U.S. DEPARTMENT OF ENERGY

Office of Energy Efficiency and Renewable Energy
Office of Electricity Delivery and Energy Reliability

Analytic Challenges to Valuing Energy Storage

WORKSHOP REPORT

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About this Report

This report was drafted by the Department of Energy under the support of Henry Kelly, Mike Davis, and Carla Frisch in the Office of Energy Efficiency and Renewable Energy and under the support of Pat Hoffman, Bill Parks, and Imre Gyuk in the Office of Electricity Delivery and Energy Reliability. Principal authors were Ookie Ma (EERE), Mark O'Malley (UCD), Kerry Cheung (AAAS, OE), and Philippe Larochelle (ORISE, ARPA-e) with contributions from Rich Scheer (Scheer Ventures). Editing services were provided by Bruce Green (NREL). We thank the participants and acknowledge Peter Wong, David Bertagnolli, and Wayne Coste of ISO New England for providing additional comments.

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Introduction and Process

The U.S. Department of Energy (DOE) has coordinated energy storage efforts across the Office of Electricity Delivery and Energy Reliability (OE), the Office of Energy Efficiency and Renewable Energy (EERE), the Office of Science Basic Energy Sciences (BES), and the Advanced Research Projects Agency-Energy (ARPA-e) from a research and development (R&D) perspective – identifying technology needs, metrics, and goals – but DOE and the research and analytic community have struggled with valuing storage at a systems level.

Sixteen stakeholders and experts from across the electric power industry, research universities, national laboratories, and federal agencies were invited to join 8 DOE staff members in a workshop on September 19-20, 2011, in Washington, D.C. to discuss the current state of knowledge for grid-scale energy storage and, in particular, the methodologies to assess its value on the grid. Storage technologies are continually evolving in terms of both cost and performance; and thus, the discussion focused on the functionalities of storage as a system-level asset for the grid rather than on individual storage technologies. The discussions were designed to generate a diversity of opinions and perspectives on analysis directions and priorities. However, having comprehensive coverage of stakeholders' opinions and achieving consensus were not goals of the workshop.

The scope of the workshop covered mechanical and electrochemical means of storing electricity including, for example, batteries, flywheels, compressed air, and pumped hydroelectric systems in grid-connected applications including frequency regulation, peak load reduction, arbitrage, distributed energy, and volt/VAr control. While energy storage systems can provide multiple services in electricity markets, there are competing technologies, tools, and techniques that also provide these same services. *A key goal was to identify the most important analysis questions to answer about energy storage in light of competing technologies and multiple applications so that policy and decision makers can more fully assess the technical and economic potential for grid-connected energy storage as a resource for power system planning, operations, and customer-side solutions.*

The workshop involved a series of discussions from a select group of individuals aimed at informing DOE about the state of the art in the analysis of grid-scale energy storage, including the relative merits of existing methods, models, computational tools, and data sources.

Key Takeaways

Flexibility − Energy storage can provide flexibility to the grid, both in operations and in planning, and adding variable renewable generation such as wind and solar onto the grid increases that need for flexibility. However, energy storage is generally not the only solution to challenges on the grid, and it competes with other options like dispatchable generation, upgrades to infrastructure, improved forecasting, better market designs, and demand response. Deployment of energy storage can yield efficiency gains through improved generator dispatch, more efficient generator operating points, and higher utilization of grid assets; but overall system-level gains are limited by the round-trip efficiency and capital cost of energy storage devices. Thus, determination of multiple price points at which energy storage technologies become the cost effective solutions is both a rich field of study and a challenging analytical task.

Market Conditions − Markets are continually evolving, and the long-term value of energy storage is difficult to capture. Niche markets have emerged, but storage still lacks a unique value proposition with a large opportunity base. Niche areas include frequency regulation in wholesale markets, stability for remote or island systems and weakly coupled sections of the grid, and, under specific circumstances, infrastructure investment deferral at both transmission and distribution levels. Other opportunities exist, but their economics depend on the compatibility of multiple applications for shared storage capacity, both in terms of revenue recovery through markets and regulatory structures (less transaction costs), and in terms of technical and operational feasibility. Wider market opportunities may emerge as storage technologies decline in cost on a power ($/kW) and energy ($/kWh) basis. The value of distributed storage to the bulk power system, and the value that can be monetized, is relatively unexplored and further research may lead to identification of additional benefits.

