Integrating Energy Storage Solutions for Fossil-Fuel Generation: Value Propositions and Pathways for Public Power

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Prepared for APPA by Beam Reach Consulting Group

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About the Association

The American Public Power Association is the voice of not-for-profit, community-owned utilities that power 2,000 towns and cities nationwide. We represent public power before the federal government to protect the interests of the more than 49 million people that public power utilities serve, and the 96,000 people they employ. Our association advocates and advises on electricity policy, technology, trends, training, and operations. Our members strengthen their communities by providing superior service, engaging citizens, and instilling pride in community-owned power.

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Executive Summary

In April 2022, American Public Power Association launched a six-month study, funded in part by the U.S. Department of Energy to explore the potential of energy storage solutions to enable public power utilities to better manage fossil-fuel power plants and to lower barriers to energy storage integration with these fossil-generation assets. The study is part of a greater five-year cooperative agreement program between DOE and APPA intended to remove barriers and increase adoption of energy storage solutions for public power.

This study is qualitative and phenomenological in nature. Data was collected through focus groups and interviews with participants in a working group, created for purposes of this study, of public power utility representatives with an identified interest in improving, influencing, or learning about energy storage strategies.

Foundational to the success of the study was the identification of the current challenges public power utilities face in regard to fossil-generation asset management. Numerous challenges quickly became evident, including:

- Political sentiment in support of the transition away from fossil assets
- Maintaining grid reliability
- Barriers to obtaining permits for new fossil assets
- The necessity of increasing utilization rates for older fossil-generating units
- Pressure to ramp faster, load follow, and black start
- Fuel price increases and volatility
- Unproven fossil-generation decarbonization technologies

Most notably, the data demonstrates that eliminating carbon and greenhouse gas emissions is a primary challenge for public power utilities managing fossil-generation assets.

Second to the identification of existing challenges was development of an understanding of the value proposition of energy storage. Existing literature shows that effective energy generation and delivery has numerous benefits, including reliability, resilience, voltage regulation, and peak energy delivery, all of which produce cost benefits that amplify the existing economic benefits associated with hedging against generation feedstock fuel pricing or fuel availability. Members of the working group named additional benefits they had achieved through their own implementation of energy storage technologies:

- Reduced transmission construction costs
- Capacity and transmission peak reduction
- The ability to maintain unit capacity during peak summer hours
- Improved reserves

This research demonstrates a significant overlap between the needs of the fossil-asset management community and the benefits of energy storage technologies. The following opportunities to utilize new technologies to meet existing needs were identified:

Table 1: Public power fossil asset needs and related energy storage technologies.

FOSSIL ASSET MANAGEMENT NEED	ENERGY STORAGE TECHNOLOGY
System Demand Reduction	Battery Energy Storage, Controllable Thermal Loads
Fuel Mixing	Hydrogen Production
Support Generator Ramp Rate	Battery Energy Storage
Enhance Load-Following Capability	Battery Energy Storage
Gas Inlet Pre-Cooling	Ice Storage
Enabling Black Start Capability	Battery Energy Storage

Ultimately, detailed action plans were created for the four opportunities considered to provide the greatest benefit:

- Battery Energy Storage for System Demand Reduction
- Controllable Thermal Loads for System Demand Reduction
- Hydrogen Production for Fuel Mixing
- Battery Energy Storage for Support Generator Ramp Rate

The working group agreed that system demand reduction through battery energy storage presented the most promising opportunity and should, therefore, be considered a priority going forward, as it is the most likely to produce near-term results.

The most significant outcome of this research was the establishment of pathways for energy storage, which should be considered a major achievement. However, it is important to recognize that this is year one of a five-year program. The results included herein only demonstrate how much work there is to be done and the extent of the potential to continue eliminating obstacles and facilitating success in integrating new energy storage technologies into traditional fossil-fuel management systems. The working group named the following needs in pursuit of those goals:

- Training on technical topics
- Access to subject matter experts
- Resources to build the internal capabilities of their staff
- Support to manage advanced technologies long term
- Demonstration projects to validate the performance of new technologies

APPA is eager to continue the progress produced so far and to continue its partnership with DOE for the benefit of the more than 49 million people served by public power utilities and the 96,000 people they employ.

Introduction

This report summarizes a six-month effort directed by APPA, funded in part by DOE, and executed by Beam Reach Consulting Group. Across the U.S., public power utilities own and operate fossil-fueled generation assets and many more rely on them to ensure regional grid stability. This project sought to better understand the role that energy storage technologies can play in enabling public power utilities to better manage its fossil-fuel power plants and to lower barriers to energy storage integration with these fossil generation assets.

This report contains findings, conclusions, and recommendations intended to support stability, reliability, and resilience for public power generation owners and distribution companies. The findings contained herein are informed by input, discussions, interviews, and research with public power utilities from various regionals of the U.S. Their insights led to the development of the strategies and framework described in this report for implementing energy storage at community-owned electric utilities with an intent to assure mutual benefits for everyone connected to the electric grid.

Background and Rationale for this Study

This study was commissioned by APPA and the DOE to help identify future opportunities that lie at the intersection of energy storage and fossil generation technologies. This study was intended to lower barriers to energy storage adoption by identifying challenges related to these technology intersections. Further, the study establishes a clear path forward that addresses the barriers identified, includes defined action steps for public power to take, and establishes reasonable timelines for these actions.

APPA and DOE designed this study to be executed by a working group of public power community members under the strategic direction of a consultant. The consultant was retained to provide technical analysis, present findings to the working group and APPA, gather feedback, and incorporate into a framework a pathway that supports public power and management of fossil generation assets. The pathways presented in this report include proven solutions that could be applied in a small- or medium-sized generator context, as well as novel opportunities that have emerged through research and discussion with working group members.

As a result of this study, the working group, APPA, and consultant developed this report to present the findings of the research and analysis performed. This report considers the opportunities and challenges present, the future direction of energy storage as it relates to fossil generation, and prioritized actions for public power and others to take to minimize barriers and maximize opportunities.

Study Methodology

The study is fundamentally qualitative and phenomenological, incorporating the direct experience of members, collected through focus groups and interviews. As part of a broader effort for energy transition, APPA reached out to members with an interest in improving, informing, or learning about energy storage strategies, especially those that integrate with fossil-fuel generation. Through this outreach, APPA identified an Energy Storage Working Group made up of public power utility representatives. These individuals offered a variety of experiences through their roles with public power, including experience with grid and generation operations, business administration, technology, leadership and management. These members participated in monthly, virtual meetings over the course of the project.

The project incorporates technology road mapping and strategic planning elements, using a compression planning approach to deliver actionable plans for resolving high priority challenges. The meetings, agenda, and focus areas and discussion topics were designed by a professional facilitator from Beam Reach Consulting Group in concert with guidance from APPA. Each meeting was designed with specific learning objectives in mind and the approach taken involved a variety of professional facilitation tools and techniques specifically used to elicit the most effective feedback while limiting bias. The methodology employed in the meetings first used various techniques to gather a broad variety of responses to questions. This design resulted in a large, divergent pool of responses. Subsequently, the facilitator invoked convergent techniques to understand commonalities and priorities among the working group members. These efforts ensure each member of the working group had an opportunity to participate actively, have their opinions heard, and resulted in effective and actionable strategies for public power.

In addition to the monthly working group meetings, APPA and consulting staff interviewed several public power utilities about their experiences with energy storage projects in their regions. The input gathered in these interviews are being transformed into case studies that will provide an overview of the project, benefits, challenges, success factors, lessons, and suitable next steps for the organization to take relative to energy storage projects. These case studies will be published on the APPA website once available.

Table 2: Members of the ESWG and other key public power utility contributors provided insights on the challenges and opportunities for energy storage in the public power utilities.

Date (2022)	Interaction	Topic	Attendance Count
April 26	ESWG Meeting	Fossil Generation Challenges and Changes Needed	15
May 26	ESWG Meeting	Energy Storage Value Propositions	17
June 16	ESWG Meeting	Fossil Energy and Energy Storage Integration Challenges	15
June 17	Public Power Energy Storage Project Interview	NYPA Energy Storage Projects	5
July 26	ESWG Meeting	Pathways for Resolution of Challenges	14
August 10	ESWG Meeting	Pathways for Resolution of Challenges (cont'd)	13
August 11	Public Power Energy Storage Project Interview	Wakefield Municipal Gas & Light Department Energy Storage Projects	4
August 30	ESWG Meeting	Review Working Group Findings	14

1. Fossil Generation Asset Challenges

The foundation for this study lies in an understanding of the fossil generation asset management and operational challenges that are being experienced by public power utilities. This study focuses on resolving these challenges through the deployment of energy storage solutions. This report chapter explores the fossil-generation-specific challenges that were identified by the members of the Energy Storage Working Group.

