AEIC Center for Operational Excellence: Workshop #1: Topic 1 - Impacts of Battery Energy Storage Systems (BESS)

Workstream: Integrating Inverter-based Resources (IBRs)

Association of Edison Illuminating Companies
607 14th Street NW, Suite 560
Washington, DC 20005
www.aeic.org

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Critical Action Forum Workshop #1: BESS

AEIC Center for Operational Excellence Overview

The mission of AEIC's Center for Operational Excellence is to provide the electricity industry with authoritative information as a basis for decision-making on local, state, and federal infrastructure investments. The Center facilitates industry workshops that address critical issues impacting power generation, power delivery, metering, engineering, and more recently, the transformation required to enable new energy resources and the impacts of electrification. By creating environments that foster powerful lessons learned, AEIC ensures that all industry stakeholders have access to trusted, actionable information. This workshop exemplifies AEIC's unique ability to bring together diverse voices to share knowledge and drive progress in the electricity sector.

Workshop Details

Workshop Name: Critical Action Forum Workshop #1: Topic 1 – Integrated Battery Energy Storage Systems, via Workstream: Integrating Inverter-Based Resources (IBRs)

Date: February 27-28, 2024

Overview: AEIC organized this workshop to discuss the integration of Battery Energy Storage Systems (BESS) (e.g., inverter-based resources (IBRs)) into the electric grid. The workshop is part of a series of events focused on advancing energy storage solutions and addressing the challenges associated with IBRs.

Purpose

This workshop aimed to bring together experts and stakeholders to share experiences, discuss best practices, and identify key challenges and solutions related to integrating IBR. AEIC pulled together a summary of the workshop to provide valuable insights and actionable takeaways for its members.

Attendees at a Glance

The workshop brought together key stakeholders from the following organizations to foster collaboration and knowledge sharing.

- **Represented Member Utilities:** Arizona Public Service Co, Cleco Corporation, Duquesne Light Company, Eversource, Florida Power & Light Co, Georgia Transmission Corp., Long Island Power Authority, North Carolina Electric Member Corporation, Orange & Rockland Utilities, Inc., PowerSouth Energy Coop., Salt River Project, San Diego Gas & Electric Co., Southern Company, Tampa Electric Company
- **Other Attendees**: AEIC, Sandia National Laboratories, Tucson Electric Power, United States Department of Energy
- **Total Attendees:** 34

Attendee List

- **AEIC:** Steve Hauser, Elizabeth Cook
- **APS:** Baj Agrawal, John Lucas, Arvind Patel
- **Cleco:** Dean Sikes
- **DLC:** Jessica Valentine
- **DOE:** Eric Hsieh
- **Eversource:** George Wegh
- **FP&L:** Bernardo Benigni, Paul Taylor
- **GTC:** Jordan Coleman
- **Long Island Power Authority:** Gary Stephenson
- **NCEMC:** Lee Ragsdale
- **ORU:** Ralph DeVitto, Andre Wellington, Won Choe
- **PowerSouth:** Adam Sowell, Brandon Garrett
- **Sandia:** Erik Spoerke
- **SDG&E:** Fernando Valero
- **Southern Company:** Tammy Upchurch
- **SRP:** LeeAnn Torkelson, Jose Martinez, Amber Clinkscales, Nicholas Andrews, Matthew Rhodes, Jawwad Lateef, Catherine O'Brien, Mike Pfeister
- **TEC:** Brian Buckley
- **TEP:** Neil Saunders, Sean Bowen, Kelly Arnold-Wilson

Key Discussions

Voices and Opinions

During the workshop, attendees shared several important points and perspectives:

- **Standards and Regulations:** Discussion on creating RFP templates, guidelines for IEEE 2800 adoption, and necessary changes for inverter compliance.
- **Safety and Reliability:** Creation of comprehensive safety protocols for BESS and inverters, addressing fire safety, performance measurement, and reliability standards.
- **Project Planning and Execution:** Lessons learned and best practices for selecting EPCs, commissioning processes, and a standardized approach for utility-led project execution.
- **Design and Technology:** Development of total cost of ownership models, standard project commissioning procedures, and optimal equipment specifications.
- **System Integration:** Integration with existing T&D infrastructure, cybersecurity, and transition to utility-managed operations and maintenance.
- **Vendor and Technology Selection:** Developing selection frameworks for vendors and technology, including criteria for location, EPC, and preferred vendor lists.
- **Operation and Maintenance:** Developing operational guidelines for BESS systems, maintenance standards, and protocols.
- **Environmental and Community Impact:** Strategies for BESS environment, recycling methods, community outreach programs, and outage management.

Additional Information

The workshop also covered topics that may interest the broader AEIC community, such as the need for standardized safety measures across different BESS sizes and use cases, and the importance of cybersecurity in BESS integration.

Conclusion and Key Takeaways

Summary of Findings:

The workshop concluded with several key takeaways and recommendations:

- There is a need for comprehensive and standardized safety protocols for BESS and inverters.
- It's important to develop total cost of ownership models to guide project planning and execution.
- There's a necessity for robust cybersecurity measures to protect BESS systems.

- Collaborative efforts in sharing RFPs and standardizing equipment specifications have high value.

For members who attended and others on a similar journey, these insights are invaluable for further investigation and addressing the challenges and gaps identified during the workshop.

List of Presentations and Presenters

Day 1: Tuesday, February 27, 2024

1. **Eversource:** Provincetown BESS, Operational Experience and Learning
(Presented By: George Wegh, Eversource)
2. **Tucson Electric Power (TEP):** Roadrunner Reserve BESS – Work in Progress
(Presented By: Neil Saunders, TEP)
3. **San Diego Gas & Electric (SDG&E):** Overview of SDG&E BESS Experiences
(Presented By: Fernando Valero, SDG&E)
4. **APS:** An Improved Approach to Safety and Availability
(Presented By: Ben Cluff & Dan Clark, APS)
5. **Salt River Project (SRP):** Oscillations at Hybrid Battery/Solar Sites
(Presented By: Chris Janick, SRP)

Day 2: Wednesday, February 28, 2024

6. **NC Electric Cooperatives (NCEMC):** Learnings from NCEMC Solar, Storage, and Microgrids
(Presented By: Lee Ragsdale, NCEMC)
7. **US Department of Energy:** Landscape of DOE Storage Activities
(Presented By: Eric Hsieh, DOE)

Challenges and Opportunities for Battery Energy Storage Systems (BESS)

AEIC's Center for Operational Excellence

Executive Summary

Inverter-based Resources (IBRs), including Battery Energy Storage Systems (BESS), are pivotal for integrating additional energy sources into the grid. While they offer significant benefits, they also pose technical and regulatory challenges. This summary outlines key challenges, opportunities, and actionable steps to address these issues.

Challenges and Opportunities:

1. **Grid Stability:**
    - IBRs can introduce harmonic distortions, voltage fluctuations, and frequency deviations.
    - Reduced system inertia and damping can compromise power quality and reliability.
    - Complex interactions with other grid components may lead to instability.
2. **Grid Integration:**
    - Challenges in the generator interconnection process include model discrepancies and inaccurate reliability studies.
    - Improved interconnection studies and modernized standards are necessary for accurate performance modeling.
3. **Operation:**
    - It's imperative to address unknown ride-through capabilities and limited short-circuit current capability of IBRs.
    - Environmental challenges can have a negative impact on inverter performance, such as mud, silt, high humidity, and increasing temperatures.
4. **Technology:**
    - When selecting the best-fit solution among different IBR technologies, utilities need to consider advantages and disadvantages.
    - Lithium-ion batteries, though popular, have issues like short lifespan and overheating risks.

5. **Interoperability and Communications:**
    - Ensuring compatibility across different devices, vendors, platforms, and regions is critical for scalable integration.
6. **Cost:**
    - Despite declining prices, BESS remains an expensive alternative to traditional grid solutions.
7. **Market Participation:**
    - There are complexities in accessing and competing in energy and ancillary service markets.
    - Managing multiple revenue streams requires sophisticated control systems.

Safety:

- Addressing fire risks, thermal runaway, and hazardous materials is essential for BESS safety.
- Implementing comprehensive fire safety measures, including detection and suppression systems, are also essential

Codes and Standards:

- Relevant standards such as IEEE 2800, NFPA 855, and UL 9540 provide frameworks for safe and reliable IBR and BESS operations.