Drivers and Synergies −The question remains to what extent increasing levels of variable renewable energy (RE) serve as a driver for deployment of energy storage. Integration of variable renewable generation is one of many aspects of the future grid that will have an impact on the value of storage. In moving forward, there are several potential synergies with renewable generation. Storage can capture intermittent renewable energy that would have been curtailed due to transmission constraints or over-generation; and current expectations are the addition of variable renewables will make more storage in the bulk power system attractive at high renewable energy penetration levels. This level is possibly in excess of 30-40% by energy, unless there are dramatic reductions in the capital costs and/or improvements in performance of energy storage. It is worth noting, that the economics of combining variable renewable plants with dedicated energy storage tend to be sub-optimal, since the value of the curtailed energy plus the avoided cost of incremental transmission capacity is typically not sufficient to cover storage costs and the lost opportunity of providing other grid services. Storage can provide flexibility to help manage variability from the large deployment of wind and/or solar PV and generally, has greater value if deployed as a system-level asset to the grid rather than one dedicated to individual wind or solar plants. Lastly, as renewables displace energy provided by dispatchable generation, capacity market prices may increase. Capacity value is also one of the many possible value streams for storage, and is necessary for utility resource planning. Determining the capacity value of energy storage technologies is a difficult research question to address, particularly for energy-limited devices, as it involves modeling detailed system operations and representing other value streams over a long time horizon.

Barriers − There are substantial challenges to incorporating energy storage into long-term utility planning. As an investment, energy storage currently struggles with demonstrating economic returns sufficiently high to justify a number of risks. Regulatory issues at the federal and state level may limit the value proposition for energy storage and removing them may be necessary to level the playing field with other technologies. Aside from the long history with operating pumped hydropower storage plants, most storage technologies do not have standard and proven characterizations, though the

Recovery Act-funded demonstration projects will provide valuable application data. Overall, the value of storage is highly system-dependent, location-dependent, and subject to risk and uncertainty; technical, regulatory, and financial. Given the complex nature of energy storage, straightforward and transparent analysis is critical to build impact with stakeholders and give functional information to decision makers.

SUMMARY OF ANALYSIS AREAS AND QUESTIONS (number of votes in bold)				
Drivers and Scenarios	**Power System Requirements**	**Valuation Methods**	**Economics**	**Electricity Markets**
▪ How will technologies, markets, and policies affect energy storage deployments (e.g., gas prices, RPS, demand response)? **(8)** ▪ What is the optimum mix of solar, wind, and storage to produce the maximum production of renewable energy on peak? **(2)** ▪ To what extent can energy storage facilitate a large scale expansion of renewable energy in a cost effective manner? ▪ What are the likely "end points" of the electric infrastructure in the 202-2050 time frame? ▪ How much does the U.S. need to invest to have a viable domestic energy storage industry?	▪ How should energy storage be integrated into long-term planning processes including what storage evaluation methods in standard reliability tools like PSLF and PSS/E can be used to fully model storage for transmission? **(11)** ▪ What level of solar penetration (%) on a distribution circuit causes uncertain voltage control? **(3)** ▪ What interconnection requirements are needed for storage? **(3)** ▪ What are the requirements for maximizing the benefits of distributed storage to the bulk power system? **(3)** ▪ What kind of grid is desired in terms of organizational structure and extent of central vs. distributed? **(1)** ▪ Are the impacts of changes in frequency on the integrity of generators fully known (in terms of $ and the ability to extract energy from the rotating moment of inertia? **(1)** ▪ What are the needs for frequency response including primary frequency response? **(1)** ▪ What are the system characteristics that drive the needs for storage?	▪ What algorithms or methodologies can be used to seamlessly aggregate several of the benefits of energy storage? **(10)** ▪ What is the value of distributed storage, including: locational values; converting impacts, to benefits, to values; for reliability, load smoothing, and integration of renewables? **(6)** ▪ What is the capacity credit to give storage for resource adequacy? **(5)** ▪ What is the state-of-the-art of existing analysis about the value of storage? **(3)** ▪ What is the set of cost effective analysis tools for valuing storage? **(1)** ▪ How to quantify the value of storage in reducing volatility? **(1)** ▪ Can energy storage be input into engineering software tools to evaluate the effectiveness of that investment? ▪ Can energy storage provide multiple services and serve multiple roles from a single facility? ▪ What are the benefits of faster response to regulation signals? ▪ How can storage be integrated into an operation paradigm for arbitrage and regulation (stacked)?	▪ How does the value of storage change depending on the capabilities (e.g., # of hours, ramp rate, and depth of discharge)? **(7)** ▪ What is the market for storage as a function of cost? **(4)** ▪ How does the value of storage vary as a function of the penetration of variable renewable generation? **(1)** ▪ Where does energy storage fit on the flexibility supply curve for integrating variable renewable generation? **(1)** ▪ What is the total installed cost of storage now and three years from now? ▪ What will it cost to operate the electric system if no new storage is built?	▪ What market structures are needed to support the energy storage business case and do existing mechanisms adequately compensate storage for all of the benefits for integrating variable renewable generation? **(6)** ▪ Are current regulatory and market mechanisms adequate for energy storage? **(1)** ▪ Is the value of energy storage enhanced if control of the facility is turned over to an RTO/ISO?

