations of 3-4 hours can provide a tremendous advantage to renewable efficiencies, easing of grid impacts, and renewable production. These devices can enable storage and discharge of renewable generation from low cost periods to high cost periods, and provide transmission relief from the stress caused by solar farms.

4.4.7 RES capacity firming

The objective of renewable capacity firming is to make the generation output somewhat constant. Storage could be used to store wind and solar power during hours of peak production regardless of demand, and discharge to supplement traditional generation when renewable output reduces during expected generation time.

4.4.8 Wind RES ramp control

Short duration intermittency from wind generation is caused by variations of wind speed that occur through the day. Storage could be used to manage or mitigate the less desirable effects from high wind generation penetration. Wind farms are subject to specific requirements in order to interconnect to the grid. Wind farm operators are contractually obligated to meet these ramping requirements, which vary by utilities, as stated in Power Purchase Agreements.

4.4.9 Supply Capacity

Energy storage could be used to defer the cost of installation of new power plants or to "rent" generation capacity in the wholesale electricity marketplace.

4.4.10 Wind RES time shift

This is a subset of Energy Time Shift (arbitrage). Renewable resources are unpredictable and don't align with typical peak load patterns. Wind production tends to peak during the evening and morning hours when load is at a low and ebbs during daytime hours when load is at a maximum. Having a storage device with durations of 4-6 hours can provide a tremendous advantage to renewable efficiencies, easing of grid impacts, and renewable production. These devices can enable storage and discharge of renewable generation from low cost periods to high cost periods, and provide transmission relief from the stress caused by wind farms. The wind farms infrastructure is typically not sized to capture the maximum output of the farm; storage can capture energy that would be typically dumped in these cases and increase the wind farm capacity factor.

4.4.11 Load following

Energy storage could serve as load following capacity that adjusts its output to balance the generation and the load within a specific region or area.

4.4.12 System ramping

Fluctuations in system loading and generation are inherent to the operation of the electric power grid. The rate of change caused by these could be quite rapid. Storage can be applied to relieve stress on generation resources by smoothing these transitions almost instantaneously. In most markets, energy storage can be committed either as load or a generator, and are sized depending on the ratings and ability to provide a certain power magnitude for a given duration.

4.4.13 Supply spinning reserve

Reserve capacity is the generation capacity that can be called upon in the event of a contingency such as the sudden, unexpected loss of a generator. Three types of reserve capacities are: Spinning Reserve, Supplemental Reserve and Backup Supply.

4.4.14 Area regulation

Area regulation is the use of on-line generation or storage which can change output quickly (MW/min) to track minute-to-minute fluctuations in loads and to correct for the unintended fluctuations in generation. It helps to maintain the grid frequency and to comply with Control Performance Standards (CPSs) 1 and 2 of the North American Reliability Council (NERC).

4.4.15 Transmission upgrade deferral

Energy storage can be installed to defer the installation or upgrade of transmission lines and substations. The value of this application may not necessarily be the cost of the alternatives but rather timing and feasibility. Siting transmission lines and substations are time-consuming challenges requiring sizeable capital expenditure. Storage can be utilized to defer the need for the additional transmission lines and substation to a later time period.

4.4.16 Transmission support

Energy storage could be used to enhance the T&D system performance by providing support during the event of electrical anomalies and disturbances such as voltage sag, unstable voltage, and sub-synchronous resonance.

5. DES Demonstration Projects

5.1 DES Projects Master List

Survey recipients were prompted to provide a list of innovative DES projects they have deployed in the past three years, or are planning to deploy within the next three years. A master list of these was assembled and is presented in Appendix B – DES Projects Master List.