Project Considerations:

- Factors such as project siting, permitting, environmental impact, and decommissioning need careful consideration.

Proposed Approach:

1. Comprehensive Studies: Utilize advanced modeling and simulation tools for optimal IBR integration.
2. Control and Coordination Strategies: Employ AI and distributed control technologies for enhanced grid performance.
3. Standards and Protocols: Collaborate with industry stakeholders to establish common standards for interoperability and reliability.
4. Market Facilitation: Develop fair market rules and innovative business models to enhance IBR competitiveness.

Conclusion:

AEIC and its utility members will drive the transition to a sustainable energy future by identifying gaps, developing action plans, fostering partnerships, and establishing standards for BESS integration.

Abstract

Inverter-based Resources (IBRs), such as Battery Energy Storage Systems (BESS), are essential for integrating new energy sources into the electric grid. However, IBRs pose technical and regulatory challenges for utilities, including grid stability, interoperability, and market participation. This white paper provides the electric utilities' perspective on the current state of IBRs and identifies some key challenges, opportunities, and next steps to address them. It serves as a resource, focusing on BESS, for industry stakeholders interested in understanding the challenges from real-world experiences and proposes an action plan to address the associated gaps.

Introduction

IBRs are transforming the grid by enabling the integration of new energy resources and energy storage systems, which are essential for an energy transition. These resources are pivotal in a modern electrical grid; they help reduce dependence on fossil fuels and lower greenhouse gas (GHG) emissions. Numerous IBR use cases support grid reliability, resiliency, and power quality. More importantly, IBRs utilizing voltage source inverters can operate in grid-following or grid-forming mode. In grid-following mode, they synchronize with the grid frequency, and in grid-forming mode, they maintain a constant internal voltage to support black start and grid stability scenarios.

As the key components of IBRs, inverters are power electronic devices that convert direct current (DC) to alternating current (AC), or vice versa, in an electric grid. They can connect renewable energy resources to the grid and store excess energy generation in batteries for future use. IBRs can provide multiple services to the grid, such as frequency and voltage regulation, peak shaving, ramping, reserve capacity, and ancillary services. In addition, IBRs can operate in different modes based on grid conditions and requirements. In grid-following mode, IBRs synchronize with the grid frequency and voltage and inject or absorb active power (P) and reactive power (Q) as required. In grid-forming mode, IBRs generate their own reference frequency and voltage and can support islanded operation or black start of a grid. IBRs can also switch between these modes dynamically, depending on the state of the grid and control strategy.

Several factors are contributing to the growth of IBRs. These factors include increasing penetration of renewable energy sources, declining cost of batteries, rising demand for grid flexibility and resiliency, and changing customer preferences and behaviors. According to the U.S. Energy Information Administration (EIA), the installed capacity of utility-scale battery storage in the U.S. increased by four hundred percent (400%) from 2014 to 2019, reaching 1.2 gigawatts (GW) by the end of 2019. Similarly, the International Renewable Energy Agency (IRENA) estimates that the global installed capacity of battery storage will increase from 9 GW in 2018 to 175 GW in 2030.

Considering the massive growth of IBRs, it is critical to understand the technical and regulatory challenges that utilities face, such as grid stability, interoperability, and market participation. By offering insights from real-world experiences, this white paper serves as a valuable resource for industry stakeholders, helping them understand the complexities and opportunities associated with IBRs. Additionally, it outlines actionable steps to address existing gaps, fostering collaboration and innovation in the energy sector. This makes it an indispensable tool for driving the transition to a more sustainable and resilient energy future.

Challenges and Opportunities

The IBR and BESS industries continue to evolve and drive the future of energy resources to address growing demand. However, several challenges exist across utilities, regulators, standards, and equipment manufacturers. At a high level, North American Electric Reliability Corporation (NERC) proposes a risk management framework that identifies six (6) steps to identify and implement an IBR risk mitigation strategy; these steps include Risk Identification and Validation, Risk Prioritization, Remediation & Mitigation Identification/Evaluation, Deploy Mitigation, Measure Success, and Monitor Residual Risk as depicted in Figure 1.

Figure 1: Risk Framework (Source: NERC)

As the grid evolves to integrate more renewable energy resources, the importance of IBRs is growing. This continued expansion introduces both challenges and opportunities for the industry. Some of these challenges include:

- **Grid Stability**: IBRs can affect the dynamic behavior and stability of the grid, especially at high penetration levels. For example, IBRs can introduce harmonic distortions, voltage fluctuations, and frequency deviations, compromising power quality and grid reliability. Moreover, IBRs can reduce system inertia and damping, which are essential for maintaining the grid frequency and resisting disturbances. IBRs can create complex interactions and feedback loops with other grid components, such as generators, transformers, and protection devices, which may lead to instability or unintended operation.
- **Grid Integration**: The reliability risks related to Bulk Power System (BPS)-connected IBRs, such as model discrepancies, inaccurate reliability studies, and poor ride-through performance, arise from challenges in the generator interconnection process. To address these issues, NERC recommends an overhaul to modernize the interconnection process by improving interconnection studies and commissioning processes. In addition, the Federal Energy Regulatory Commission (FERC) has proposed new or modified reliability standards to address the IBR-related gaps. The challenges associated with modeling IBRs and

validation across interconnection-wide planning models vary. To address these modeling challenges for interconnecting new IBRs, it is imperative that interconnection standards explicitly define the modeling necessities to guarantee the provision and validation of precise models. All modeling types must present the most current and accurate performance of the resource for interconnection studies.

- **Operation**: There are challenges associated with the unknown ride-through capabilities of IBRs. Addressing wide ride-through capabilities in grid-forming inverters remains challenging for many inverter companies. A robust IBR ride-through, particularly during low-voltage faults or frequency variations, needs further assessment. Additionally, IBRs have limited short-circuit current capability, affecting the proper operation of the protection system and their ability to provide sufficient power during a black start. Limited research exists on how IBRs respond to asymmetrical faults in grid-forming operation mode.

  Also, IBRs face environmental challenges that impact inverter performance. Mud, silt, or dirt intake through cooling systems can pose significant challenges, especially in environments with high levels of particulate matter. Operating in high-humidity environments can lead to corrosion and other issues that may impact the longevity and functionality of inverters and other power electronics. Increasing temperatures over time can push inverters to operate at a de-rated capacity, which is particularly concerning in the context of global warming and climate change, where temperature increases could be more pronounced.
- **Technology**: Different technologies are implemented for different IBRs. It is important to understand the advantages and disadvantages of each to select the best-fit solution for the given application. For example, lithium-ion (Li-ion) batteries have high efficiency, lower/declining costs, and widespread adoption in BESS applications, but they have relatively short lifespans compared to other technologies. In addition, they may overheat and become damaged beyond repair at high voltage levels. Alternatively, flow batteries have longer lifespans and are more scalable. This technology is utilized to smooth fluctuations in demand and supply due to renewable energy resources. During blackouts, it can keep critical facilities like military bases and hospitals online. However, flow batteries suffer from lower energy density and slower charge/discharge rates compared to other battery types.
- **Interoperability and Communications**: IBRs need to communicate and coordinate with other grid elements and operators, such as energy management systems (EMS), distribution management systems (DMS), distributed energy resource management systems (DERMS), supervisory control and data acquisition (SCADA) systems, and independent system operators (ISO). However, there are challenges around standards and protocols for IBRs to ensure interoperability and compatibility across different devices, vendors, platforms, and

regions. These challenges can lead to deployment complexity, challenges in scalable resource integration, and inefficiencies in grid operations.

- **Cost**: Increasing IBR and BESS manufacturing production and capacity will impact the market, lowering prices for Li-ion battery packs and energy storage systems. Figure 2 depicts the capacity of Li-ion manufacturers and global demand. Stationary storage additions are expected to reach a record 57 gigawatts (136 gigawatt-hours) in 2024, driven by falling prices and increased adoption. However, BESS is still considered an expensive non-wires alternative (NWA) as a grid asset compared to traditional solutions currently utilized by utilities to address load growth and grid expansions.