Analysis Areas

The remainder of this document summarizes several key questions that were identified by the workshop participants. The questions are categorized in the table above. The workshop participants were asked to identify the key questions that they felt were most important to answer in order to better understand the value of storage. The participants then formed groups to create a research project that could answer these questions. The summaries of the resulting research projects in each of the Analysis Areas are presented below.

SCENARIOS AND DRIVERS			
Analysis/ Research Question	How will storage deployment be impacted by the following scenarios & drivers?		
	• Low-cost PV • High penetration of variable renewables • Low storage costs • Fossil fuel prices	• Demand response and efficiency increase • Low and high transmission build outs • Low growth and high growth	• Policy scenarios • Financial collapse • Climate change • Market structures
Preferred Methodologies and Tools	Tools and methods should factor in: • Path dependency (evolution) • Multi-agent aspects • Multiple time horizons • Supercomputing needs • Capturing multiple values • Production cost simulation • Representation of smart grid • Population shifts and locations • Borrow from other domains like National Energy Modeling System (NEMS)		
Data Needs and Gaps	• 20 years of 1-minute resolution for renewable generation (wind and solar) • Loads aggregated and not distributed • Storage life cycle and trigger points		
Risks, Limitations, and Caveats	• Simplifying for computational reasons can miss important elements • Lack of data at extremes leads to very large errors • Level of uncertainty may be so ill defined as to lead to meaningless results • Time to do the story and the time of the story horizon • Credibility and the sources of the data		
Level-of-Effort	\$10 – \$20 million per year		
Key Features to Make the Analysis Used and Useful to Policy and Decision Makers	• Ability to re-run and repeatability of results • Open source • Simple distribution • Community of researchers		

Scenarios and Drivers

Analyzing the value and/or impact of any grid scale technology in the context of the future developments is important, particularly for those that impact the grid itself. This is a difficult task because the future is far from certain. Examples of the types of changes that may impact the value of storage include: high gas prices, renewable portfolio standards, and developments in demand side response, etc. Questions pertaining to these various scenarios include what is the optimal mix of renewable energy sources and storage in the future grid. Answering these questions presents a very high dimensional problem-domain with a vast number of possible outcomes, is path dependent, and very sensitive to initial conditions. Substantial computational resources may be required in addition to borrowing from methodologies from other disciplines, and all approaches will require extensive and detailed datasets (which currently may not exist). Finding robust results within all the uncertainty is a very difficult task and any approach will necessarily have to be probabilistic, require very detailed models, and are computationally very challenging. Furthermore, the quality of the answers for any analysis conducted with existing capabilities is unlikely to be sufficiently robust considering the complexity of the problem, the lack of high-quality data, etc.

POWER SYSTEM REQUIREMENTS, Part 1	
Analysis/Research Question	How can storage be integrated into long-term planning? • How do we know when storage can displace transmission in the queue? How does this coordinate with stochastic transmission planning and operations? • How do we integrate it? How do we operate it? • How do we compute system reliability? Should we really use N-1 contingency analysis? Or maybe a more complex assessment?
	• Development of software • (N-1 or some) contingency analysis • Standardized storage types • Development of storage dispatch algorithms • Including storage in GTO long- term plan • PROMOD, UPLAN, WASP, etc.
Preferred Methodologies and Tools	New tool or new module within an existing tool • Physical model of voltage, amps, power • Economics (costs of operating compared to others) • Automatic generation control (AGC) for storage devices (comparison within storage and with other assets) • Dispatch and control strategies • LMP calculations need to be modified to include storage • Model 17 benefits of storage, but model has to be able to optimize based on user needs (practicality says 2 – 3 of the 17 benefits)
Data Needs and Gaps	• Validation data (provide some kind of incentives for utilities to provide the right kind of data • Operators experience with storage explicitly • Reliability/improvements experience system wide
Risks, Limitations, and Caveats	• Volume of data (reduce risk of basing decisions on wrong data) • System wide data • Development of models/policy based on early/new technologies like storage can be misleading
Level of Effort	Greater than 10,000 person-hours
Key Features to Make the Analysis Used and Useful to Policy and Decision Makers	• Illustrate the benefits clearly in comparison with other technologies, including cost-efficiency and carbon impacts • Clearly articulate message to the audience