5.2 Innovative Projects

5.2.1 Snohomish PUD Projects

Project Name	TBD - Li-ion	TBD - Flow battery
Commission Date	2014	2015
Location	Substation	Substation
Ratings	1-2MW/2-4MWh	2-4MW/4-6MWh
Intended function(s)	Wind integration/peak shifting	Wind integration/peak shifting

Table 3 - Snohomish PUD Projects Overview

Comments from Snohomish PUD – [The] lack of open, comprehensive standards are a significant barrier to the availability of economically viable energy storage systems. The above projects will focus on demonstrating a viable solution to this challenge via the MESA (Modular Energy Storage Architecture) in partnership with 1Energy Systems, Alstom Grid, the University of Washington and major battery manufacturers.

5.2.2 PNM Project

Project Name	Prosperity Energy Storage Project
Commission Date	Initial 9/11 full 2/1
Location	Albuquerque
Ratings	0.5MW/.1 MWH
Intended function(s)	Smooth and shift PV

Table 4 - PNM Project Overview

Comments from PNM - Standards and code overlap for electrical energy storage systems installed within the last three years. Lack of clarity from NESC vs. NEC (480V systems in utility owned equipment)

5.2.3 SCE Projects

Project Name	TSP	ISGD	ISGD	Distribution Energy Storage Integration (DESI)	PLS
Commission Date	2014	2013	2013	2015	2014
Location	Monolith, CA (sub-station)	Irvine, CA, CES	Several residential units	Not chosen yet	Customer site
Ratings	8MW/32MWh	25kW/50kWh	14 units @ 4kW/10kWh ea	~ 2MW/4MWh	100kW/500kWh
Intended function(s)	Grid support & market	Load leveling, voltage support	Back-up power, utility control, customer energy management	Grid support	Permanent Load Shifting technology demo

Table 5 - SCE Projects Overview

Comments from SCE - Each system is semi-custom at best; there's no "off-the-shelf" solution. Jurisdictional issues when sited at customer sites and lack of presence of applicable standards for fire suppression [are hindering interconnection efforts].

5.2.4 Kokam Projects

Project Name	Duke Marshall	KCP&L	CES – AEP, DTE, Duke, SDG&E	Del Lago	DTE PV demonstration
Commission Date	~Q4 2011	~Q4 2011	~Q1 – Q2 2013	~Q4 2013	~Q4 2013
Location	Charlottesville, NC	Kansas City, MO	Detroit, Columbus, North Carolina, San Diego	San Diego, CA	Detroit, MI
Ratings	1 MW/750 kWh	1 MW/1 MWh	Units of 25 kW/25 kWh	200 kWh	500 kWh Provided cells only
Intended function(s)	Time shifting	Smart Grid, including islanding	Reliability, PV mitigation, Peak shaving, etc.	Reliability, PV mitigation, Peak shaving, etc.	PV mitigation

Table 6 - Kokam Projects Overview

Comments from Kokam - Standard tests are not available and accepted so each customer/end user must make up their own standards which can provide challenges during FAT and commissioning. These projects have largely been demonstration projects for which commercial drivers, supported by regulatory decisions, are not available.

5.2.5 Duke Projects

Project Name	Notrees	McAlpine	Rankin	Marshall	Clay Terrace
Commission Date	2012	2012	2011	2012	2012
Location	Wind farm	Substation	Substation	Substation	Behind the meter
Rating	36 MW / 24 MWh	200 kW / 500 kWh	482 kW / 282 kWh	250 kW / 750 kWh	75 kW / 42 kWh
Intended Function	Frequency Regulation	Renewable smoothing / energy shifting / utility microgrid	Circuit smoothing	Renewable smoothing / Energy Shifting	Renewable smoothing / Energy shifting / Demand side management

Table 7 - Duke Projects Overview

Comments from Duke - Each system is custom at this point in time. No real standards exist yet for energy storage both behind the meter and at the T&D level. Lack of algorithm development exists for energy storage. Developing systems and controls which allows energy storage to provide multiple value streams for the grid and customers is critical.

5.3 Recommended DES Projects

Based on the survey responses, various project types were identified as the most valuable projects to demonstrate various value streams of DES projects. These are presented in Table 8.