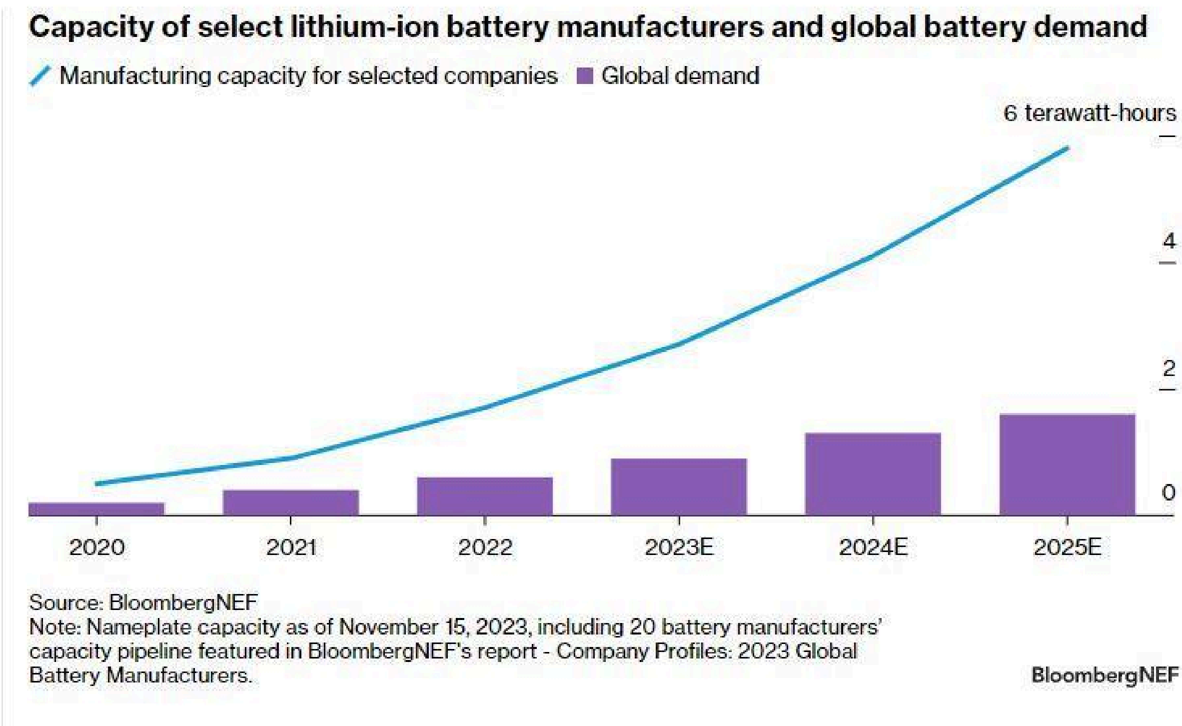

Figure 2: Capacity of Li-ion Manufacturers and Global Demand (Source: BloombergNEF)

- **Market Participation**: IBRs can participate in various energy and ancillary service markets, such as capacity, energy, frequency regulation, spinning reserve, and voltage support. However, IBRs face complexities in accessing and competing in these markets. Some examples include market rules, eligibility criteria, bidding mechanisms, pricing signals, and compensation schemes. While BESS developers are exploring revenue stacking by participating in various market services (e.g., peak shaving, load shifting, frequency regulation), managing multiple revenue streams requires sophisticated control systems and market expertise, making BESS control and operation systems more complex. These systems must be capable of real-time decision-making to optimize performance across different applications.

Safety

Ensuring the safe operation of IBRs remains a top priority, and addressing fire risks, thermal runaway, and hazardous materials is critical. For example, BESS systems implementing lithium-ion batteries are susceptible to fires. Fire risk concerns are especially sensitive due to the potentially devastating consequences. These can be caused by a range of factors including electrical faults, mechanical damage, or thermal runway. Thermal runway, an increase in temperature within a battery cell, can lead to a self-sustaining series of reactions, causing further heat generation. If not controlled, thermal runaway can result in fires or explosions.

Comprehensive fire safety measures, such as fire detection and suppression systems, are necessary to mitigate these risks. Preventative measures include proper battery design, cooling systems, and a Battery Management System (BMS) to monitor and control the battery's operational parameters.

Codes and Standards

Several relevant codes and standards should be considered during the lifecycle of IBRs and BESS. These regulations provide frameworks for their installation, operation, and maintenance. Standards are essential for ensuring safety, reliability, and compliance in their installation and operation on the grid.

Table 1: Relevant Codes & Standards

#	Code/Standard	Description
1	IEEE 2800	Establishes a uniform set of technical minimum requirements for the interconnection, capability, and lifetime performance of IBRs that connect with electrical transmission and sub-transmission systems. IBRs must meet specified performance criteria, including voltage and frequency regulation, power factor control, and dynamic response during grid disturbances. IBR must have protective functions to prevent unsafe operating conditions, such as overvoltage, overcurrent, and islanding. IBRs should also support grid voltage and frequency control through voltage ride-through (VRT) and frequency ride-through (FRT) capabilities. In addition, IBRs should communicate with the grid operator or control center to exchange information on operating conditions and respond to grid commands. IBRs must undergo rigorous testing to verify such compliance.

2	NFPA 855	Provides detailed requirements for mitigating hazards associated with battery energy storage systems. It covers design, construction, installation, commissioning, operation, maintenance, and decommissioning of BESS. Adhering to NFPA 855 is critical for ensuring BESS safety.
3	NFPA 1 Fire Code	Chapter 52 of NFPA 1 mandates compliance with NFPA 855 for energy storage systems. NFPA 1 advances fire and life safety for the public and first responders by addressing fire and explosion hazards, life safety, and property protection.
4	National Electric Code (NEC)	Article 706 specifically outlines requirements for Energy Storage Systems over 1 kWh. It covers practical safeguarding from electrical hazards.
5	UL 9540	Safety standard applies to energy storage systems and equipment intended for connection to a local utility grid or standalone application. Compliance with UL 9540 is essential as are rigorous requirements for the design, construction, testing, and operation of energy storage systems, including batteries, to ensure their safe and reliable operation.
6	International Fire Code (IFC)	Like NFPA 1, this code includes regulations to safeguard life and property from fires and explosion hazards. The IFC contains BESS-related content in Section 1207, and it is largely harmonized with NFPA 855.

Project Considerations

When designing a BESS project, multiple factors must be considered. Some of these considerations include project siting, land availability, existing facilities, permitting needs, environmental impact, optimum sizing, warranties, operations and maintenance, workforce development, grid needs, battery losses, and community impact.

Siting

When identifying and selecting a project site for a utility-scale BESS or other IBR, several factors should be considered to ensure safety, efficiency, and compliance with local, state, and federal regulations and codes. Table 2 lists some project site factors that should be considered.

Table 2: Siting Considerations

#	Consideration	Description
1	Land Availability	Proximity to the grid for interconnection and sufficient space for the BESS units and associated infrastructure, including step-up transformer and grid integration switchgear.
2	Auxiliaries	Access to necessary auxiliary services such as an electric circuit and water for cooling or fire suppression systems.

3	Civil and Structural Consideration	Designing foundations to support the BESS units' weight, withstand environmental conditions, and follow seismic codes.

Permitting & Environmental Considerations

In addition, there are important permitting and environmental considerations. These considerations are provided in Table 3.

Table 3: Permitting & Environmental Considerations

#	Topic	Details
1	Permitting	For investor-owned utilities, this can fall under the Public Utilities Commission (PUC)'s jurisdiction, which may define permitting requirements for utility-owned infrastructure. It may be prudent to involve local communities in the permitting process to address concerns related to visual impact, noise, etc.
2	Environmental Impact	Conducting environmental impact assessments to ensure compliance with regulations and address ecological concerns, including soil quality, water resources, and wildlife habitats. Siting plans may need to address underground utility lines, noise, height requirements, fencing, and visibility impacts.

Design

A system impact study is necessary when performing an integration study and designing a BESS system. This study is recommended to be based on the electric grid model with the planning load and generation data including, but not limited to:

Table 4: Design Considerations

#	Consideration	Description
1	Demand Profiles	Hourly, daily, and seasonal electricity demand patterns, including load forecasts of various types of load (e.g. EV)
2	DER Profiles	Current and planned variable renewable energy resource profiles, including residential and community-based solar PV.
3	Cost Benefit Analysis	This analysis should determine the best size of the BESS for a specific utility application, such as a non-wire solution. It is valuable to capture the stacked benefits of BESS, such as peak shaving, frequency regulation, voltage support, renewable integration, and backup power, where applicable. Additional benefits of the BESS, including revenue from participating in an energy market, avoided infrastructure costs, and reliability improvements, may need to be evaluated and compared against the capital and operational costs of the BESS.
4	Battery Losses	Regardless of the system type (i.e., AC-coupled or DC-coupled), losses will occur during energy conversion at multiple points of the charge/discharge

		process. Since batteries degrade, some developers opt to "overbuild" to guarantee capacity and fulfill regulatory, contractual, and/or financial obligations.