During the April 2022 meeting of the Energy Storage Working Group, attendees were presented with a series of focus questions related to fossil generation. Participants provided written responses to each question, and then engaged in additional dialogue. Responses were documented, analyzed, and synthesized. The results presented in this chapter reflect the full discussion held.

Summaries of the responses received for each focus question can be found in the tables that follow within this chapter. In some instances, participants were asked to rank the importance of challenges identified. In these cases, participant responses are presented in rank order within the summary table, and a separate column indicates the number of votes received for each response.

Key takeaways from the discussion are summarized as follows:

- Working group members expressed that political sentiment in their communities supports a transition away from fossil assets and toward intermittent renewable resources.
- Maintaining grid reliability will require the use of peaker plants and energy storage, to manage intermittency.
- It is difficult to obtain permits for new fossil assets. Therefore, aging plants are being operated for longer lifetimes, with higher utilization, and under more dynamic ramping and load following conditions.
- The additional strain will impact the lifetime of these traditional fossil assets, increase their maintenance costs, and decrease their operating efficiency, resulting in even more emissions.
- Fossil generation assets face increasing pressure to ramp faster, load follow, and black start.
- Fuel price increases and volatility are negatively impacting the economics of managing fossil units.
- Fossil generation decarbonization technologies (like Carbon Capture Utilization and Storage) are not yet mature, and their overall impact on existing plants is still unknown. Commoditization of captured CO_2 could improve system economics.
- Commissioning new, more efficient fossil generating units with enhanced load following abilities would lower overall emissions, especially when compared to the extended operation of older, less efficient units. This approach faces political opposition.

New or different use cases:

- Hydrogen fuel mixing in natural gas generators.
- Repurposing retired fossil assets to store energy in the form of hydrogen (old natural gas fields) or thermal energy (retired boilers).

April 2022 ESWG Focus Question #1: Summary of Discussion

Prompt to Participants	
Describe the primary challenge you see in the management of fossil generation assets.	
Summary of Responses	**Votes**
Eliminating Greenhouse Gas (GHG) emissions: Many states moving toward carbon-free generation goals; concern in transitionary phase; operational challenges in the interim; maintaining reliability and eliminating emissions are often opposing ambitions.	8
Political pressure to divest from fossil fuels: Many states and localities are transitioning away from fossil generation; utilities are mandated to replace traditional baseload with intermittent renewables and other solutions; what is best for the system and reliability differs from political will.	3
Managing system reliability in the face of changes: Reliability of these resources compared to intermittent resources; control over fuel source with fossil-based generation; controlled production, generation; less control with replacements; losing direct control over reliability; challenges in operating regional system with retiring resources; regional basis; having enough resources to fill in the gaps.	2
Providing non-energy generation services: Such as ramping, load following, and black start Baseload restricted in flexibility, by design; produces more emissions when operated as not designed.	1
Handling generation cost dynamics: Peak shaving assets are maintained; only generation assets managed; global supply chain constraints and impact on generation costs.	1

April 2022 ESWG Focus Question #2: Summary of Discussion

Prompt to Participants
Do you anticipate changes will be needed to the way fossil generation assets are being used, or have been used in the past? If so, what changes do you anticipate?
Summary of Responses:
Strained Operation of Older Fossil Units: Older fossil generating units will be faced with higher utilization rates and more frequent ramping, both of which can lead to increased emissions, and will impact maintenance schedules and plant lifetime. Permitting new fossil units can be extremely difficult. Older units will be faced with higher utilization to fill the gaps. Higher emissions from these less efficient resources may occur in the near term as decarbonization and electrification (EVs/heating) intensifies. Nuclear and fossil units are retiring, and no new ones being built. Existing units are being pushed harder and operating more than in the past; 20 - 30% more in some cases. Emissions increases are expected as a result.
Fossil Generation Replacements: Fossil assets may be phased out and replaced with peakers and storage, renewables, non-carbon-producing generation, storage, or similar dispatchable sources with low to no GHG emissions. Drastic increases in electrical load, due to EV deployments, electrifying oil and gas appliances, and other factors. More transmission capacity will be needed, leading to cost increases.
Decarbonization Technology: Fossil plants will be required to adhere to point source carbon capture and sequestration requirements. Operational changes and cost impacts are difficult to predict because the technology is not yet mature. It is not yet possible to predict the changes to the plant, or the effectiveness of the technology.

April 2022 ESWG Focus Question #3: Summary of Discussion

Prompt to Participants
Describe any new or different use cases for fossil assets that you are considering for your organization, or are aware of.
Summary of Responses:
Hydrogen Fuel Mixing: Utilities are investigating mixing hydrogen into the natural gas used in gas turbines. New Siemens turbines, owned by public power members, are capable of using 45% hydrogen. Operational plans involve making hydrogen when electricity is being curtailed or is very cheap. At least one demonstration project is currently in the works in California.
Repurposing Retired Fossil Assets: It is possible to repurpose retired fossil equipment for energy storage purposes. There has been consideration of using old boiler units as housings for molten salt based thermal energy storage systems. Parallel efforts are being made to consider the use of old natural gas fields for storing hydrogen.
Operating Limits of Fossil Plants: It is unclear how low of a capacity factor, traditional baseload resources (i.e., coal) can achieve while still being technically and economically viable. If coal resources do not go away due to complications from aging, they may retire from a lack of competitiveness; fixed costs may exceed revenue from energy produced.

April 2022 ESWG Focus Question #4: Summary of Discussion

Prompt to Participants
Is there anything we haven't discussed that you would like us to know?
Summary of Responses:
Lowering Overall Emissions: The inability to replace older inefficient fossil generation with newer, smaller fossil generation that can load follow and mesh with the grid better - but runs into environmental opposition. The new generation profile is cleaner, but environmental groups take the position that all load should be met with intermittent renewables and storage. This will cause utility directors to resign as they don't want to be responsible to North American Electric Reliability Corporation for running an unreliable utility system.
Availability of Energy Storage Technologies: It would be helpful to see a presentation of various energy storage technologies and levelized cost of those technologies. I would like to hear about the DOE Energy Storage Shot.
Increasing Revenue: Commoditization of captured $\mathbf{CO_2}$.

2. Energy Storage Value Propositions

The value, benefits, and opportunities of energy storage in the public power utilities were investigated through past member experience and the collective knowledge of the ESWG. Further literature review and research was performed to identify and analyze energy storage value both broadly, and specifically as it relates to fossil-fuel generation. These analyses were further examined through the lens of public power generation asset owners and operators, utilities operating distribution assets, and the ultimate customers of public power.

Publication Findings

There is an extensive existing body of research on energy storage. In addition, APPA's own Public Power Energy Storage Tracker provides meaningful data to evaluate ongoing trends.

The research points to a variety of benefits related to effective energy generation and delivery. These include improved reliability and resilience, such as the use of storage during outage events both for supply delivery and black start. Operational benefits include the ability to better regulate power delivery (voltage regulation) and peak energy delivery over various time spans which could mitigate the need for additional delivery infrastructure or additional generation. These reductions or deferral of capital expenditures were identified as cost benefits of energy storage in addition to economic benefits associated with hedging against generation feedstock fuel pricing or fuel availability.

Further benefits were identified related to adoption of renewable energy generation, both as a means to regulate intermittency of certain renewable generation and as a method to achieve state carbon reduction goals. The benefits that make up the value proposition are enumerated below.

Cost Reductions

- Cost savings from deferrals or reduced need to replace or rebuild line (distribution and transmissions savings)
- Cost savings from potential reduction in "customers' peak coincident charges"
- Mitigate against temporary fuels shortages and rising fuel prices

Renewable Generation Adoption

- Integration of intermittent renewable generation (both commercial and residential) and move towards decarbonization goals
- Drive solar and wind adoption

Facilitates Reduction of Greenhouse Gas (GHG) Emissions

- Reduce need to run back-up diesel generation if batteries are available
- Allows for the provision of rated power with lower emissions

Grid Reliability
- Act as a back-up during outages and emergency weather situations
- Perform demand curve shifting by reducing oversaturation of energy production during lower demand times

Grid Resiliency
- Expedites recovery by providing spinning reserves for "black start" situations
- Peak load reduction / Capacity/Peak Shaving (through supplementing energy demand)
- Lower transmission and capacity charges
- Congestion/Peak demand management
- Voltage support on distribution system
- Mitigate negative impacts of intermittency and variability of solar production
- Mitigate against temporary fuels shortages

Efficiency
- Use of ice storage as a means to capture excess renewable generation leads to reduction of fossil fuel consumption
- Peak load reductions for more efficient generation

Learning and Testing Benefits
- Learn how to lower overall System-Levelized Cost of Energy for solar energy and storage
- Enable solar energy and power system studies to expand solar, energy storage, and other distributed resources
- Help determine appropriate battery applications for each type of battery technology
- Allow testing of new types of energy storage (flywheel energy storage, hydro pump storage, etc.)