Application I	Application II (Compatible)	Other	Comments	Value Demonstration
Load following (balance system by energy into system)	Upgrade deferral	Ramping (regulation / renewable / etc.), voltage regulation	Fast multi-hour storage application	Site Specific; $/kW
Capacity	Ramping (regulation)	Voltage regulation	Fast Multi-hour	Compare with peaker plant, $/kW; operating cost; total cost of ownership
Energy Shifting	Backup	Smoothing	Fast Multi-hour	Energy cost; genset; $/kW
Micro Grid support		Voltage support		Challenge of merged w/o ES
Renewable shifting / firming	Backup		Multi hour	Alternative generation; Curtailment; availability; capacity factor
Renewable smoothing	Regulation		Under 1 hour	Accommodate more renewables; increase penetration

Table 8 - Recommended DES Project Types

Comments from First Energy - The next DOE demonstrations need to focus on the technical ability of integrated and interoperable utility energy storage systems, including communications and control needed for integration.

[First Energy] supports energy storage technology development because as it is potentially an important option for utilities to enhance reliability and flexibility of the electric delivery system. Storage can be a flexible asset to address the integration of increasing renewable generation resources such as wind and solar. Storage can also be a tool to improve distribution asset utilization if it can be produced at a very low cost.

[First Energy proposes a project], which was developed in an industry collaborative with EPRI, [that] is a DES Demonstration Project that could feature both large energy storage systems deployed at substation level or on a distribution circuit. One type would sized from 500kW to 10 MW for 1 to 6 hours and another a smaller energy storage utility systems deployed on the circuit and sized between 50 to 500 kW for 2 to 4 hours. Both types of systems need to have the capability for interoperable control from a utility SCADA or a distributed energy resources management systems as well as local automated control. Secure, reliable communication networks are needed to support various control frameworks using utility communications protocols with appropriate cyber security considerations.

Comments from UL LLC - One value demonstration for energy storage projects not noted in the column on the right of Table 8, may be verification of the safety of these systems through safety evaluation and actual field use. This is especially true for those systems closer to the user such as community energy storage as well as those systems that may be utilizing emerging technologies. The demonstration of the safety of the system may not be as quantifiable as determining $/kW costs, but it is can be an additional benefit of conducting demonstrations.

Comments from EPRI – The Energy Storage Integration Council (ESIC) has initially identified two products categories of interest, "Large Sale Energy Storage Systems at Substation Level or Along the Distribution Feeder" (0.5MW to 10MW for 1-6 hours), and "Small-Scale Energy Storage Systems at Edge of Grid" (25kW to 500kW for 2-4 hours), both inspired by the previous efforts. The identification of these product categories came about through intensive discussions with utilities, energy storage vendors, and other stakeholders. EPRI asks that these categories be considered for the two primary categories for demonstration.

Comments from PNM – PNM suggests a project combining the following features: 1) utilizing a DES system to provide fast frequency response, 2) testing the volt/var capabilities of its power control system in conjunction with batteries, and 3) testing forward forecasting techniques relating to 1-2 minute ahead cloud prediction.

Comments from EaglePicher Technologies – EaglePicher suggests a project combining advanced communications and controls technology with a hybrid DES system with the modularity and interoperability of multiple electro-chemistries in order to meet the complex needs of multiple projects and applications. EaglePicher believes that once a hybrid system can prove itself in application and through a demonstration, a packaged solution suitable for commercial installation and for many applications can quickly be made available.

Comments from GS Battery (U.S.A.) Inc. and EPC Power Corporation – GS Battery and EPC Power suggest a project utilizing a portable DES system utilizing a standard Tricon container footprint. The system would be tested in emergency response applications (acting as a microgrid to provide power to critical load) and in commercial buildings (to demonstrate demand charge reduction, volt/VAR support, frequency support and backup for critical loads). The system would be Scada ready using DNP3 over IP.