Procurement

When procuring a Battery Energy Storage System (BESS) as a utility asset, several key factors in the vendor contract must be considered to ensure reliability, performance, and cost-effectiveness.

Table 5: Procurement Considerations

#	Category	Details
1	Performance	The vendor should provide data on the expected performance and reliability of the BESS over time. This can be captured by requesting a Reliability, Availability, and Maintainability (RAM) analysis, a crucial process for evaluating system performance and efficiency. RAM analysis helps identify potential weaknesses in system design and operation, allowing for improvements that can enhance overall performance and reduce BESS lifecycle costs. In addition, the contract should include compensation mechanisms for underperformance, such as financial penalties or extended service provisions.
2	Warranty	It is recommended that the warranty include coverage for all critical components such as battery modules, power conversion systems, and control software. Response times for maintenance and emergency repairs should also be clearly defined. It is also prudent to include options for system upgrades to take advantage of advancements in BESS technology.
3	Spare Parts	It is recommended that provisions be included for keeping a stock of essential spare parts, especially those supporting the system's control and protection, either on-site or readily available from the vendor.
4	Training	The vendor should provide comprehensive training for operating and maintaining the utility's BESS. It is recommended to include options for on-site troubleshooting and assistance.
5	Interoperability	It is recommended to include requirements for system interoperability for communications and control.

Decommissioning

Another consideration includes the future decommissioning process and requirements. During decommissioning, federal, state, and local safety, regulatory, and environmental factors must be considered. Some factors include disposing of battery components, conducting an environmental impact assessment to minimize the ecological footprint, and establishing safety protocols for handling and transporting battery components. It is essential to identify and involve the necessary stakeholders throughout the decommissioning process and to maintain comprehensive documentation for reporting, compliance, and capturing lessons learned.

Proposed Approach

To address the challenges and gaps associated with IBRs, utilities need to adopt a collaborative, holistic, and proactive approach that involves the following actions:

1. Conduct comprehensive studies and assessments of the impacts and benefits of IBRs on the grid using advanced modeling and simulation tools and techniques, such as power flow analysis, stability analysis, sensitivity analysis, and optimization methods. These studies can help utilities identify and quantify the optimal locations, sizes, types, and modes of operation of IBRs and the potential issues and risks they may pose to the grid.
2. Develop and implement effective control and coordination strategies for IBRs using state-of-the-art technologies and methods, such as artificial intelligence (AI) and distributed control. These strategies can help utilities optimize the performance and utilization of IBRs and enhance the situational awareness and operational flexibility of the grid.
3. Develop and establish common standards and protocols for IBRs in collaboration with other industry stakeholders, such as regulators, manufacturers, developers, and customers. These standards and protocols can ensure the interoperability of IBRs with other grid devices and systems and improve the grid's cybersecurity, reliability, and resilience.
4. Facilitate IBR market participation by creating fair and transparent market rules and regulations, and by developing innovative business models and value propositions. This will allow utilities to capture mutual benefits for both customers and the grid. Additionally, it has the potential to generate new revenue streams and enhance the competitiveness of IBRs, while transforming the industry and traditional cost-benefit models.

As a result of the feedback received from industry, AEIC member utilities, and our independent research, the proposed action plan is depicted in Figure 3.

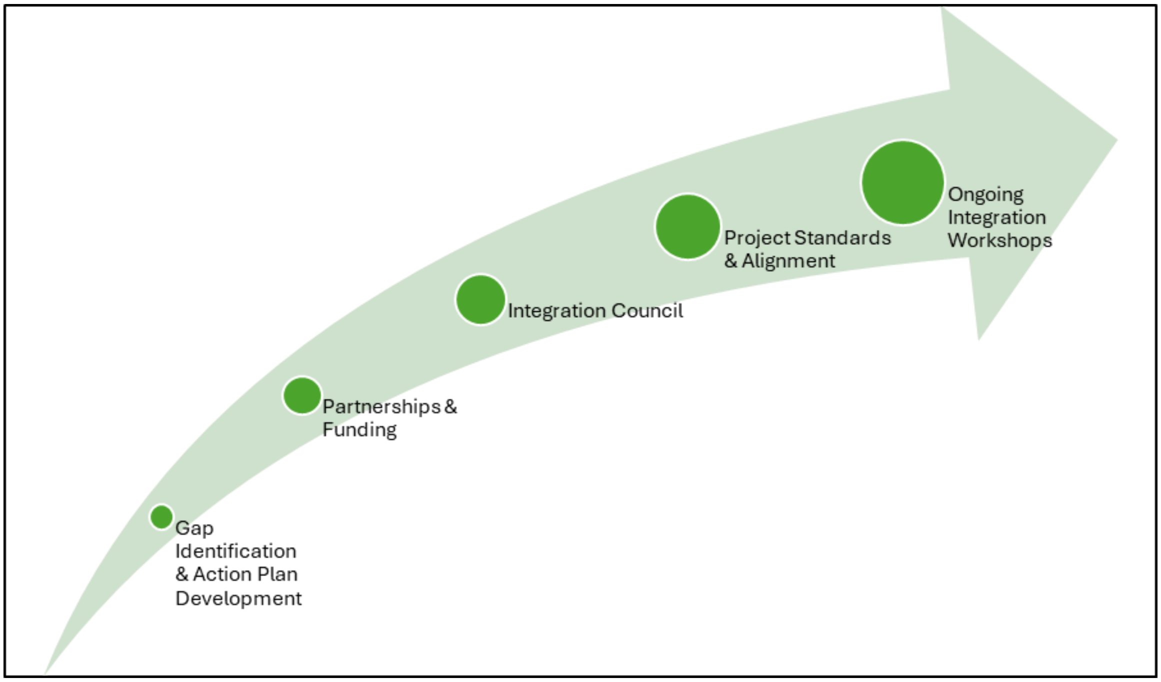

Figure 3: Proposed Approach

In this approach, AEIC and its utility members will identify gaps and challenges, disseminate learnings, develop action plans, attract partnerships and funding, develop standards, and collaborate with the industry to close these gaps and address the challenges. Table 6 describes the steps in the proposed approach.

Table 6: Approach Description

#	Step	Description
1	Gap Identification	Workshops, presentations, and offline communications to identify gaps, challenges, and lessons learned.
2	Action Plan Development	Host Solution Summits to bring the industry together and develop solutions to close the gap and address challenges.
3	Partnerships & Funding	Foster an environment for open, transparent cross-collaboration between industry stakeholders (e.g., regulatory, utilities, developers, manufacturers, technology vendors, private capital, community, etc.)
4	BESS Integration Council	Launch a dedicated council within AEIC to focus exclusively on advancing BESS integration across the utility industry.
5	BESS Project Standards Platform	This platform will streamline a screening process for sizing and siting of BESS as a utility asset across the grid, by evaluating the electrical grid needs, determining use cases, and proposing optimum sizes and locations of the BESS across a selected area within the utility's service territory.

6	Align Standards	Lead working groups to create and disseminate standardized safety protocols and project execution strategies.
7	BESS Integration Workshops	Host quarterly BESS Integration Workshops to share best practices and showcase innovations in BESS technology.

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Appendix A: Quick Links Guide

This section serves as a quick reference guide establishing connections between the AEIC white paper on IBRs BESS and related documents available on the U.S. Department of Energy's (DOE) IDSP website. The guide provides direct links and brief descriptions of the related sections to facilitate easy access and cross-referencing.

Related DOE IDSP resources

The following table provides lists all resources on the DOE and Berkeley Lab's IDSP websites that have been linked so far.