Findings from the ESWG Discussion

During the May 2022 meeting of the ESWG, attendees addressed a series of focus questions and topics that were designed to address the value proposition of energy storage, including direct and indirect benefits. As with other Working Group meetings, participants provided feedback via discussion as well as via written response to each prompt. These collective responses were documented, analyzed, and synthesized. Results of this analysis are included in this chapter.

Summaries of the responses received for each focus questions can be found in the tables that follow within this chapter. Some respondents provided their names or organization names as part of their response to questions. However, to aid with preservation of Chatham House Rules that were indicated to the participants at the outset of the meetings, names have been removed. The results shown represent the collective response of the working group.

May 2022 ESWG Focus Question #1: Summary of Discussion

Prompt to Participants
If applicable, describe the fossil generation assets managed by your organization. What type? What capacity? Etc.
Responses:
Peaking generation. Peak Shaving.
Natural gas, diesel, various industrial/commercial sites.
Primarily peak shaving diesel generators and dual-fuel natural gas and diesel combustion turbines.
Small diesel generators (300 kilowatts) to supplement smaller 200 kW hydro generation.
Intermediate generation 54 megawatts (10+44)
Two natural gas boilers, a LM6000 gas turbine with heat recovery system generator behind it. All three steam sources supply steam to two steam turbines. Gas turbine output is ~45 MW and steam turbines are ~24 MW each.

May 2022 ESWG Focus Question #2: Summary of Discussion

Prompt to Participants
If applicable, describe the energy storage technologies deployed by your organization. What type? What capacity? Etc.
Responses:
10 MW Battery storage pilot project planned.
A 3 MW/9 megawatt-hours battery storage facility is planned for installation by the end of June. Battery is manufactured by Contemporary Amperex Technology Company.
1 MW BESS Peak Shaving.
Two member cities have deployed small (2-4 MWh) BESS for peak shaving.
Evaluated, but opted out of a 500 kWh/250 kW battery energy storage system.
Deployed system builds ice during off-peak hours to be used for inlet cooling of combustion turbines during on-peak hours. This technology supports 3 units at the same plant, increasing their capacity during peak summer conditions by a significant amount of MW.

May 2022 ESWG Focus Question #3: Summary of Discussion

Prompt to Participants
If applicable, describe the R&D topics and technologies your organization has interest in.
Responses:
Currently investigating the feasibility of pairing BESS with an existing solar plant.
Interested in learning more about new and developing battery chemistries other than Li-Ion.
Currently investigating a thermal energy storage system that is in development.
Behind the meter energy storage.
Have explored early wind and solar and EV studies (via Demonstration of Energy & Efficiency Developments) in the past. Currently in the process of negotiating a contract for a battery storage project.

May 2022 ESWG Focus Question #4: Summary of Discussion

Prompt to Participants	
What problem were you attempting to solve by deploying an energy storage technology?	
Responses:	
Problem Addressed	**Comments**
Peak shaving to reduce capacity obligations	Environmental approach; reducing peaks reduces capacity obligation; changes environmental impact; Peak shaving to reduce cost and environmental impact with respect to capacity obligations; Peak shaving to reduce capacity obligations and environmental impact
Providing peaking power with lower environmental impact	Environmental approach; reducing peaks reduces capacity obligation; changes environmental impact; Peak shaving to reduce cost and environmental impact with respect to capacity obligations; Peak shaving to reduce capacity obligations and environmental impact; Allow peaking power with lower/no emissions
Peak shaving to avoid demand charges	Peak shaving to reduce demand charges from our power provider; Peak shaving – dispatching during peak periods; charging from solar or grid;
Energy storage to provide a non-wires solution to offset an expensive transmission upgrade	Peak summer load; approaching thermal limit on transmission interconnection; two parallel lines; one primary line and one backup; utility study identified alternatives; split load at the substation, to better utilize both lines; created N-1 contingency on hot days; battery storage became N-1 solution
Implementation of thermal energy storage, in the form of ice, to support inlet	Around since 1990; warm summer temperatures, reduce combustion

cooling to maintain the output of combustion turbines during peak summer conditions	turbine output; MW output degradation; inlet chilling, can be done with online chillers, tricks generator into thinking the ambient temp is lower; peaking plant, make ice at night and on the weekend; allows enough time/
Reduced need to run back-up diesel generation for peak load management	Battery storage intended to utilize off-peak renewable energy generation to meet peak needs. Considered – cost effectiveness was not there at the time; chose to use water heater-based demand response solution instead
Peak shaving to reduce capacity charges under wholesale full-requirements power purchase agreement	
Non-wires alternative for critical customer requiring redundancy	Two lines off of the same substation feeding a critical customer; looking at battery, instead of running a third line
Providing provide market and reliability services, supporting a community microgrid	Installation in urban city center; peak load deferral; using in Southwest Power Pool market for arbitrage; placed in the heart of community microgrid – providing backup power for critical community services (police, gov, etc.); Supplements natural gas generation, solar, dual fuel and black-start capable generator as the heart of the microgrid.
Grid stability and physical flows	

May 2022 ESWG Focus Question #5: Summary of Discussion

Prompt to Participants	
If you previously considered an energy storage project, but did not proceed with implementation, what were the factors that drove your decision making?	
Responses:	
Decision Factors	**Comments**
Thermal energy storage was considered, but ultimately, and online chilling system was installed.	We had to forego thermal energy storage at one of our local power stations because the projected operations wouldn't guarantee enough down time to build the ice. We had to go with online chilling as an alternative.
Funding sources	With our power purchase contract, it is difficult to make the economics work without subsidies/grants.
Total system costs extend beyond the battery	Bid prices and total installed costs were significantly higher than originally estimated. The total price for the 500 kWh storage was $1.1 million. Upgrading existing plant to handle the new battery system.
Considered in context of hybrid resource but decided to go with solar only.	Capacity targets have been established for solar, storage, and hybrid; independent targets have been set in each category.
Opposition from wholesale power supplier; increasing BESS costs and inadequate peak shaving run time.	Contract does not specifically include language related to storage; the wholesale power supplier interpreted this as an indication that batteries were disallowed.

May 2022 ESWG Focus Question #6: Summary of Discussion

Prompt to Participants	
How did you intend to measure the value derived from the technology?	
Responses:	
Intended Measure of Value	**Comments**
Financial impact on bulk electric bill.	
Environmental benefit.	There is no clear, standard approach for determining the environmental benefit.
Avoided demand cost.	Historically, peak shaving was accomplished with natural gas or diesel gensets, or demand-side management. A DEED project evaluated energy storage as an alternative. A pilot project using energy storage was then conducted, revealing operational issues.
Measure actual reduction of need for peak generation.	
Lower capacity market requirement.	Energy storage project economics are based on dispatching the storage system during monthly peaks to lower regional transmission costs, and during annual peaks to lower capacity market requirement. The annual capacity charge in the Northeast is a one-time per year charge at a specific time of year. The regional transmission charge is similar; measured monthly. These charges are specific to the market structure in NE, though similarities may exist elsewhere.
Financial benefits, peak load deferral	For a planned battery storage project, the market side can be tracked by the financial benefits accrued. Operations staff can report on the effectiveness of the battery storage system in deferring peak load on the distribution and/or transmission system.

Comparing the capital and BESS charging and other ancillary costs to the avoided capacity charges.	
Dispatch effectiveness.	Follow through compared to declared maximum power scheduled.
Cost compared to other peak shaving approaches.	Including gas turbines or other methods.
Availability.	Some batteries have issued related to availability; can we rely on it when we need it? Failures have been documented; availability needs to be factored into resource management.
Ancillary and reliability services.	Energy, capacity, spinning and non-spinning reserves, regulation up and down, black start, fast ramp, solar shaving, others. All of these services can be considered mutually exclusive of each other.

May 2022 ESWG Focus Question #7: Summary of Discussion

Prompt to Participants
What value did you actually derive from implementation?
Responses:
First value was to save transmission construction costs. Ongoing savings come from capacity and transmission peak reduction.
With regards to thermal energy storage for combustion turbine inlet cooling, we were able to maintain most of the units' capacity rating during peak periods, pretty much as expected.
High dispatch performance and availability for peak shaving.
Reserves represent the largest area of value for balancing authorities.