6. Information Sharing

A mechanism to share general information about DES projects amongst utilities is crucial to promoting deployment efficiency. The DES Advisory Committee defined the scope of valuable information that could be made publicly available and identified ways to share this data amongst participant in the following subsections.

6.1 Scope of Shareable Information

Some information can reasonably be made public without compromising security or breaching Non-Disclosure Agreements. The project information identified by the DES Advisory Committee can be divided into the following 6 categories:

- Technical parameters of the DES device(s) and site
- Financial parameters of the project
- Details on Interconnection with the existing power system
- Details on Control strategies and purpose
- Details on evaluation methodology
- Miscellaneous information including standards and lessons learned

6.1.1 Technical Information

- DES technology
- Power and energy ratings of the DES unit(s)
- AC Voltage rating at the output of the DES unit(s), and at the point of interconnection
- One-line diagram of complete system(s)

6.1.2 Financial Information

- Cost of components and processes given as percentage of total project cost
- Targeted project life

6.1.3 Connection Information

- Geographic and Grid location of DES site(s)
- List of additional equipment necessary for safe connection, such as transformer(s), breaker(s), etc.
- Issues integrating with the utility data management system

6.1.4 Control Information

- List of targeted application(s)
- Control methodology(ies)
- Operational criteria and plans

6.1.5 Evaluation Information

- Performance metrics
- Performance analysis method
- Value verification methodology

6.1.6 Miscellaneous Information

- Safety and protection issues
- Tests and protocols performed
- Applicable standards identified
- Top 3-5 lessons learned

6.2 Sharing Methodology

Considering the number of projects and the scope of the information identified in section 7.1, a concise sharing methodology must be established to simplify the process for DES adopters and make the repository as accessible as possible. Three potential methods were identified:

- Sharing information through the DoE via a web repository
- Sharing information through the DoE via a Sandia Report or white paper format
- Sharing information through EPRI working groups

6.2.1 Web Repository

A web-based approach would allow for versatility in data aggregation and accessibility for all concerned parties. Additionally, a web site could potentially host various applications to assist with project design tasks, such as a Cost-Benefit Analysis or a Technology Selection tools. Creating and maintaining a web-site along with validating the data would require a significant investment.

6.2.2 Report Publication

Another method involves using the current methods of publishing white paper or Sandia Report. This method would not necessitate significant investments, but would require more effort from potential participants.

6.2.3 Working Groups

Information can also be gathered and processed through Working Groups and stakeholder Forums through periodic meetings where various stakeholders assemble and present current and future projects, technological advancements, etc.

7. Conclusion

The survey of utilities and other stakeholders conducted as part of this study offers an insight into how utilities and other stakeholders value the types of services that DES systems can provide. Although there was not a consensus on all issues, there were clear preferences by the majority that are captured in the following highlights:

- Most of the respondents who were non-vendors had no preference in battery technology
- Meeting the grid needs, achieving financial benefits, and compliance with standards were the top drivers identified
- High cost and the maturity level of energy storage system technology were the top two barriers identified
- Distribution upgrade deferral and fast regulation were identified as the most valuable primary applications
- Voltage support and service reliability were identified as the most valuable secondary applications
- There is a preference to share project data via a website through DOE, EPRI or working group forums

It is the general consensus of the stakeholders that participated in this study that the key to making DES systems attractive to utilities is improving the ability of individual DES systems, or networked groups of DES systems, to perform multiple applications on the grid, including the high value applications identified in this report. These multiple applications must be performed, or “stacked”, in a manner that maximizes, without need of material human intervention, the aggregate value of those multiple applications. Only by optimally stacking applications and maximizing their aggregate value can utilities achieve an acceptable rate of return on investment that justifies the cost of DES system deployment.