Resource #	Resource Topic/Title	Description
[1]	Distribution System Evolution	Outlines the three-stage progression of the distribution system to accommodate ever-increasing levels of DER and electrification, including technical and institutional considerations.
[2]	Distribution Grid Code Framework	Provides an introduction to a distribution grid code framework that encompasses the various institutional, business, and technical activities associated with integrating and utilizing DER, microgrids, and electrification into a structured set of best practices and associated technical standards.
[3]	Operational Coordination across Bulk Power, Distribution and Customer Systems	Provides a comparative summary of the status of leading global discussions through 2018 regarding transmission-distribution-customer frameworks to reliably manage the integration and utilization of DER.
[4]	Operational Coordination	Provides an overview of developing regulatory, business, and technical practices to ensure effective coordination and integration of distributed energy resources (DERs) with utility operations, including creating distribution grid codes and practical guides for stakeholders.

Quick Links Table

#	IBR White Paper Section	Related DOE Resource #	Related DOE Resource Topic/Title	Text (in IBR)	Text (in Resource)	Comment
[1]	Introduction	[1]	Distribution System Evolution	IBRs are transforming the grid by enabling the integration of renewable energy resources	Implement foundational grid infrastructure and technologies necessary to enable deep	Both texts emphasize the role of IBRs in integrating renewable energy and

				and energy storage systems, which are essential for a clean energy transition.	decarbonization and climate adaptation while also creating a delivery system for DER to deliver grid services by providing clean energy and demand flexibility to help minimize costs, improve resilience, and provide other consumer benefits.	supporting grid evolution for clean energy and resilience.
[2]	Introduction	[4]	[Operational Coordination]()	In addition, there are multiple IBR use cases that support grid reliability, resiliency, and power quality. IBRs, utilizing voltage source inverters, can operate in grid-following or grid-forming mode.	This is expanding the need for maturing practices and setting rules by which all participants involved in the utilization of distributed energy resources can coordinate effectively in real-time operational settings.	Both texts highlight the need for effective coordination and rules for utilizing DERs to ensure grid reliability and resiliency.
[3]	Challenges and Opportunities	[2]	[Distribution Grid Code Framework]()	IBRs can affect the dynamic behavior and stability of the grid, especially at high penetration levels.	The “DER and Microgrid Integration” code family captures functions and technologies required to support grid resilience and practices to enable system safety and reliability at all levels of DER penetration.	Both texts address the impact of high penetration levels of IBRs on grid stability and the need for integration practices to ensure reliability.

[4]	Challenges and Opportunities	[3]	[Operational Coordination across Bulk Power, Distribution and Customer Systems]()	The reliability risks related to **Bulk Power System (BPS)**-connected IBRs, such as model discrepancies, inaccurate reliability studies, and poor ride-through performance, arise from challenges in the generator interconnection process.	The advancement in distribution energy resource (DER) technology and its adoption by utility customers, as well as policies directed at improving system resilience, are changing the operation of the electric grid for both distribution and bulk power systems.	Both texts discuss the challenges related to BPS-connected IBRs and the evolving grid operation due to the adoption of DER technology.
[5]	Challenges and Opportunities	[2]	[Distribution Grid Code Framework]()	Furthermore, IBRs have limited short-circuit current capability, affecting their ability to provide sufficient power during a black start.	Develop a standard microgrid island engineering study, design of microgrid controllers, and testing procedures for black start and islanding.	Both texts highlight the need for specific engineering and testing procedures to address the limitations of IBRs during black start and islanding.
[6]	Challenges and Opportunities	[1]	[Distribution System Evolution]()	Increasing IBR and BESS manufacturing production and capacity will impact the market, leading to lower prices for both Li-ion battery packs and energy storage systems.	The most common forms of DER adoption include the growth of customer-sited storage, smart thermostats and other home automation, and EVs, in addition to solar photovoltaic (PV) cells.	Both texts discuss the market impact of increased manufacturing and adoption of DERs and energy storage systems.
[7]	Challenges and Opportunities	[2]	[Distribution Grid Code Framework]()	Market Participation:	Stage 3 (Energy Markets)	The white paper text relates to the resource's discussion on the stages of energy markets

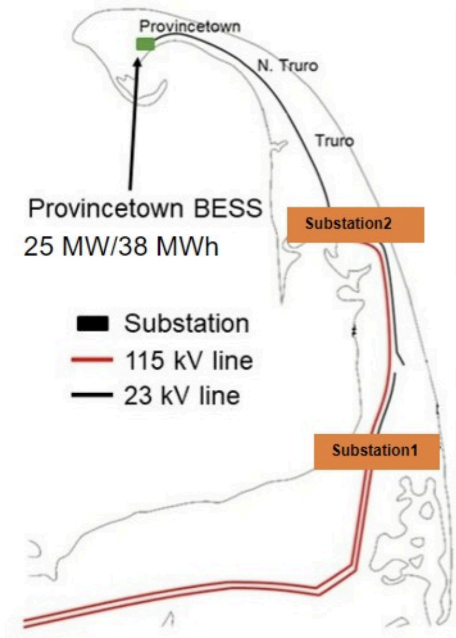
						and participation frameworks.
[8]	Challenges and Opportunities	[1]	[Distribution System Evolution]()	IEEE 2800:	Interconnection standards should be updated to reflect current technical standards (e.g., IEEE 1547-2018, IEEE 2030.5, NIST cybersecurity).	Both texts emphasize updating interconnection standards to reflect current technical requirements.
[9]	Considerations	[2]	[Distribution Grid Code Framework]()	Project Siting	Foundational investments in aging infrastructure replacement and initial grid modernization also enable increased adoption of DERs and utilization in Stages 2 and 3.	Both texts address infrastructure investment for increased DER adoption and grid modernization.
[10]	Proposed Action Plan	[2]	[Distribution Grid Code Framework]()	Develop Standardization Protocols	Implement relevant technical standards, communication protocols, and architectures for maximizing the benefit of smart inverters.	Both texts focus on developing and implementing standardization protocols to maximize smart inverter benefits.

Appendix B: Summary of Workshop Presentations

Notes / Key Concepts:

Eversource – Provincetown Battery Energy Storage System (BESS) Operational Experience and Learnings

- Project Background (Location – Cape Cod National Seashore):
  - The area is served by long radial transmission and sub-transmission circuits, historically a poorly performing circuit at Eversource.
  - BESS addresses reliability issues and avoids the need for a new sub-transmission circuit.
  - BESS operates in Grid Forming Mode at all times and can serve the load in islanded mode if the sub-transmission circuit is disconnected.
  - The BESS and microgrid can seamlessly restore power to 5,685 customers in Provincetown during faults.
  - The BESS is oversized for high-impedance fault detection and supports deferring a second 13-mile 115-kV transmission line.



Project avoids a 13-mile distribution line through the Cape Cod National Seashore

- Project Scope & Statistics:
  - Building Size: ~10,000 square feet
  - Battery Size: 25 MW / 38 MWh, Lithium Ion
  - Charge Time: ~8 hours (10 hours max)
  - Discharge Time: 1.5 – 3 hours (peak), 10 hours (off-peak)
  - Battery Life: 12 years
  - BESS Supplier: NEC/LG Energy Solutions Vertech LGESVT
  - Inverter Supplier: SMA
  - Inverters: 16, with 27 battery racks/inverter, 14 battery modules/rack, totaling 6048 battery modules
  - GSU Transformers: 16, Grounding Transformers: 2
  - Inverter rating: 3600 kVA
  - Plant capacity: 57.6 MVA
  - Inverters/breakers: 4
  - Inverters/POI: 8
  - Tie positions: 2
- Fire Protection Systems:

    - NFPA69-required ventilation system installed (design based on Underwriter Laboratories (UL) testing of Samsung batteries) to prevent explosions.
    - Activates when H_2 or CO levels reach 25% of the Lower Explosive Limit (LEL).
    - 8 fans/battery room to draw air and enable fresh air from outside, reducing the concentrations of H_2 and CO.
    - Clean Agent (Novec) System to prevent thermal runaway and extinguish fires quickly.
    - Sprinkler System installed for additional safety.
- Microgrid and System Planning:
    - In service since December 2022, serving 10,000 customers across 4 towns.
    - Comprises of:
        - Pole Top Reclosers: 17
        - Automatic Switches: 5
        - Substation Upgrades: 2
        - 3 communication mediums (Fiber Optic, Radio and Microwave)
    - The microgrid ensures voltage support, peak shaving, and islanding capabilities.
    - Short circuit ratio at the point of interconnection is very low, about 0.7 under N-1 condition.
- System Planning Studies & Lessons Learned:
    - Adjusting droop settings and virtual impedance mode improves inverter control stability under weak grid conditions.
    - Customizing inverter control with the OEM is necessary to fit project needs.
    - Grid-forming inverters can operate reliably under weak grid conditions.
- Protection and Controls Design:
    - Innovative Protection Coordination Scheme using IEC-61850 technology for both grid-connected and islanded operations.
    - Fast fault detection and clearing are necessary to maintain stability and minimize outages.
- BESS Microgrid Islanding and Automatic Restoration – Success Story!
    - Successful Islanding:
        - Over 1.5 years of service, the BESS has successfully islanded Provincetown load upwards of 10 times for both temporary and permanent faults.
        - The microgrid automatically expands the island to maximize customer restoration during permanent faults.
    - Automatic Islanding and Resynchronization:
        - For temporary faults, automatic islanding and resynchronization with the grid have been executed successfully multiple times.