May 2022 ESWG Focus Question #8: Summary of Discussion

Prompt to Participants	
In consideration or implementation, did you find unexpected benefits? Drawbacks?	
Responses:	
Unexpected Benefit or Drawback	**Comments**
Product maturity.	As we have gone through the research phase, we realized we do not want to own this generation or perhaps the next generation of product.
System performance issues, unavailability	A pilot project compared energy storage to gas or diesel; all have issues. General findings: battery system online for a few years; many issues encountered with system not being available; low charge, error, fault conditions, etc.; operate monthly, for peak demand cost savings; having generation available when needed (24/7) is important to keep cost down; issue could be manufacturer specific; 1 MW/ 2 MWh LFP.
Drawbacks. Need to be more specific in the agreements. Otherwise, will not receive the desired level of performance.	Capacity, peak shaving; systems 10 – 20 MW as learnings for larger systems in the future; if we want ancillary services or value stacking, ride through voltage sags, etc. – if we want these features, we need to be more specific in power purchase agreement; e.g. everyone defines state of charge differently.

May 2022 ESWG Focus Question #9: Summary of Discussion

Prompt to Participants
What were the factors that drove success in your project or consideration? Factors could include regulatory environment, incentives, business models, or other.
Responses:
The economic aspect; avoidance of a huge expenditure.
Nothing magic. A realistic and well thought out plan, dedicated and talented staff and a good consultant.
Business decision to reduce carbon footprint and recognizing the critical role batteries play in making that happen.

May 2022 ESWG Focus Question #10: Summary of Discussion

Prompt to Participants	
What were the barriers that had to be overcome, in your project or consideration?	
Responses:	
Barriers to Overcome	**Comments**
Specification development, Supervisory Control and Data Acquisition integration.	Specifications and requests for proposals had to be detailed enough to get what was needed out of the resulting system;
Convincing folks it would work, as the use of thermal energy storage for this application was cutting edge at the time.	Break it down into simple form; show the past examples across industries;
The most significant barrier was working with the investor-owned utilities who we interconnect with.	They required some significant mitigating equipment to avoid impacts on their system, since we are connected to them at a distribution level voltage. Also a case of first impressions, first system in state; IOU pushed hard on protective equipment on their system and related cost sharing;
Acquiring permits and educating technical staff on the different ways that battery/inverters operate compared to the way our existing generating resources operate.	Use case differences; lack of available inverter tech to support use cases, switch between operating modes; grid-following, grid connected, and load following;
Experience and knowledge about these resources as they compare to traditional generation.	It is anticipated that this will continue to be a barrier until we have more learnings and success.
Design vs. actual implementation.	Many differences have been observed between expected system performance, and actual system performance.

3. Fossil Assets and Energy Storage Technology Intersections

Several of the energy storage value propositions explored have the potential to directly address fossil asset generations that were previously identified. This chapter reports on the opportunities found at the intersection of energy storage technologies and fossil generation assets. This chapter seeks to characterize the opportunity space for deploying energy storage technologies in support of fossil assets.

An initial analysis of the results collected during the working group discussions exposed significant overlap between the needs of the fossil asset management community, and the services that can be provided through the deployment of energy storage technologies. An initial listing of the emergent opportunities was further analyzed, to better characterize aspects of each opportunity, including:

- The applicable fossil generation asset challenge
- The appropriate energy storage technology for addressing the challenge
- The use case, or method by which the energy storage technology would be used to address the challenge
- The value proposition offered in deploying the storage solution, or methods through which the opportunity could be characterized financially

The table below shows the opportunities identified, as well as the various aspects of each opportunity, mentioned above.

Energy Storage Technology	Use Case	Relevant Fossil Asset	Problem Addressed	Value Propositi on	Description
Battery Energy Storage	System Demand Reduction	Baseload Peaking Backup	Decarbonization Emissions Reductions Generation Cost Fossil Asset Optimization Managing Intermittency	Non-wires alternatives transmission and distribution investment deferral Reduced capacity obligations Reduced fuel consumption. Reduction in operations and management costs	Energy arbitrage using batteries. This can lower system peak demand, deferring transmission upgrades, and reducing fuel costs. Lowering system demand dynamically during periods of renewable energy intermittency can increase system reliability.
Ice Storage	System Demand Reduction	Baseload Peaking Backup	Decarbonization Emissions Reductions Generation Cost Fossil Asset Optimization	Non-wires alternatives T&D investment deferral Reduced capacity obligations Reduced fuel consumption. Reduction in O&M costs	Energy arbitrage using ice storage systems to supply cooling loads during peak hours. This approach can ease the operation of fossil generators, preventing emissions, and lowering fuel consumption.
Controllable Thermal Loads	System Demand Reduction	Baseload Peaking Backup	Generation Cost Fossil Asset Optimization Managing Intermittency Decarbonization Emissions Reductions	Non-wires alternatives T&D investment deferral Reduced capacity obligations Reduced fuel consumption. Reduction in O&M costs	Demand response utilizing thermostatically controlled customer loads. This approach can be used for short duration demand reductions, and needs to be coordinated with customers, to prevent dissatisfied utility customers.

Energy Storage Technology	Use Case	Relevant Fossil Asset	Problem Addressed	Value Propositi on	Description
Battery Energy Storage	Ramp Rate Control	Baseload Peaking Backup	Managing Reliability Fossil Asset Optimization Decarbonization Emissions Reductions	Reduction in O&M costs Reduce generator stress. Support system stability	Deploying battery storage can allow fossil generators to ramp at a natural rate, while batteries are discharged to meet the additional demand.
Controllable Thermal Loads	Ramp Rate Control	Baseload Peaking Backup	Managing Reliability Fossil Asset Optimization Decarbonization Emissions Reductions	Support system stability. Reduced generator stress. Reduced fuel consumption. Reduction in O&M costs	Loads can be dynamically controlled to lessen the severity of ramping requirements, allowing generators to maintain optimal setpoints, or ramp at natural rates.
Ice Storage	Gas Inlet Pre-Cooling	Baseload Peaking	Generation Cost Decarbonization Emissions Reduction	Reduction in O&M costs	Ice-based cooling systems can be used to lower the temperature of ambient air, prior to use in combustion within gas turbines. Pre-cooling increases the turbine operating efficiency, preventing increases in emissions, and reducing fuel consumption.
Hydrogen Production	Fuel Mixing	Baseload Peaking	Decarbonization Emissions Reductions Generation Cost	Reduce renewable energy curtailment. Reduce hydrogen production costs	Use hydrogen in gas turbine fuel mixing to reduce emissions. The cost to generate hydrogen can be lowered by using renewable generation that would otherwise be curtailed. Overall fuel costs may be lowered.

Energy Storage Technology	Use Case	Relevant Fossil Asset	Problem Addressed	Value Propositi on	Description
Battery Energy Storage	Enhancing Load Following Capability	Baseload Peaking Backup	Managing Reliability Fossil Asset Optimization Managing Intermittency	Reduction in O&M costs Reduced generator stress	Allow generators to stay at their natural set points, and instead use energy storage to handle deviations in demand. This can reduce the wear on older fossil generators and can prevent increases in emissions due to suboptimal generator dispatch.
Battery Energy Storage	Enabling Black Start Capability	Baseload	Managing Reliability	Increased utility revenue Support system stability	The sale of electricity during high price periods may justify the investment in energy storage.

This chapter presents the potential intersections between storage technologies and fossil needs. Not every opportunity proposed can be considered both technically and economically feasible. For the purpose of this study, further analyzing the most promising opportunities is most likely to result in near-term benefits. Therefore, an initial down selection of the opportunities was conducted, by allowing working group members to cast votes, indicating their preference for the pursuit of the opportunities identified.

The following table shows the votes accrued for each technology, as working group members provided indications for their preferences.

Technology	Use Case	Votes
Battery Energy Storage	System Demand Reduction	6
Controllable Thermal Loads	System Demand Reduction	3
Hydrogen Production	Fuel Mixing	2
Battery Energy Storage	Support Generator Ramp Rate	2
Battery Energy Storage	Enhance Load Following Capability	1
Ice Storage	Gas Inlet Pre-Cooling	1
Battery Energy Storage	Enabling Black Start Capability	1
Ice Storage	System Demand Reduction	0
Controllable Thermal Loads	Support Generator Ramp Rate	0

4. Action Plans

The detailed listing of storage opportunities presented in the prior chapter was summarized in tabular form and presented to the ESWG during its June meeting. Participants were prompted to comment on each opportunity, considering the benefits and constraints, as well as the technical deployment challenges. The main challenges that need to be overcome, to enable the use of energy storage in the four high priority use cases, were identified during the discussion.