Future demonstration project should focus on proving that DES systems can optimally stack multiple grid-related applications. Optimizing the stacking of applications is largely a function of command and control technology. While many aspects of DES technology have been adequately demonstrated by previous government-supported DES demonstration projects, this report concludes that the command and control technology necessary to optimize the value of grid applications that DES systems provide has not yet been adequately proven. Utilities and other potential users of DES technology have not yet seen practical demonstrations of DES technology that prove out its theoretical ability to optimize the value of the multiple applications such systems can bring to the grid.

It is the opinion of this report that future government-funded DES projects should focus on demonstrating command and control technologies that will permit the owners and operators of DES systems to optimize the value of the multiple applications that those systems can provide to the grid. Demonstrating the maximization of the economic value of DES storage systems (or their value to the grid, whether or not capable of monetization due to regulatory restrictions) is the most important function that future, government-funded DES demonstration projects can serve.

This report does not intend to minimize the importance of other initiatives necessary to enable the widespread deployment of DES technology on the grid. Reducing the cost of DES technology is critical. Special notice is taken of industry efforts to standardize codes, terminology, interfaces and products, such as that being undertaken by the Energy Storage Integration Council (ESIC) under the leadership of EPRI. Future demonstration projects should seek to incorporate these emerging standards.

More demonstration projects of existing storage technology are necessary to move DES technology from theory to reality on the grid. Future demonstration projects should focus on optimizing the economic benefits (or grid benefits) of DES systems. Until utilities can see specific examples of how DES systems can maximize benefits and generate an acceptable return on investment, incenting additional voluntary utility investments in DES systems will be challenging.

Appendix A1 – Initial Survey

This document is the initial survey distributed to industry stakeholders.

Survey Questions for a successful distributed energy storage project at the substation level (DES 1-4 MW)

1- Your contact Information:
   a. Name:
   b. Position in your company:

2- Your business type:
   - ☐ Utility
   - ☐ ISO
   - ☐ Energy Trader
   - ☐ Storage Vendor
   - ☐ Consultant/Analyst
   - ☐ Government
   - ☐ other

3- In your opinion, what are the key drivers behind a successful energy storage project in a distribution substation (DES, 1-4 MW)?

Drivers behind a successful energy storage project (1-4MW)	0 = insignificant 10 = key driver
Meeting grid needs (DG & renewable flow control, ramp control, voltage support, reliability)	
Financial values and incentives (regulation, T&D deferral, arbitrage)	
Ability to bundle multiple applications for increased benefits	
Likeliness to compete with alternatives like gas turbines and Demand Response	
Simplicity of controls and operation (fitting into the current SCADA system)	
Potential to be widely replicated (by the same or other utilities)	
Other:	

4- In your opinion, which of the following storage applications would be most likely served in a successful energy storage project in a distribution substation (DES 1-4 MW)?

Storage applications that would likely be served in a successful DES project	0 = unlikely 10 = very likely As the main application	0 = unlikely 10 = very likely As a secondary (bundled) application
Load Following		
Voltage Support		
Upgrade Deferral - Distribution		
Upgrade Deferral - Transmission		
Transmission Support		
Supply Capacity		
Supply Spinning Reserve		
Service Reliability		
Renewable time shift - Solar		
Renewable time shift - Wind		
Renewable Ramp Control - Solar		
Renewable Ramp Control - Wind		
Renewable Capacity Firming		
Area Regulation		
Fast Regulation		
Other:		

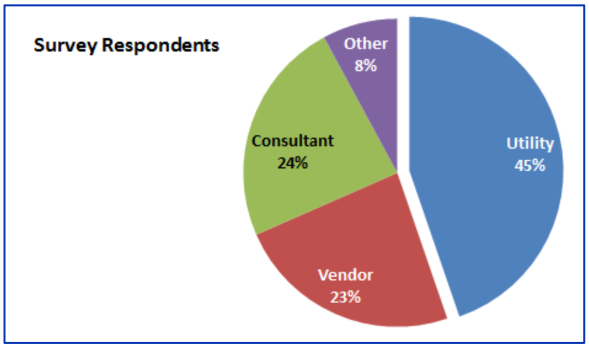
5- Additional Comments:

Appendix A2 – Follow-up Survey

This document is the follow-up survey developed using input from the initial survey, and distributed to industry stakeholders who responded to the initial survey.