    - Customer Voltage Stability:
        - No issues with customer voltage dips upon island formation.
    - Sensitive Overcurrent Protective Elements:
        - Necessary for achieving fault detection and coordination but have caused unwanted backbone trips during BESS fast charging.
    - Issues identified:
        - BESS fast charging rates and moderate loading on the feeder caused the PCC recloser to trip when reconnected and charging from a 28% state of charge.
        - Recommendations include evaluating charging currents/rates when BESS is heavily discharged and updating dispatcher instructions to charge only one BESS at a time.
- BESS Availability Issues:
    - Significant Issue:
        - BESS inverter self-diagnostic systems taking power blocks offline.
        - Only two weeks since August 2022 with all 16 power blocks online together.
    - Causes:
        - Inverter communications board failure.
        - Inverter buffer and power supply failure.
        - Power stack failure.
        - Unique/different systems complicate troubleshooting.
    - Actions:
        - Battery vendor and inverter manufacturer working on root cause and corrective actions.
    - Challenges:
        - Voltage coordination issues between 24 VDC supply and buffer.
        - Current spikes at 230 VAC input due to non-galvanically isolated transformer.
    - Corrective Actions:
        - Modify voltage settings on 24VDC supply and buffer – Complete.
        - Install galvanic isolation transformer at 230VAC aux power input to inverter – Completed on one power block.
    - Status:
        - Improved availability with setting changes, but issue not fully resolved.
- BESS Performance During Faults (Two Fault Events in Provincetown Area):
    - First Event (08/23/22):
        - Cause: A squirrel initiated a fault at the PCC backbone recloser.

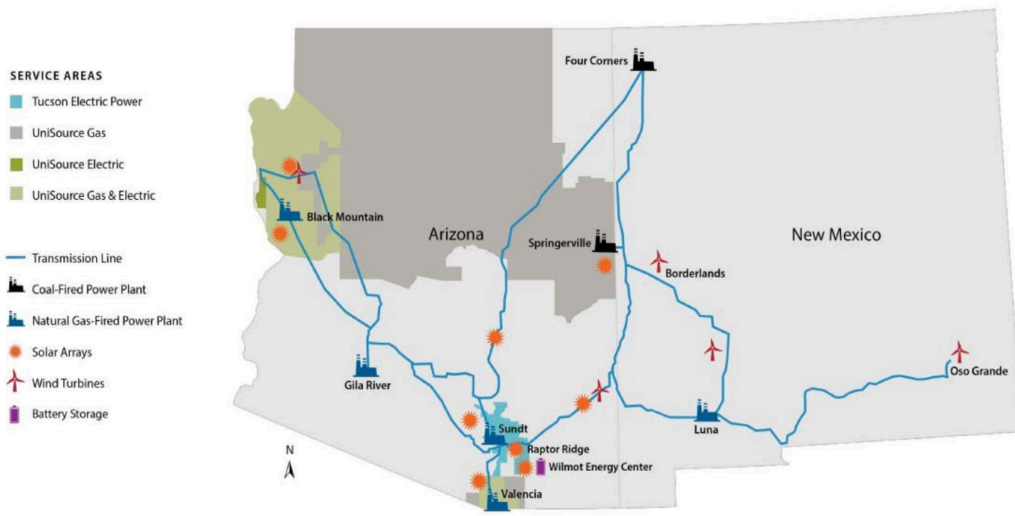
        - Response:
            - Fault isolated by the upstream recloser device.
            - Microgrid correctly isolated the BESS1 half, and BESS2 islanded the remaining load.
        - Outcome:
            - After one hour, BESS2 tripped offline, dropping all load.
            - Analysis showed 3 power blocks in BESS2 went offline due to an inverter firmware glitch.
            - BESS2 had 1 power block offline prior, leaving 7 available.
            - Operators did not tie BESS1 and BESS2 after island formation.
            - The loss of PB 12 caused the available power blocks to drop below 7, triggering the microgrid controller to trip BESS2 offline.
    - Corrective Actions:
        - Inverter firmware upgrade needed and completed on 9/22/2022 for all inverters.
        - Operations guide updated to tie BESS1 and BESS2 via the N.O. tie breaker.
    - Second Event (04/16/23):
        - Cause: A 2600A B-G fault at a side tap recloser (RCL-10).
        - Response:
            - BESS1 sourced 1000A, BESS2 sourced 1200A, system sourced 400A.
            - Fault isolated, both BESS plants stopped sourcing fault current, and voltage recovered.
            - RCL-10 reclosed, fault reignited as a B-C-G fault, and was isolated again by RCL-10.
            - BESS plants sourced 1000A each, system sourced 500A; however, voltage did not return to normal.
        - Outcome:
            - After the second fault isolation, BESS1 and BESS2 drew significant MW and VARs, causing 12 power blocks to trip offline.
            - Feeder voltage recovered to nominal after power blocks tripped.
            - RCL-10 reclosed 15 seconds after the second event and stayed closed.
        - Investigation Conclusions:
            - Ongoing Investigation:
                - Remote access issues delayed retrieval of BESS and inverter records.

        - Inverter records were overwritten.
    - Manufacturer Findings:
        - Manufacturer's report (without inverter manufacturer input) concluded 12 power blocks tripped due to exceeding DC bus voltage limit.
        - BESS was running at 95% State of Charge (SOC), leaving only 22 volts of DC bus voltage margin.
    - Recommendations:
        - Reduce BESS SOC from 95% to 90% to allow more margin for transient event response.
        - ES is considering this recommendation.
    - Additional Factors:
        - Tight voltage and frequency droop settings may have contributed to the unexpected inverter response.
        - These settings are necessary to mitigate stability issues found in PSCAD transient stability studies.
- Operational Experience Summary Conclusions:
    - The facility has significantly mitigated customer interruptions on the Provincetown 23kV feeder.
    - Challenges due to the transition from NEC to LGESVT and the immaturity of BESS technology.
    - Importance of remote access to BESS data and long-term service contracts.
    - Continued work with BESS and inverter vendors to address availability issues.

Tucson Electric Power (TEP) – Utility Scale Battery Energy Storage Systems (BESS)

- TEP and UNSE Overview:
    - TEP serves 442,000 customers in Tucson metro area with a 2500 MW peak load and 1.23% annual retail load growth.
    - UNSE serves 100,000 customers in Mohave and Santa Cruz counties with a 500 MW peak load and 1.55% annual retail demand load growth.

Figure 1: TEP and UNSE Electric Service Area



- 2038 Goals:
  - o TEP: Add 2 GW of renewable resources (PV and Wind), 1 GW of battery storage, and achieve 80% carbon reduction by 2035.
  - o UNSE: Add 350 MW of renewable resources (PV and Wind), 225 MW of battery storage, and achieve 80% carbon reduction by 2035.
- Existing Battery Storage Locations:
  - o Tucson Area: Pima and Iron Horse (2017) for frequency response and disturbance recovery with <15min discharge.
  - o Wilmot Solar (2021) and Vail BESS (2024) for solar peak charge and evening peak discharge.
  - o Prairie Fire and Solon 1 (2017) for R&D purposes.
- 2022 All Source RFP:
  - o Issued April 19, 2022, seeking 250 MW renewable and energy efficiency resources and up to 300 MW of firm capacity with at least four hours of continuous dispatchable energy.
  - o Proposals due July 1, 2022, with a commercial operation date no later than May 1, 2025.
- RFP Timeline and Process:
  - o Preliminary and final diligence processes involving third-party oversight and consultant evaluations.
  - o Selection and contracting of EPC proposals based on various performance categories, including BESS performance, safety, and environmental considerations.