During the July and August working group meetings, each high priority use case was further elaborated on, discussing approaches for resolving the identified challenges, and actions that could be taken. All the findings from the July and August meetings have been integrated into Action Plans, which are presented in this chapter.

A template was developed for structuring the action plans. Working group members completed the templates in small groups, presented them to each other in large group sessions, accepted feedback from each other, and edited and updated the templates based on the feedback provided. The templates were designed to extend the findings of the prior activities, identifying challenges to technology deployment, activities that can be undertaken to overcome the challenges, and to identify metrics and milestones that can be used to track progress toward overcoming the challenges. In addition, the template was used to identify resources needed to tackle the challenges and assisted in identifying necessary stakeholders related to the effort.

Action plans were completed for the four intersections indicated as being most important to the working group members, namely:

- Battery Energy Storage for System Demand Reduction
- Controllable Thermal Loads for System Demand Reduction
- Hydrogen Production for Fuel Mixing
- Battery Energy Storage for Support Generator Ramp Rate

Each action plan is followed by notes representing additional discussion held by working group members, relevant to the content of the action plan.

<table>
<tr><th colspan="3">Action Plan #1 | Battery Energy Storage for System Demand Reduction</th></tr>
<tr><th>Relevant Fossil Asset</th><th>Anticipated Integration Challenges</th><th>Required Improvements</th></tr>
<tr><td>Baseload, Peaking, Backup</td><td rowspan="5">- High system implementation costs
- Navigating contract limitations with wholesale power suppliers
- Justifying cost vs. other options
- Ensuring the storage duration is long enough to cover the totality of the peak load period, which is related to cost
- Sizing batteries to ensure sufficient discharge capacity over desired demand intervals
- Gaining access to appropriate project financing
- Supply chain disruptions and cost impacts
- Finding a common communication protocol so that multiple battery systems can be combined using an existing SCADA system
- Accurately characterizing the differences between designed system capabilities verses actual performance
- Organization-wide agreement on the use of battery assets</td><td rowspan="5">- Establishing a front end understanding of the energy storage technology, across the organization, collectively
- Understanding and navigating regulatory requirements and cost
- Retaining institutional knowledge during staff transitions; building organizational capacity
- Lobbying at state/federal level. Funding from the state can help with cost
- Materials innovations in batteries may lead to lower cost products that are produced domestically and are not subject to supply chain disruptions
- Standards improvements are needed, including enhanced communication protocols</td></tr>
<tr><th>Problems Addressed</th></tr>
<tr><td>Decarbonization, Emissions Reductions, Generation Cost, Fossil Asset Optimization, Managing Intermittency</td></tr>
<tr><th>Value Proposition</th></tr>
<tr><td>Non-wires alternatives, T&D investment deferral, Reduced capacity obligations, Reduced fuel consumption, Reduction in O&M costs, Reducing renewables curtailment, Ancillary services, Pricing hedge/stability</td></tr>
</table>

Action Plan #1 | Battery Energy Storage for System Demand Reduction		
Major Activities, Milestones, and Metrics	**Resources Required**	**Key Stakeholders**
- Organizational effort has to be made. Identify group/people that have different background to be educated. Have training, knowledge, experience - Get involved with other states or other utilities in the energy space	- Feasibility study at a high level to identify gaps - Power engineering to guide - Trained and knowledgeable staff - Subject matter experts to fulfill knowledge gaps	- City Council - Public Utility Advisor Boards - Representative from each group within the utility - Regional Planning Commissions at the county level

Further Discussion:

Value Proposition:

- Excess solar generation/wind generation during times of low load. Battery storage offers an opportunity to put excess solar and wind generation into storage instead of curtailing when there is not a lot of load in real time.
- Largest profit potential for energy storage comes from ancillary services. Batteries can be used to fulfill reserve margins/requirements.
- Renewable energy is usually priced using fixed contracts. Coupling energy storage with renewables can provide a hedge and support price stability.
- Ancillary services represent a significant market opportunity for energy storage systems. However, unlike traditional generation, energy storage cannot be bid for multiple ancillary services in the same day.

Challenges:

- Considering PPAs and wholesale providers, it is unclear if energy storage constitutes generation, or if it is contractually allowable.
- Summer runs can extend longer than winter. Batteries need sufficient capacity to endure long demand periods.
- Summer run can average around four hours.
- Batteries are not always the lowest cost option. Other options include adding generation, or employing demand side management.
- Batteries represent a non-wires alternative solution. Past deployments have required financial expenditures on substation upgrades. Project success was achieved through a partnership between the utility and a technical contractor. The contracting partner paid for the battery. Both organizations shared the savings from the capacity market, as well as savings from regional transmission charges abated.
- Lithium costs and supply chain issues. Batteries are difficult to procure.
- New battery chemistries and approaches can be future alternatives for long duration storage and to avoid supply chain issues associated with certain traditional chemistries.
- Design versus actual capability
- Different departments within the utility have different ideas concerning how to best operate the battery system, and what purposes it should be used for. An interdepartmental consensus needs to be established, along with a clear understanding of the personnel within each department that will be responsible for the battery's operation.
- The following topics related to energy storage training are critically important:

  - Electric system fundamentals
  - Utility interconnections
  - Distribution systems engineering
  - Energy storage technologies
  - Risk management
  - Energy storage evaluation

Required Improvement:

- There are gaps in the evaluation process for energy storage projects. It's not easy to perform a good evaluation. Different subject matter experts have different ways of valuing energy storage resources.
- Understanding how these resources can fit into specific applications on a utility system is critical for an accurate valuation. For example, how is storage used in "X" state vs. "Y" state. An appropriate and collective front end understanding can help utilities avoid mistakes.
- Utilities need to understand their internal capacity for managing energy storage projects over the long term, considering factors like regulatory requirements, operations and maintenance costs, staff time needed, and operational requirements.
- Turnover needs to be addressed. Employee retirements reduce institutional knowledge and impact organizational stability.
- New laws or lobbying can boost the value of storage systems by allowing them to address multiple value propositions, if states approve.
- Other battery chemistries being developed that can be produced domestically and may not have the supply chain issues accompanied by foreign projects. This represents a long-term solution.
- Insufficient standards exist for batty system SCADA integration.
- Share lessons learned and learn from the experiences of other utilities. Know what questions to ask.

Major Activities/Milestone:

- Get trained and educated on topics internally within the utility before engaging SMEs. Identify the trainings that have been most successful and useful to others in the past.
- In California, InfoCast (a membership organization) provides information on California energy commission sponsored workshops.

<table>
<tr><th colspan="3">Action Plan #2 | Controllable Thermal Loads for System Demand Reduction</th></tr>
<tr><th>Relevant Fossil Asset</th><th>Anticipated Integration Challenges</th><th>Required Improvements</th></tr>
<tr><td>Peaking, Backup</td><td rowspan="5">- Security of the demand response networks and control
- Ensuring customer doesn't see unacceptable/unreasonable temperature swings
- Being able to operate the demand reduction very quickly in response to other instantaneous load changes
- Temperature mixing valves to avoid scalding (re: hot water heaters)
- System impact studies could delay project up to one year[1]
- Customer acceptance vs. better economic alternatives[2]
- These programs should be opt-in only and customers should be incentivized with lower energy prices.</td><td rowspan="5">- Develop and deploy a robust education program to ease public concern about power being leveraged over residences, to provide transparency in technology use and benefits.
- No incentive is large enough if the customer is concerned about what *exactly* you can do in their residence or business.
- Communicate what the program can and can't do. Explain customer impacts.
- Ensure safe equipment operating conditions
- Improve market pricing predictions to guide investments and determine when to engage thermal loads; insight into rate stability.
- Define number and type(s) of customer overrides.</td></tr>
<tr><th>Problems Addressed</th></tr>
<tr><td>Generation cost, Fossil asset optimization, managing intermittency, Decarbonization, Emissions Reductions, Reducing curtailment</td></tr>
<tr><th>Value Proposition</th></tr>
<tr><td>Non-wired alternatives, T&D investment deferral, Reduced-capacity obligations, reduced monthly peaks and meet capacity reduction targets, Reduced fuel consumption, Reduced O&M costs--trading O&M demand response vs. alternative asset (depends on specific tech)</td></tr>
</table>

[1] The ESWG discussed the possibility of installing utility-controlled distributed thermal loads for energy storage. This could include expanded storage at generation facilities such as a concentrated solar power plant or other facility. The group noted that if these generation assets are already sited and operational then environmental or other regulatory impacts would be lower than if a wholly new facility (including energy storage) was developed.