Preliminary Survey Results

Summary of the received surveys as of Sept 31, 2013:



The preliminary analysis of the data on the survey responses received to date makes us conclude the following:

- Top two drivers for justifications of a distributed 1-4 MW storage

Utility Responses only	Non-Utility Responses
Meeting grid needs (DG & renewable flow control, ramp control, voltage support, reliability, etc.)	Meeting grid needs (DG & renewable flow control, ramp control, voltage support, reliability, etc.)
Financial values and incentives (regulation, T&D deferral, arbitrage)	Financial values and incentives (regulation, T&D deferral, arbitrage)

- Top two primary applications:

Utility Responses only	Non-Utility Responses
Fast Regulation	Upgrade Deferral - Distribution
Renewable Ramp Control - Solar	Fast Regulation

- Bottom two primary applications (least desirable or least expected for DES):

Utility Responses only	Non-Utility Responses
Upgrade Deferral - Transmission	Voltage Support
Transmission Support	Transmission Support

- Top two secondary applications (to be bundles with the primary application)

Utility Responses only	Non-Utility Responses
Voltage Support	Voltage Support
Service Reliability	Service Reliability

Follow-up Survey Questions for an energy storage project, 1-4 MW

Notes:

- The new follow-up questions, based on your feedback, are highlighted. You may still respond to the original questions if you want to have your earlier responses modified or adjusted.
- Power or discharge duration of storage depends on the preferred applications
- Aggregation of distributed storage should be considered for providing values at transmission, generation or general system level

6- Your contact Information:

a. Your Name:
b. Company Name:
c. Position in your company:
d. Any specific regulatory/policy ties?

7- Your business type

- ☐ Utility
- ☐ Storage Vendor
- ☐ Consultant/Analyst
- ☐ other

8- Thinking beyond a technology demonstration, what is your preferred technology to demonstrate the operational values and benefits of energy storage?

- Lead Acid (conventional or advanced)
- Li-ion
- NaS
- NaNiCl
- Vanadium Redox Flow Battery
- ZnBr flow battery
- Flywheels
- No Preference
- Other ____________________________

9- What location you prefer for distributed energy storage (DES)?

- At a substation
- On feeders closer to load or renewable generation
- No Preference

10- Please list any energy storage project you have demonstrated or installed in the last 3 years or plan to do in the next 3 years

Commission Date (from 2010 to 2016)	Project Name	Location	Ratings MW/MWh	Intended function(s)

11- Any issues with interconnection, standards, commercial availability, etc., for electrical energy storage systems installed (within the last three years).

12- In your opinion, what are the key drivers behind a successful energy storage project, 1-4 MW to be started in the next few years?

Drivers behind a successful energy storage project (1-4MW)	0 = insignificant 10 = key driver
Meeting grid needs (DG & renewable flow control, ramp control, voltage support, reliability, etc.)	
Financial values and incentives (ROI or savings in regulation, T&D deferral, arbitrage, etc.)	
Ability to bundle multiple applications for increased benefits	
Likelihood to compete with alternatives like gas turbines and Demand Response	
Simplicity of controls and operation (fitting into the current SCADA/ EMS)	
Potential to be widely replicated (by the same or other utilities)	
Reliability and safety of the storage system	
Footprint and portability	
Regulatory and public acceptance	
Compliance with applicable safety standards and installation codes	
Be integrated and operated easily in the electricity T&D system	
Other:	

13- In your opinion, which of the following storage applications would be most likely served in a successful energy storage project, 1-4 MW? Secondary application is meant to be what you would do with storage for additional benefits but could not use it to justify the storage (like a flashlight on a cell phone)