- Roadrunner Reserve BESS Project:
  - First utility-scale BESS project with a 20-year contract, involving DEPCOM for design, construction, and maintenance.
  - Utilizes:
    - Batteries: 360 Canadian Solar SolBank units (Capacity: 2.8MWH)
    - Inverters: 66 Power Electronics (Capacity: 4200kW)
    - BESS Switchyard GSU: (Capacity: 34.5kV – 138kV)
  - Guaranteed project substantial completion date of August 1, 2025.
  - Includes a comprehensive plan for procurement, engineering, and construction phases, with key milestones such as site re-zoning and substation completion.
- Commercial Terms and Challenges:
  - Establish Base Contract Terms:
    - EPC (Engineering, Procurement, and Construction) / LTSA (Long-Term Service Agreement)
    - 20-year contract addressing long-term market uncertainties
    - Limited expertise in operating utility-scale BESS
  - Long-Term Warranty:
    - Ensure performance and availability
    - Address supply chain issues, especially summer demands
  - Procurement Challenges:
    - Long Lead Items (GSU/Breakers/Control Equipment)
    - Union Labor and Apprenticeship Programs not established prior to IRS guidance
    - Lithium Price Index considerations.
- One Source EPC / OM Solution:
  - DEPCom:
    - Design, build, and maintain the project over a 20-year design life
    - Partnership with EPC contractor invested in design, construction, and operation
  - Key Components:
      - 360 SolBank Canadian Solar units and ancillary equipment
      - Compliance with TEP standards
      - Substantial Completion Date: August 1, 2025
      - TEP obligation to procure and supply the GSU
  - Credit Support and Warranties:
    - BESS shelf life (Distribution Aux)
    - 2-year EPC fully wrapped warranty
    - 20-year BESS warranty

- Warranty and Performance:
  - LTSA:
    - 5 years with options, including T&M Substation
    - Long-Term Warranty with Assignment
    - Spare Parts and Augmentation (3-5 years)
  - Operating Limits:
    - 365 cycles, 50% SOC (State of Charge)
  - Availability and Performance Testing:
    - Availability at Point of Interconnection (POI)
    - Testing for Round-Trip Efficiency (RTE) and Capacity
- Integration:
  - System Integration:
    - Work Management Systems
    - Energy Management Systems
    - EIM (Energy Imbalance Market) Communication
  - FERC Changes:
    - Interconnection Agreement adjustments
    - Accounting modifications
- Integration and Execution Leadership:
  - Coordination across multiple workstreams, including energy resources, T&D engineering, technology and cybersecurity, and a separate 230 kV upgrade project at the same location.
  - Emphasis on thorough integration of work management, energy management systems, and compliance with FERC changes.
- Roadrunner Reserve Development Plan:
  - Comprehensive site layout including the BESS switchyard, inverters, security measures, and first responder station.
  - Detailed electrical and security plans to ensure reliable and safe operation.
- Final Thoughts:
  - Challenges include schedule compression, simultaneous negotiations and design, and company-wide engagement.
  - Opportunities to build new contract templates and address process gaps in operating utility-scale BESS.

San Diego Gas & Electric (SDG&E) – Overview of BESS Experiences

- California Context and SDG&E's Energy Storage (ESS) Portfolio:

- SDG&E provides clean, safe, and reliable energy to 3.7 million consumers through 1.4 million electric meters and 873,000 natural gas meters in San Diego and southern Orange counties.
- SDG&E employs over 4,000 people, covering a 4,100 square-mile service area (spanning 2 countries and 25 communities).

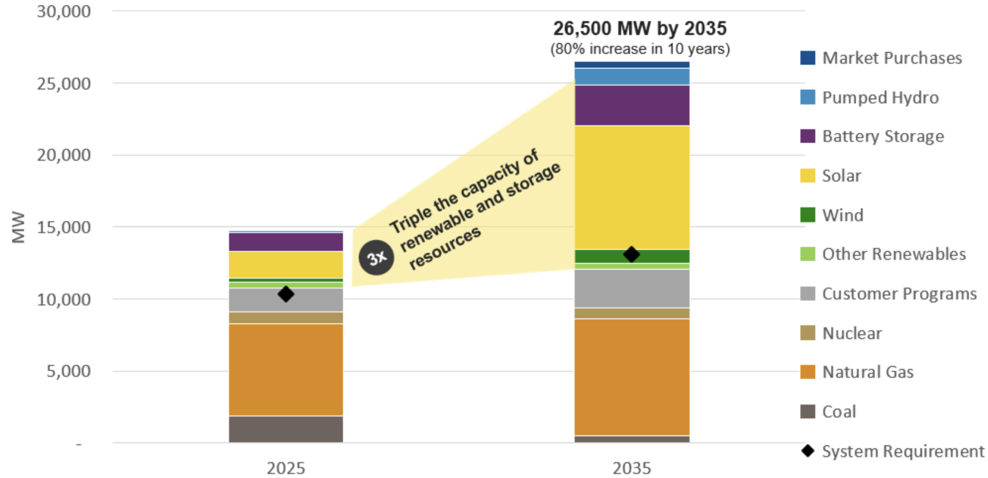
- California ESS Use Cases/Markets:
  - Energy storage is fundamental to achieving California's climate goals, requiring significant amounts of storage to meet Senate Bill (SB) 100 and 1020 targets.
  - SDG&E continues to facilitate energy storage development and deployment to meet state climate and reliability goals.
  - Installed battery capacity includes 6,675 MW as of 2023.
- ESS Project Implementation – Key Learnings:
  - Project Locations and Capacities:
    - Various in-service projects totaling ~335 MW, including Borrego Springs, Canyon Crest, Pala, Ortega Hwy, Escondido, El Cajon, Miguel VRF, Miramar Top Gun, Kearny, Ramona Air Attack Base, Fallbrook, Westside Canal, Pala-Gomez Creek, Melrose, Boulevard, Clairemont, Paradise, Elliot.
    - Projects in development or under construction totaling ~49 MW, including Butterfield, Cameron Corners, Shelter Valley, Remote Grid, Borrego Microgrid Expansion, Fallbrook 2, Santee.
    - SDG&E will have over 380 MW of utility-owned storage in operation by the end of 2024.
  - Battery Deployments:
    - In 2023, over 2,100 MW of battery storage were added, providing ~3,500 MW on peak demand days.
  - Optimization:
    - Optimize owner and vendor scope of work (SOW), utilize existing substation land, optimize interconnection, commission fire monitoring systems, standardize network and HMI.
- Industry Needs & Opportunities:
  - Opportunity Challenge #1: Standardize System Controls:
    - Current Dependence on Vendor/OEM:
      - ESS owners rely on vendor/OEM OS, firmware, and software serviceability.
      - Updates or changes can be expensive.
      - Vendor insolvency presents significant challenges for ESS operations, making repowering or reverse engineering costly.

    - Potential Solutions:
        - Develop an open-source "Energy Management System" standard.
        - Ensure equipment vendors provide serviceable system-level networking and control equipment.
        - Prioritize this as ESS solutions diversify.
- Opportunity Challenge #2: OEM Reliability:
    - Persistent Issues:
        - Serial defects in the PCS world.
        - Uncertain long-term performance of lithium-ion chemistry.
        - Failures in balance of plant, control, and network equipment beyond 10 years.
    - Mitigation Strategies:
        - Addressing equipment and vendor exposure to vendor insolvency risks.
        - Understanding augmentations and repowers to maintain reliability.
- Opportunity Challenge #3: ESS Technology:
    - Increased Investment:
        - Significant investment in material science for ESS technology, partly driven by EV space.
    - Research and Development:
        - Encourage publicly available research on alternative battery chemistries and technological performance.
        - Aim to improve ESS availability and reliability as they become more integral to the system portfolio.
    - Standardization and Automation:
        - Focus on recycling viability, standardization, and automation over the next 5 years.
        - Improve integration and fire safety standards for battery enclosures.
- Opportunity Challenge #4: Microgrids:
    - Autonomous, Sustainable Microgrids:
        - Limited instances of fully autonomous, 100% renewable-powered microgrids.
    - Policy and Regulation:
        - Improve interconnection policies and regulations for generation and islanding systems.
        - Enhance resiliency use cases and the value proposition of ESS.
    - Standardization:

        - Standardize microgrid controls and interfaces with grid operators to simplify implementation.
- SDG&E ESS Safety:
    - Requires NFPA 72 Certified Monitoring systems for projects, ties systems into third-party monitoring, and performs end-to-end testing.
    - Coordination with emergency responders, site signage to guide fire containment.
    - Continuously review and assess safety measures, protocols, and procedures, and determine regulatory and funding paths for enhancements.