[2] A member of the ESWG pointed out a beneficial use case of capturing waste heat (combined heat and power) to support district heating system as an energy store. However, some customers are currently investing in their own gas-fired boilers to manage heat load peaks at their facilities. The ESWG member utility is building the waste heat capture process to make the district heating solution a more affordable option and encourage customers to avoid capital investment in individual gas boilers.

Action Plan #2 Continued | Controllable Thermal Loads for System Demand Reduction			
Major Activities, Milestones, and Metrics	**Resources Required**	**Monitoring**	
- Define and develop education/marketing program - Define the case for the customer--what benefits can they expect? What security concerns are there? Exposure of network? - Define overrides - Select good partner to work with and able to ensure project is accomplished - Develop an understanding of connected utility needs - Make financial case - Build pilot program to improve uptake--thermal demand management impacts quality of life of customer - User agreement--contract	- Good/skilled engineers - Legal help for contractual relationships - Financial help - Marketing and education outreach events for residents - Skilled data modeling--statistician	Metric: - Curtail installation of individual boilers using fossil heat and installation of new electric heat - MW reduction at time of peak - Percentage of water heaters signed up or customers enrolling in HVAC control - Penetration: how many applicable customers signed up - Demand reduction: how much demand was shed per customer - Customer experience: post-event surveys of participants to gauge their feelings about the program	Target Value: - Reduce (keep low) percentage of customers adopting fossil boilers and electric heat - MW contributed at peak - 100% participation

Further discussion:

Challenges:
- In many places, utility programs do not exist that allow for direct control of consumer appliances.
- For programs to be successful, consumers need to actually sign up; it must be attractive for them and meet their need.
- Operationally, an effective system would include automatic start of generators when load increases beyond a point and the impacted frequency hits a pre-set metric.

Opportunities:
- Use of thermocouples to extract thermal load, based on a recent MIT-funded effort.

Value Proposition:
- Cost reductions from transmission and capacity savings. The savings amount depends on which Regional Transmission Organizations/Independent System Operators the utility operates in. On a monthly peak basis, it is possible to save on transmission costs. Capacity costs are evaluated on a monthly or annual basis.
- It is important to note that energy storage systems have costs associated with maintenance and replacement of additional equipment. If energy storage is used as a replacement for gas peaking plants, the implementing utility will not see a 100% reduction on the O&M costs of the peaking plant.
- A past project investigated the use of thermal energy storage to run a power plant during off-peak hours. The system in question existed behind the meter, which was unique within the operating territory.
- A related effort is utilizing district heating to reduce waste heat and maximize value to customers, avoiding the need for purchases of industrial steam plants.

Ideas for monitoring metrics:
- Penetration: how many applicable customers signed up.
- Demand reduction: how much demand was shed per customer.
- Customer experience: post-event surveys of participants to gauge their feelings about the program.

Action Plan #3 | Hydrogen Production for Gas Turbine Fuel Mixing		
Relevant Fossil Asset	**Anticipated Integration Challenges**	**Required Improvements**
Baseload, Peaking **Problem Addressed** Decarbonization, Emissions Reductions, Generation Cost **Value Proposition** Reduce renewable energy curtailment, reduce hydrogen production costs	- Producing the hydrogen cost-effectively - Finding a way to transport the hydrogen that would leverage existing infrastructure as much as possible, - Ensuring that the generator can support a reasonable fuel mix to make it worthwhile, etc. - The hydrogen source and production method (grey, blue, green, etc.) impact the cost of hydrogen, which can vary significantly. The DOE Hydrogen Shot should help reduce costs. - Gas turbines have been replaced with newer models allowing up to 45% hydrogen mixing capability.	- Understand the costs, given the high cost of H_2, could be significant concern - Address unintended consequences of mixing such as increasing NO_x emissions - Need to present the costs to voting members; learn and overcome - Build understanding of the technology - Environmental organizations' opposition to Natural Gas. - Education processes. - Cost of hydrogen: could be addressed through subsidization, collaboration with industry/government. - New England not at "duck curve" solar level, though there is a push for offshore wind. - Could lead to excess renewable generation capacity. - The Southwest could have excess renewable generation within four-five years.

Action Plan #3 Continued | Hydrogen Production for Gas Turbine Fuel Mixing			
Major Activities, Milestones, and Metrics	**Resources Required**	**Monitoring**	
- Conduct a pilot/demo. Consider a small hub. Utilize existing unused space within service territory. - Grant writing. - Seek infrastructure funding (identify programs, funding sources). - Education and awareness workshops.	- Availability of Hydrogen. Needs to be trucked in, or need to create a H2 production facility. - Evaluate the total carbon footprint of the solution. - For utilities that do not traditionally operate generation (esp. Hydrogen), need commitment. - Industry partners. - Internal agreement within the utility.	Metric: - Demonstrate that generation using a mix can be achieved. - Perform cost/benefit analysis. - Price environmental attributes. - Track activity completions. - Measure against sustainability initiatives, including carbon reductions. - Verify the safety of the fuel (incl. public perception) - Validation of design vs. actual performance	Target Values: - Does it work or not? - Does it provide the required generation capacity? - No incidents - Emission values - Ramping rates - Runup rates - Start times

Further Discussion:

Improvements:

- Better understanding the cost elements of a hydrogen system. For small utilities that have to be concerned about their rates, hydrogen represents a major concern.
- Hydrogen within the context of energy storage is a new technology and requires a more extensive understanding for serious consideration.
- Although the concept of hydrogen fuel mixing with natural gas has merit, in certain parts of the country, the opposition to the use of any natural gas at all can present a barrier to technology adoption.
- Public education efforts are needed on topics like fuel choices, electric system reliability, environmental impacts, and the benefits of fuel mixing.
- In addressing the cost, opportunities exist for government subsidies to be developed, and for collaborative projects involving industry and government.

Are there any issues with curtailment (wind resources, excess solar, or other sources)?

- In the Northeast, permitting and early-stage construction of wind is underway, with thousands of MWs in queue. This may result in needed renewables curtailment in years to come.

Activity/Milestones:

- Pilot/Demonstrations can help to spur technology adoption.
- In Arizona, powerplants are closer to the city then was typical in the past. The region does not possess a significant amount of gas generation, so a hub could be useful. Hydrogen hubs may serve as a potential source of funding to enable further exploration.
- Grant writing could be an approach for addressing cost issues.
- Education workshops can help to promote an understanding of hydrogen and its potential.

Monitoring:

- For success on the project, initially functionality must be proven. It must be shone that the selected gas turbines can run on a hydrogen mix.
- Any hydrogen project outcomes should contribute to organizational sustainability initiatives related to carbon reduction.

- Fuel safety: the public perceives hydrogen as being difficult to manage. Metric: Generators with mixed fuel do not cause explosions. Safety precautions must be implemented.
- Design vs. actual performance data points must be tracked for verification purposes.

Project Plan/Resources:

- There is no hydrogen production in many regions of the U.S. This presents a difficulty for getting the hydrogen to a site.
- How do we venture into Hydrogen? Resource tie. Bridging the gap for resource.

Additional Comments:

- Addressing environmental opposition to the use of any gas at all.
- Coal plants 10 years ago were shut down due to opposition.
- Permitting for combined heat and power plants can be nearly impossible in many regions of the country.
- Natural gas was positioned as a transition fuel to get off of coal, but opposition has grown and that sentiment has shifted.