Storage applications that would likely be served in a successful Distributed Storage Project	0 = unlikely 10 = very likely As the main application	0 = unlikely 10 = very likely As a secondary (bundled) application
Load Following		
Voltage Support		
Upgrade Deferral - Distribution		
Upgrade Deferral - Transmission		
Transmission Support		
Supply Capacity		
Supply Spinning Reserve		
Service Reliability		
Renewable time shift - Solar		
Renewable time shift - Wind		
Renewable Ramp Control - Solar		
Renewable Ramp Control - Wind		
Renewable Capacity Firming		
Area Regulation		
Fast Regulation		
System Ramping		
Other:		

14- You have identified in Item 8 the two most likely applications that would be served by a 1-4 MW storage system. Please rank in order of importance (1, 2 and 3) the top three barriers that have kept utilities from deploying DES systems that address those most likely applications to date.

- Technical
- Lack of open, non-proprietary standards
- Economic
- Social
- Policy
- PUC
- Other ___________________________

15- Developing a mechanism for utilities to share best practices for deploying, operating and evaluating similar DES projects is an important goal of this project. Please share any suggestions you may have about mechanisms or practices that could be put in place that would make that sharing effective and efficient for utilities

11- Additional Comments:

Appendix B – DES Projects Master List

Company Type	Company Name	Project Name	Commission Date	Location	Ratings (MW/MWh)	Intended Function(s)
Utility	Snohomish PUD	TBD - Li-ion	2014	Substation	1-2MW/2-4MWh	Wind integration/peak shifting
		TBD - Flow battery	2015	Substation	2-4MW/4-6MWh	Wind integration/peak shifting
	PNM	Prosperity Energy Storage Project	Initial 9/11 full 2/12	Albuquerque	0.5MW/.1 MWH	Smooth and shift PV
	Con Edison of New York	Transportable Energy Storage	2014-2015	NYC	500 kW/800 kWh	Address network constraints during contingency
	National Grid	Distributed Energy Storage System Demonstration (an ARRA SGDP project)	Q1 2015	Everett, MA	500kW / 2MWh	Circuit load leveling; reactive power control; renewable capacity firming (w/ 600kW solar gen)
		Distributed Energy Storage System Demonstration (an ARRA SGDP project)	Q1 2015	Worcester, MA	500kW / 2MWh	Customer demand control; TOU optimization; renewable capacity firming (w/ 600kW wind turbine)
	Duke	Notrees	2012	Wind farm	36 MW / 24 MWh	Frequency Regulation
		McAlpine	2012	Substation	200 kW / 500 kWh	Renewable smoothing / energy shifting / utility microgrid
		Rankin	2011	Substation	482 kW / 282 kWh	Circuit smoothing
		Marshall	2012	Substation	250 kW / 750 kWh	Renewable smoothing / Energy Shifting
		Clay Terrace	2012	Behind the meter	75 kW / 42 kWh	Renewable smoothing / Energy shifting / Demand side management
		McAlpine CES	2012	Transformer	25 kW / 25 kWh	Voltage support / Back up power
	SDGE	Pala Energy Storage Yard	In Service		500kW / 1500kWh	Substation Storage
		TBD- 1MW-3MWhr	In Progress		1000kW / 3000kWh	Substation Storage
		Jamacha C75	In Progress		1000kW / 2000kWh	Substation Storage