Power System Requirements

To meet electric systems requirements, it is important to understand how storage can be integrated into long-term planning and how storage can displace the competing alternatives in the planning process. To do this effectively, there needs to be a tool that can model and quantify the impacts of storage, as well as its value. The results will depend on the scenario chosen and the valuation methodologies used. One way to proceed is to ensure an accurate module can be used with existing tools (power flow, dispatch, and economics, etc.), or, if not, a new tool may be needed. This links directly to the issue of how best to operate storage to maximize the value and to capture all the benefits, in particular, reliability, while avoiding perceived benefits that may not materialize. Ultimately, the tool should be able to perform contingency analyses, provide a standard representation of storage types, and be capable of testing alternative dispatch algorithms and assumptions. Since multiple benefits of storage have been recognized, it would be useful to understand the value of each benefit individually and how 2 or 3 benefits combine together optimally. Data will be needed to validate these tools or modules and current demonstration projects should be leveraged. Another aspect to understand is the role and impact that distributed storage has on bulk power markets. A tool should be able to help determine the optimal size and location in several scenarios for decision makers and planners.

POWER SYSTEM REQUIREMENTS, Part 2	
Analysis/Research Question	How to maximize the benefits of distributed storage in bulk power markets? • Optimal size/optimal location – electrical, physical • Quantify the value of each benefit • Determine 2-3 optimal sub-sets at each deployment and account for appropriate revenue streams
Preferred Methodologies and Tools	• Economic analysis • Reliability analysis • Societal and environmental analysis
Data Needs and Gaps	• Data from users • System data
Risks, Limitations, and Caveats	• May not have identified all of the applicable benefits • Need better cost analysis • Need data from multiple sources/storage types • Perceived benefits that don't materialize
Level of Effort	Significant amount of time to collect data
Key Features to Make the Analysis Used and Useful to Policy and Decision Makers	• The tool that analyzes several scenarios and clearly reflects the optimal sub-set will be crucial for decision makers

Electricity Markets

Existing market structures are proxies for competitive markets, and participation spans the spectrum from regulated entities subject to the traditional ratemaking process to deregulated entities bidding into organized wholesale markets run by the regional transmission operators. The economic viability of energy storage may depend on its ability to recover capital costs through multiple value streams, and full revenue recovery may not be possible even if there is a potential societal benefit. In the current structures, the lack of revenue recovery may result from various issues; some grid services are not monetized, grid product definitions have technology biases, or system operations do not perform necessary co-optimizations. Additionally, most current structures do not allow revenue recovery simultaneously as a regulated asset and as a participant in wholesale markets. Therefore, even if revenue recovery is possible for individual value streams, only a subset may be realizable for a single installation.

There is a need to look at the underlying demand and supply for grid services and identify system needs, including what sources are providing those services and who else could enter a market for those services. To justify new market structures, the analysis should demonstrate a substantial consumer or producer surplus to be captured, understanding that in designing new market structures, there is a trade-off between optimization and transaction costs. Optimal commitment and dispatch of storage may require managing the state-of-charge based on projections of future prices. The time horizon increases with the hours of energy storage, on the order of the dispatch schedule interval for energy-limited devices and on the order of days for large bulk storage technologies like pumped hydropower or compressed air systems. New market structures can be built into unit commitment/dispatch models with examination of shadow prices or can be based on engineering assessments of power system requirements with a supply curve for each service.