<table>
<tr><th colspan="3">Action Plan #4 | Battery Energy Storage for Ancillary Services</th></tr>
<tr><th>Relevant Fossil Asset</th><th>Anticipated Integration Challenges</th><th>Monitoring</th></tr>
<tr><td>Baseload, Peaking</td><td rowspan="7">- Coupling gas turbines with a battery derives more value from quick start capability; but will the market provide enough of a reward to justify it? The problem is financial.
- In western interconnect, regulation up and down is related to ramp control, but more profitable within the market.
- In the California market construct, the San Diego Gas & Electric Escondido battery project was intended for peak shaving, but found more value in operating as up and down regulation service.
- ISO NE has a regulation market; energy storage operates behind the meter but still qualifies in the regulation market;
- Challenge: making sure the battery is loaded up when needed, and able to follow the ISO regulation signal;
- Making sure one value stream doesn't compromise the other; not easy!</td><td rowspan="7">Metrics:
- Tracking monthly transmission peak and monthly and annual capacity peak, as well as real dollars saved.
- Degradation of battery; 10 years later? 15? How much capacity lost annually, etc.
- Ramping metrics; flex requirements in the California ISO market.</td></tr>
<tr><th>Problem Addressed</th></tr>
<tr><td>Managing Reliability, Fossil Asset Optimization, Decarbonization, Emissions Reductions</td></tr>
<tr><th>Value Proposition</th></tr>
<tr><td>Reduction in O&M costs, reduce generator stress, support system stability, reduction in generation cost</td></tr>
<tr><th>Required Improvements</th></tr>
<tr><td>- Cost optimizing tools; need tools to perform value stacking, manage battery charging and discharging
- Modeling charging/discharging behavior of battery systems while capturing the energy stored and available at all times.
- Owning vs leasing, warranties; performance restrictions related to warranty (operational); wear and tear vs warranty; lesser warranty or higher upfront cost</td></tr>
</table>

Action Plan #4 | Battery Energy Storage for Ancillary Services		
Major Activities, Milestones, and Metrics	**Resources Required**	**Key Stakeholders**
- Work with local investor-owned utility; perform system impact study; fully involve all stakeholders impacted. - Design protection schemes. - Share best practices; learning from others that are doing this; asking detailed questions from those with experience.	- Financing mechanism. Good agreement (similar to PPA) with partner. - Lending mechanism on system. - System changes, including reconfiguring substations, adding protections, integrating batteries, and updating control system strategies.	- Neighboring Utilities. - Equipment/ Warranty providers. - Lending Partners or Finance Providers. - State Government (Provided grants for a past project). - State Energy Office. - Good attorney!

Further Discussion:

Comments:

- In addition to ramping support, batteries can be used for regulation up and down.
- Utilities have a desire to improve response speed compared to natural gas generation. Batteries can respond more quickly than natural gas generators. It may be possible to use batteries to displace natural gas in some markets.
- Regulation up and down are related to adjusting ramp rate and could be considered a subcategory. Regulation up/down seems to be a better application than ramping control.

Value Proposition:

- Generation costs will be lower when batteries are used as a substitute for gas generation.
- Could there be economic advantage associated with reliability metrics (e.g. penalties for outages?), or opportunities for energy cost arbitrage?

Challenges:

- ISO NE- The unit does not have to look like a generator. Batteries still qualify for participation in the regulation market.
- Use of batteries for peak load management and for up/down regulation represent two competing objectives. Peak load management typically returns at a higher rate. Therefore, it is important to ensure that batteries are sufficiently charged for meeting peaks, even if they are being used to provide ancillary services.
- One case study concerning active management of the battery capacity involves a battery management technical contractor that pulls the battery out of the market early in the morning to charge, then puts it in the regulation market during the day, so that the battery stays charged enough to allow for discharge during the peak period.
- When value stacking, it is important to ensure that one value is not compromising another. This can present operational and management complications.

Improvements:

- Cost optimizing requires an improved understanding of the operational characteristics of the technology, including not just the battery, but the environment in which it is placed.

- Battery vendors may include operational restrictions in their warranties. Using the battery system to ramp up or down will introduce more wear and tear. Battery vendor will want to be compensated for that, typically with a reduction in the warranty or increase in price.

Activities/Milestones:

- To develop a framework for approaching project implementation, it is important to ask detailed questions, share learnings, and find out how others are finding success.
- Need to understand what drove success in other instances, and understand the key differences between application scenarios.

Monitoring:

- Calculate real dollars saved by looking at generation on regional peak hour savings.
- It is important to understand the estimated degradation in battery performance over the lifetime of the asset.
- In some markets, ramping metrics are associated with flex. Flex = ability to ramp in response to market signals, per MW/min, compared to the reference generator resource data template.
- Success can be measured by comparing actual ramping rates to the GRTD template.

Resources:

- Battery deployment often requires updates to the current electrical system that also require a financial/lending/financing mechanism.
- Changes to operations, including substation equipment upgrades, control systems, and protection systems.

5. APPA Opportunities

During an August meeting of the ESWG, members were asked to brainstorm ways in which APPA and the DOE could support the adoption of energy storage within the public power utilities. In addition, suggestions were extracted from prior discussions held by the working group, especially those related to the development of the action plans. This table below aggregates and summarizes the opportunities uncovered.

Prompt to Participants
What actions do you believe APPA or DOE could take, to assist this community in successfully deploying energy storage technologies to solve the challenges identified?
Summary of Responses:
Development of Analytical Tools: Working group members identified cybersecurity risks as a major barrier to the implementation of thermal demand response and vehicle to grid programs. Customer perceptions of cyber risks can negatively impact program participation. DOE and APPA can assist through the development of cybersecurity tools and resources, both for utilities, and for customers participating in utility programs. Working group members identified a need for analytical tools that can capture the dynamics of energy markets, grid demand, and energy storage system performance, combining all factors to provide recommendations for energy storage system charging and discharging periods. Utilities desire a tool that can account for behind-the-meter devices like the Powerwall, and similar technologies.
Support for Pilot and Demonstration Projects: Pilot and demonstration projects are needed for a variety of reasons, including the validation of technology performance, baselining technology costs, and establishing best practices related to management and operations. DOE and APPA can support public power utilities by providing funding to enable demonstration projects, reducing the cost of implementation projects, and providing incentives that encourage the consideration of energy storage.
Provide Operational Insights: It was suggested that utilities might need assistance with new rate designs for retail customers, especially related to the development of rates that properly incentivize owners of EVs to charge or sell back to the utility at optimum times (including real time pricing).

It was acknowledged that battery storage has many potential applications and technical capabilities beyond that of traditional generating sources. Working group members expressed a need for guidance around reserve strategies for battery management.
Build Organizational Capacity: Members desire training on technical topics related to energy storage system technology options, adoption, economics, procurement, integration, and management. Utilities desire means to increase their access to energy storage subject matter experts that can provide insights and services as needed. Utilities are interested in building the internal capabilities of their staff, and in enhancing their ability to manage advanced technologies, over the long term.

Summary

Energy storage technologies and solutions that support energy generation and utility operations continue to evolve rapidly. Public power utilities will benefit from monitoring these changes and developing plans to integrate storage solutions in ways that minimize the barriers to adoption.

The value proposition of energy storage is manifold. Benefits to grid operators and customers include increased reliability and resilience, peak load management, and operational improvements such as voltage regulation. These values can be stacked, building upon existing generation assets, extending life, and positioning the utility to integrate new generation, including renewable generation systems. For the utilities considering carbon reduction measures, energy storage solutions offer a variety of benefits that aid with GHG emission reduction and carbon management.

To maximize the value of energy storage solutions, public power utilities must consider potential barriers and develop strategies to mitigate challenges. Challenges include economic factors such as fuel prices, managing long-lived generation assets and using these assets in ways that may not have been their original intent, timeline impacts to address permitting, and the ongoing need to maintain grid reliability while the energy storage technology project is implemented and once it is operational.

Public power utilities considering energy storage have several options but will benefit most from prioritizing the four use cases identified by the research: battery energy storage and controllable thermal loads for demand reduction, hydrogen production for fuel mixing, and battery energy storage to support generator ramp rates. Successful implementation of one or more of these solutions is dependent on several elements, including training and technical expertise, technologies to support and management the energy storage solution, and beginning with demonstration projects to validate the performance of the new technologies.

As the ESWG continues to work with APPA and DOE to move forward with tractable energy storage solutions for public power, additional lessons from public power early adopters will be shared and new demonstrations are expected to be initiated. The results of the working group's continued efforts are expected to be shared in subsequent reports in the upcoming years of this five-year program with DOE.