		TBD- 1MW-3MWhr	In Progress		1000kW / 3000kWh	Substation Storage
		TBD- 1MW-3MWhr	In Progress		1000kW / 3000kWh	Substation Storage
		Santa Ysabel - Renewable Support	In Progress		30kW / 34kWh	Substation Storage
		Santa Ysabel - Renewable Support	In Progress		6kW / 10kWh	Substation Storage
		Mission Valley- Skills Training Center	In Service		25kW / 72kWh	CES
		Clairemont	In Service		25kW / 72kWh	CES
		Poway	In Service		25kW / 72kWh	CES
		Borrego Springs CES	In Service		25kW / 25kWh	CES
		Borrego Springs CES	In Service		25kW / 50kWh	CES
		Borrego Springs CES	In Progress		25kW / 50kWh	CES
		Century Park CES	In Service		50kW / 82kWh	CES
		Energy Innovation Center- Outdoor	In Service		10kW / 10kWh	CES
		Energy Innovation Center- Indoor	In Service		5kW / 11kWh	Demand Side
		Energy Inovation Center- DC Fast Charging	In Service		Does not discharge to grid kW / 24kWh	DC Fast Charging
		San Diego Zoo	In Service		100kW / 100kWh	Other
		Energy Innovation Center- ICE Bear	In Service		12kW / 72kWh	Other
		UCSD MESOM	In Progress		6kW / 11kWh	Other
		Suites at Paseo (SDSU Private Dormitories)	In Progress		18kW / 32kWh	Other
	SCE	TSP	2014	Monolith, CA (sub-station)	8MW/32MWh	Grid support & market
		ISGD	2013	Irvine, CA, CES	25kW/50kWh	Load leveling, voltage support
		ISGD	2013	Several residential units	14 units @ 4kW/10kWh ea	Back-up power, utility control, customer energy management
		Distribution Energy Storage Integration (DESI)	2015	Not chosen yet	~ 2MW/4MWh	Grid support
		PLS	2014	Customer site	100kW/500kWh	Permanent Load Shifting technology demo
Storage vendor	Kokam	Duke Marshall	~Q4 2011	Chalottesville, NC	1 MW/750 kWh	Time shifting
		KCP&L	~Q4 2011	Kansas City	1 MW/1 MWh	Smart Grid, including islanding
		CES – AEP, DTE, Duke, SDG&E	~Q1 – Q2 2013	Detroit, Columbus, North Carolina, San Diego	Units of 25 kW/25 kWh	Reliability, PV mitigation, Peak shaving, etc.
		Del Lago	~Q4 2013	San Diego	200 kWh	Reliability, PV mitigation, Peak shaving, etc.
		DTE PV demonstration	~Q4 2013	Detroit	500 kWh Provided cells only	PV mitigation
	EaglePicher Technologies, LLC	EP Power Pyramid™	29-Jun-12	Joplin, MO	1 MW/2 MWh	Multiple
		ATK Power Pyramid™	8-Jul-13	Salt Lake City, UT	300 kW/1.2 MWh	Peak Shave, renewable
		Carthage Utility Power Pyramid™	Feb-14	Carthage, MO	100 kW/220 kWh	Multiple
		NREL/USNORTHCOM	Sep-14	Golden, CO	300 kW/400 kWh	Multiple
		ARISTA NYC Project	Feb-14	New York, NY	200 kW/900 kWh	Multiple
Consultant / Analyst	Technology Insights	Presidio	Apr-10	Presidio, TX	4 MW / 24 MWh	"T" upgrade deferral
		Catalina	Sep-11	Avalon, CA	1 MW / 6 MWh	"D" upgrade deferral
		Vaca-Dixon	Aug-12	Vacaville, Ca	2 MW / 12 MWh	PV, feeder reliability
		NEDO	Sep-12	Los Alamos, NM	1 MW / 6 MWh	Smart grid demo
		Yerba-Buena	May-13	San Jose, CA	4 MW / 24 MWh	"D" reliability, ancillary services
Other	Amperex Technology Limited		Project 1		100kW / 120kWh	
			Project 2		125kW / 250kWh	
			Project 3		14kWh / 14kWh	
			Project 4		50kW / 75kWh	
			Project 5		650kW / 2.6MWh	
			SSL		1MW / 2MWh	
			ND		1MW / 2MWh	
			TOA		1MW / 2MWh	
			TrinaSolar		100kW / 250kWh	
			State Grid		4MW / 16MWh	
			BMW		250kW / 313kWh	