ELECTRICITY MARKETS		
Analysis/Research Question	What market structures are needed to support the energy storage business case? • How do you lower grid capital and operating costs (or delivered cost of energy) without preference to any resource?	
Preferred Methodologies and Tools	• Voltage support • Regulation • Primary frequency response (0-4 seconds) • Voltage stability • Transient stability	• Small signal stability • Remedial action schemes • Black start • Non-spinning reserve • Capital deferment • Capacity
Data Needs and Gaps	• Planning models (e.g., NERC ERAG, MMWG, PSS/E, PSLF) • Dynamic PSLF model • Generation schedules, forecasts of load, wind, solar, etc., load data, interchange data	• Correlation of renewable integration, regulation requirements • High speed frequency • Supply curves (gap?)
Risks, Limitations, and Caveats	• Lack of understanding • Regional evolution of markets • Path dependent (sequencing) • Stakeholder engagement/regulatory risks • Software tool development risks • Risk of not needing a market due to policy changes(obsolescence of market design)	
Level of Effort	Investigating one regional market proof-of-concept – 2,000 to 3,000 person-hours	
Key Features to Make the Analysis Used and Useful to Policy and Decision Makers	• Increase the consumer and producer surpluses • Load transaction costs	

VALUATION METHODS, Part 1	
Analysis/Research Question	Recognizing that distributed storage can be committed to multiple applications, are there tools to help find the total value of "combined" applications for the next 10 years for both distributed and bulk system applications for both distributed and bulk system applications?
	• This would be a forward looking tool for decision making
Preferred Methodologies and Tools	• Need to determine the individual value of each application using enhanced production cost and capacity expansion models, distribution systems modeling, power flow, etc. – different applications may need different methods. • Need to quantify the compatibility between different applications. This is done for market applications, but needs to be expanded to all applications of energy storage, e.g. compatibility between distributed application for supporting distributed PV and same storage in a market. • Need to optimize for maximum total value – will be different in different systems.
Data Needs and Gaps	• Required data is generally available and can be obtained
Risks, Limitations, and Caveats	• The uncertainty resulting from forecasting future scenarios from past data sets is likely to be greater than the uncertainty from the methodology itself.
Level of Effort	10,000 person-hours
Key Features to Make the Analysis Used and Useful to Policy and Decision Makers	• User friendly • Transparency of modeling assumptions • Apply simple stochastic approaches (sensitivity analysis to input data)

VALUATION METHODS, Part 2	
Analysis/Research Question	What is the capacity credit to give storage for resource adequacy?
Preferred Methodologies and Tools	• Apply established ELCC and LOLP methods to storage, but modified to consider storage dispatch • Evaluate how storage fits into existing capacity markets
Data Needs and Gaps	• Use standard datasets used for typical LOLP analysis • Evaluate storage dispatch strategies that can account for low-probability but high cost/value reliability events such as stochastic dynamic programming
Risks, Limitations, and Caveats	--
Level of Effort	Less than 2,000 person-hours
Key Features to Make the Analysis Used and Useful to Policy and Decision Makers	• Examine how capacity credit changes as a function of the size of the storage reservoir (i.e. is the capacity credit of 15-min of storage different than the capacity credit of 2 hours, 6 hours, or 12 hours of storage?) • Account for uncertainty in the timing and duration of reliability events for determining the contribution of an energy-limited resource to adequacy.

Valuation Methods

Algorithms and methodologies are needed to assess the value of a combination of location-specific, compatible revenue streams over the future lifetime of a storage asset so investment decisions at present can be made. The value of individual applications/revenue streams should be calculated using production cost and capacity expansion models as well as other suitable models for different applications. The compatibility assessment and optimization between different applications has been partially conducted for production cost related applications, but must be extended to all uses of storage, so that different applications can be looked at in parallel without double counting. Existing data is available to quantify the value streams at present in some situations, but using these to forecast what the application values will be in the future is a significant source of uncertainty. It is critical that the presentation of results be user friendly and accessible to decision makers. The value of distributed storage to the bulk power system can be incorporated into this effort.

The appropriate capacity credit given to storage for resource adequacy can be determined by applying established effective load carrying capacity (ELCC) and loss of load probability (LOLP) methods, modified to consider the detailed operation of storage, which can be non-trivial. A related area for investigation would be to evaluate how storage fits into existing capacity markets and what changes can be made, such as having more granular time resolution, that would enable the system value of storage to better represented.