Appendix A: List of Acronyms

AGC – automatic generator control

APPA – American Public Power Association

BESS – battery energy storage system

CAISO – California Independent System Operator

CCUS – carbon capture, utilization and storage

CHP – combined heat and power

DEED – Demonstration of Energy & Efficiency Development

DOE – U.S. Department of Energy

ESWG – Energy Storage Working Group

EV – electric vehicle

GHG – greenhouse gases

GRDT – generator resource data template

HRSG – heat recovery system generator

HVAC – heating, ventilation and air conditioning

IOU – investor-owned utilities

ISO – independent system operator

kW – kilowatt

kWh – kilowatt-hour

LCOE – levelized cost of energy

LFP – lithium iron phosphate

MW – megawatt

MWh – megawatt-hour

NERC – North American Electric Reliability Corporation

NG – natural gas

NYPA – New York Power Authority

O&M – operations and management

PMAX – declared maximum power

PPA – power purchase agreement

RFP – request for proposal

RTO – regional transmission organization

SCADA – supervisory control and data acquisition

SDG&E – San Diego Gas and Electric

SME – subject matter expert

SOC – state of charge

SPP – Southwest Power Pool

T&D – transmission and distribution

Appendix B: Glossary

black start – the ability to restore power to an electric power station or part of a power grid after a blackout without relying on external power sources

behind-the-meter – a term referring to power produced and consumed on site

carbon capture, utilization and storage – the process of collecting the carbon dioxide emissions released during energy production to be reused or stored as opposed to being allowed to enter the atmosphere

decarbonization – reduction of carbon dioxide emissions associated with the burning of fossil fuels

duck curve – a graph that shows the difference between electricity demand and available solar power

dynamic ramping – varying a generator's ramp rate in relation to energy demands to improve efficiency

electrification – the process of transitioning technologies that rely on fossil fuels to electric power

energy arbitrage – storing a surplus of energy when costs are low to use when prices increase

generator ramp rate – the maximum speed in megawatts/minute at which a generator can increase or decrease electrical power

heat recovery system – technology that recycles existing warm air in a home or building to reduce energy consumption

hydrogen hub – a coalition of stakeholders across the hydrogen and fuel cell supply chain, working together to increase investment and create opportunities related to hydrogen and fuel cell technologies

ice storage – a process for thermal energy storage, which shifts energy use from peak to off-peak hours by storing energy as ice during off-peak hours, reducing total energy use

independent service operator – a federally regulated entity designed for the purpose of ensuring non-discriminatory access to the electric grid

levelized cost of energy – a metric that compares the costs of energy storage systems with varying characteristics on a comparable basis by measuring the average total cost of building, operating and maintaining the system relative to the total electricity generated

load-following – producing varying power outputs in response to changing demand or operating conditions

natural gas fuel mixing – the addition of hydrogen to natural gas to reduce the emissions created during natural gas combustion

N-1 contingency – a back-up plan that allows a system to continue to operate in the case of failure of a single element

non-wires alternatives – an electrical grid investment that uses technologies that reduce or eliminate the reliance on equipment upgrades

peak load reduction – lessening energy consumption during periods of high demand

peaking power plants – power plants that operate only during periods of peak demand

peak shaving – implementing strategies to eliminate peaks and stabilize energy use by industrial and commercial consumers

power purchase agreement – a long-term contract for the purchase of electricity

renewable generation intermittency – the irregularity of the energy produced by renewable sources (e.g., wind energy can only be produced when there are windy conditions; solar energy can only be produced in sunny conditions)

regional transmission organization – an entity that serves to manage electricity transmission and maintain the electric grid for a specified region in North America

reserve margins for power plants – the amount of excess capacity over expected demand, calculated as [(capacity-demand)/demand]

transmission congestion – the state at which the capability of electric transmission lines is insufficient to meet demand

voltage regulation – the ability to maintain the voltage of a power source within acceptable limits regardless of variation in load conditions

Appendix C: Additional Resources

In addition to the input provided by the Energy Storage Working Group, this report includes information, analysis, and findings from the following sources:

Akhil, A., Huff, G., Currier, A., Kaun, B., Rastler, D., Chen, S., Cotter, A., Bradshaw, D., & Gauntlett, W. (2015). (tech.). *DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA* (pp. 29–111). Albuquerque, NM: Sandia National Laboratory. https://doi.org/10.2172/1170618

American Public Power Association. (n.d.). Public Power Energy Storage Tracker. Retrieved September 30, 2022, from https://www.publicpower.org/resource/public-power-energy-storage-tracker

Henry, A. (2022). *Thermal Energy Grid Storage (TEGS) Using Multi-Junction Photovoltaics (MPV).* Advanced Research Projects Agency-Energy (ARPA-E) Technology Projects. Retrieved September 30, 2022, from https://arpa-e.energy.gov/technologies/projects/thermal-energy-grid-storage-tegs-using-multi-junction-photovoltaics-mpv

Institute of Electrical and Electronic Engineers (IEEE). (n.d.). PES Energy Storage and Stationary Battery Committee ESSB. Retrieved September 30, 2022, from https://cmte.ieee.org/pes-essb/

Pathak, P. K., & Gupta, A. R. (2018). Battery Energy Storage System. *2018 4th International Conference on Computational Intelligence & Communication Technology (CICT)*, 1–9. https://doi.org/10.1109/CIACT.2018.8480377

Research Technology Investment Committee (RTIC). (2020). (rep.). *Energy Storage Grand Challenge Roadmap* (pp. 11–54). Washington, DC: U.S. Department of Energy.

Appendix D: Meeting Agendas

Energy Storage Working Group – April 2022 - Meeting #1
April 26, 2022 2-3:30pm Eastern Time

Meeting Objective

The American Public Power Association (APPA) **thanks you** for your participation in the Energy Transitions Community (ETC) Energy Storage Working Group (ESWG). This working group will explore ways in which energy storage solutions can address challenges for fossil generation assets owned by public power members. We thank you for joining us for the kick-off meeting, and look forward to your input and participation.

In recognition of your service, all members of the ESWG will be credited in resulting publications related to the intersection of fossil generation and energy storage technologies. You will receive a citation noting your contribution and recognizing the time and effort you dedicated to improving operations for public power nationwide.

As a working group member, you will shape future reports, guidance, and best practices for deploying energy storage solutions to address fossil generation challenges for public power across the country. ESWG members will also get early access to resources that will be tailored to the unique needs of public power. Finally, you will have an opportunity to network with and learn from other electric utilities seeking to improve their operations.

Agenda

Time	Event
2:00pm to 2:15pm	Welcome and Background • Purpose of the Working Group • Scope and Activities • Ground Rules
2:15pm to 2:25pm	Energy Storage Working Group Member Introductions • Introductions exercise
2:25pm to 3:10pm	Facilitated Discussion: Identifying Energy Storage Challenges • Focus Area: Fossil Generation Challenges • Prioritization: Prioritization Prompt TBD
3:10pm to 3:25pm	Open Discussion • Member-led discussion
3:250pm to 3:30pm	Next Steps • Use of information collected • Next meeting date

Energy Storage Working Group – May2022 - Meeting #2
May 26, 2022 2-3:30pm Eastern Time

American Public Power Association
Energy Transition Community
Energy Storage Working Group

Energy Storage Working Group

May 2022 | Meeting #2

Meeting Date and Time:

May 26th, 2022, 2:00 – 3:30 PM Eastern Time

Meeting Purpose:

The second meeting of the APPA ETC Energy Storage Working Group will explore ways in which energy storage solutions can provide value propositions to public power members.

Meeting Agenda:

Time	Activity
2:00pm to 2:10pm	Welcome and Introduction • Welcome to members • Scope and current status • Governing Rules
2:10pm to 2:15pm	April Meeting Report Out • Summary of discussion and outcomes
2:15pm to 3:00pm	Facilitated Discussion: Energy Storage Value Propositions • Ice Breaker Questions • Core Inquiry
3:00pm to 3:25pm	Open Discussion • Member-led discussion
3:25pm to 3:30pm	Next Steps • Use of information collected • Next meeting date • Adjourn

Energy Storage Working Group – June 2022 - Meeting #3
June 16, 2022 2-3:30pm Eastern Time

Agenda

- Welcome, Scope, Current Status, Discussion Rules
- Report out from last meeting
- Core discussion: challenges in integrating fossil assets and storage technologies
- Open discussion
- Next steps and next meeting

Energy Storage Working Group – July 2022 - Meeting #4
July 26, 2022 2-3:30pm Eastern Time

American Public Power Association
Energy Transition Community
Energy Storage Working Group

AMERICAN PUBLIC POWER ASSOCIATION

Energy Storage Working Group

July 2022 | Meeting #4

Meeting Date and Time:

July 26th, 2022, 2:00 – 3:30 PM Eastern Time

Meeting Purpose:

Discuss the high priority pathways to resolve challenges with implementing energy storage solutions

Meeting Agenda:

Time	Activity
2:00pm to 2:10pm	**Welcome and Introduction** • Welcome to members • Scope and current status • Governing Rules
2:10pm to 2:15pm	**June Meeting Report Out** • Summary of discussion and outcomes
2:15pm to 3:00pm	**Action Planning - Two Breakout Rooms** • Topic 1: Battery Energy Storage for System Demand Reduction • Topic 2: Controllable Thermal Loads for System Demand Reduction
3:00pm to 3:25pm	**Report Outs**
3:25pm to 3:30pm	**Next Steps** • Use of information collected • Next meeting date • Adjourn

Energy Storage Working Group – August 2022 - Meeting #6
August 30, 2022 2-3:30pm Eastern Time

Agenda

- Welcome, Code of Conduct
- Working Group Scope and Current Status
- Findings to Date
- Feedback
- Open Discussion
- Next Steps