ECONOMICS		
Analysis/Research Question	What is the value of energy storage as a function of cost?	
	Incumbents: • What applications? Include separate applications and quantify separately • Identify incumbents • Cost, performance, sensitivities for the incumbents…cost (net present value)	Market size: • Present market size by application • Resize different markets by scenario (e.g. how does regulation market size change in scenarios with high RE?)
Preferred Methodologies and Tools	• Economic analysis of each…quick pass top identify "best" and "niche", focus on "best" applications. • Literature to develop baselines and summarize past studies and obtain past databases and update • Establish market sizes and relationships/functions between scenarios and markets • Obtain relationship between market size and performance of storage (does regulation market size shrink w/ fast response storage?)	
Data Needs and Gaps	• Accurate cost/performance curves for existing technologies • Collect cost/performance for U.S. ARRA storage projects and establish value story • Biggest data challenge: Identify number of lines, transformers, and candidates for storage involving deferral of T&D infrastructure. • Need to interview utilities and establish relationships	
Risks, Limitations, and Caveats	• Accurate incumbent technology cost curves • Accurate scenarios of macroeconomics and markets	
Level of Effort	• 5,000 person-hours • Establish ~10 member Technical Review Committee that knows the incumbent technologies and markets • Review study quarterly	
Key Features to Make the Analysis Used and Useful to Policy and Decision Makers	• Select relevant policies and regulations for each scenario • Strike a balance between depth/thoroughness, and broadness and focus on big markets rather than niche markets • Clearly identify gaps and the importance of the gaps • Highlight trigger points needed for storage to grow rapidly	

Economics

It is important to understand the economics of storage, namely the size of the storage market as a function of storage cost and capabilities. Improved understanding of the “cost-curves” for storage can help in giving more clarity to investment decisions in terms of high value applications and large market segments. There are published reports of “cost-curves” for storage, but they are only applicable for a particular set of assumptions. A framework that can be applied for a wide range of scenarios is desirable.

One potential framework that can be used is to characterize and quantify the different applications and services where storage can be used. The first step would be to identify the incumbent technologies that currently provide the identified grid services and to understand the costs, performance, and sensitivities associated with those incumbents. Next, it will be necessary to identify the market size for the various applications and gain an understanding of how those market sizes will change according to the scenario. A quick pass can identify the “best” and “niche” applications for storage, and a literature search can provide a baseline for these applications. It is important to keep in mind how the market size for an application may change depending on the performance/characteristics of storage.

A simple and transparent analysis framework is necessary for stakeholder buy-in. A well-developed framework can then be used to identify the value that storage can provide, setting the target cost needed for storage to become economical. There will be local differences in markets and values for applications and services, and these differences also need to be kept in mind.

Appendix

Participants

Invited Experts

Audun Botterud	ANL
Paul Denholm	NREL
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Gerald Heydt	ASU, PSERC
Michael Kintner-Meyer	PNNL
Rao Konidena	MISO
Soorya Kuloor	GRIDiant Corporation
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Bill Parks	OE
Rich Scheer (Facilitator)	Scheer Ventures

Initial Questions

The following questions were posed to the workshop participants ahead of the workshop and were designed to stimulate thinking.

1. Valuing storage is a multi-dimensional problem. Are there ways to come up with simple parameterizations that capture the costs and benefits based on system characteristics and location?

    a. How important is detailed modelling in valuing storage?
    b. Do we need high time resolution (seconds or less) detailed models (e.g., explicitly model fast response like regulation services)?
    c. How important is detailed modeling of the network topology in valuing storage e.g., storage may have localized benefits due to congestion patterns)?
    d. Do we need multi-scale models that are coordinated (i.e., hourly to five minutes to seconds and/or EHV to distribution)? If yes, how integrated/coordinated should the effort be in terms of temporal and spatial scales?

2. Should we use a market/price-based approach in valuing storage, OR should we look at a cost-based approach (e.g., storage should depress price spreads, killing its own market, but may still provide value to the system from a cost perspective)?
    a. Should we use historical or simulated market price data to value storage?

3. Should we model long-term evolution issues? How far forward should we consider(i.e., today, 5 years, or 10 years or more)?

4. How should we model storage providing ancillary services, especially those that are not currently market-based (e.g., there is no market for inertial response or frequency response, so valuing them is difficult)?

5. What are the critical modelling issues in valuing multiple value streams for storage (e.g., storage can provide energy arbitrage opportunities and contingency reserves and get paid for both – but how can we model this accurately as they occur at such different time scales)? Also, from a reliability perspective, getting multiple services from any one source is prone to possible double counting.

6. What storage scenarios are most important to examine?

Group Discussion Template

ANALYSIS AREA	
Analysis/Research Question	
Preferred Methodologies and Tools	
Data Needs and Gaps	
Risks, Limitations, and Caveats	
Level of Effort	
Key Features to Make the Analysis Used and Useful to Policy and Decision Makers	