Salt River Project (SRP) – Oscillations at Hybrid Battery/Solar Sites

- Overview of SRP:
    - One of the nation's largest public power utilities, serving over 2 million people.
    - The largest raw-water supplier in the Valley, delivering about 800,000 acre-feet of water annually.
    - Peak load of over 8,000 MW.
- SRP Electric System:
    - 12,000 MW generation portfolio, with 8,500 MW owned generation.
    - 60 owned generating units, 25,000 miles of T&D lines, 325 substations, 92,000 miles of fiber, and 20 mountaintop communication sites.
- SRP 2035 Sustainability Goals:
    - Achieve a 20% reduction in generation-related water use intensity.
    - Eliminate or offset power generation groundwater use in Active Management Areas (AMAs).
    - Reduce CO_2 emissions by 65% from 2005 levels by 2035, and by 90% by 2050.
    - Focus areas include carbon footprint reduction, customer/community engagement, water resiliency, supply chain and waste reduction, customer and grid enablement.
- Growth in Inverter-Based Resources:
    - Annual energy growth projected at 4.6% through FY35.
    - Annual peak growth projected at 3.2% through FY35.



- Addition of Solar and Battery Storage:
  - o SRP's commitment to adding solar and battery storage to enhance reliability and sustainability.
- Operational Readiness:
  - o Emphasis on readiness for integrating solar and battery storage systems into the grid.
- Major System Events with Inverter-Based Resources:
  - o Experiences with significant generation tripping offline due to improper inverter settings preventing "ride through".
- Specific Facility Events:
  - o Facility A (September 20, 2023): 16-minute duration of oscillations.
  - o Facility A (November 1, 2023): 7-minute duration of oscillations.
  - o Facility B (November 3, 2023): 32-minute duration of oscillations.
- Causes and Corrective Actions:
  - o Common cause: improper software settings.
  - o Contributing factors: various technical and operational issues.
  - o Corrective actions:
    - ▪ Enhanced monitoring (on-site and at remote control centers).
    - ▪ Constraining output during commissioning.
    - ▪ Improved alarming systems.
    - ▪ Strengthened internal controls related to commissioning.
- Actions Taken by Industry & Regulators:
  - o Focused on inverters:
    - ▪ Institute of Electrical and Electronics Engineers (IEEE) standards.

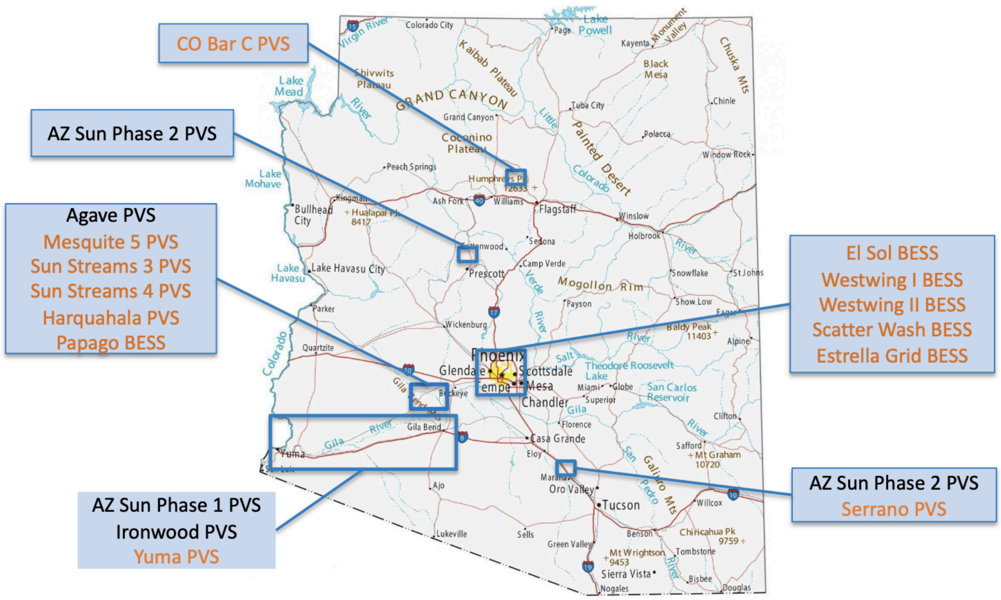
- North American Electric Reliability Corporation (NERC) reliability standards.
- Regional Transmission Organizations (RTOs) establishing technical requirements.

o Focused on inverters but opportunity to adjust:
- Electric Power Research Institute (EPRI) supplemental projects.

o Best opportunity to address recent challenges in a timely manner:
- North American Transmission Forum (NATF) initiative on best practices for generator interconnection requirements.

Arizona Public Service (APS) – Battery Energy Storage Systems (BESS): An Improved Approach to Safety and Availability

- McMicken Event:
  - 2MW/2MWh Li-Ion NMC commissioned in May 2015.
  - On April 19th, 2019, a fire alarm at the McMicken site led to an explosion, injuring four first responders.
  - Post-event, APS developed stringent safety requirements for BESS projects.
- BESS Safety since McMicken:
  - Each BESS designed, built, and operated with a strong emphasis on safety.
  - No occupiable enclosures; only "cabinet style" designs.
  - Safety requirements include industry-leading standards, third-party reviews, and ongoing updates.
- BESS Contracts and Installations:
  - Over 2.6 GW of BESS contracted since McMicken.
  - Notable projects include AZ Sun Phase 1 & 2, Serrano PVS, Agave PVS, Mesquite 5 PVS, Sun Streams 3 & 4, Harquahala PVS, Papago BESS, El Sol BESS, Westwing I & II BESS, Scatter Wash BESS, Estrella Grid BESS, Ironwood PVS, Yuma PVS, CO Bar C PVS.

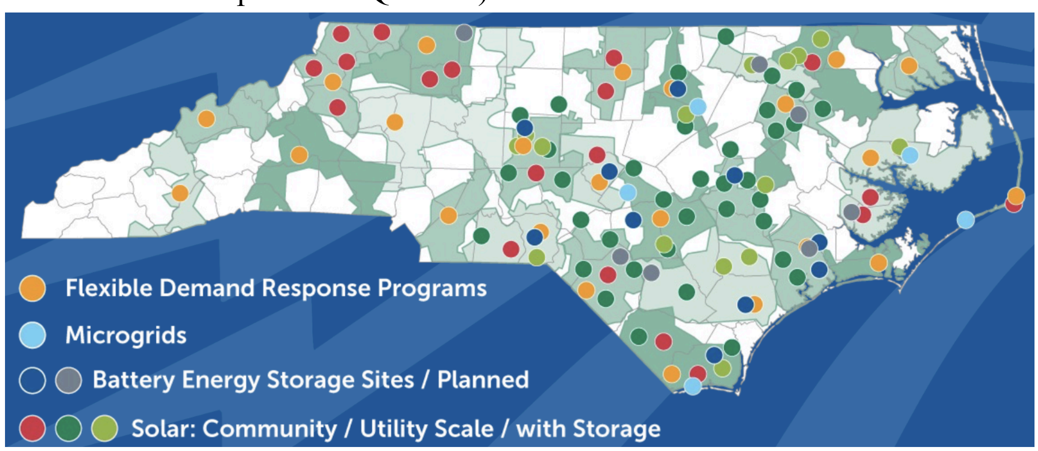


- Battery Rack Specifications:
  - AZ Sun Phase 1 - Powin:
    - 1,500 Volts DC, 230 kWh, LFP Chemistry, air-cooled, BMS/controller.
  - AZ Sun Phase 2 - Fluence:
    - 1,500 Volts DC, 187 kW, 750 kWh, LFP Chemistry, liquid-cooled (glycol), BMS/controller.
- Thermal Runaway Testing:
  - Importance of testing for understanding failure modes and prevention.
  - NFPA 68 method for controlled explosion through ventilation.
  - NFPA 69 method for deflagration prevention by air introduction.
- Availability & Response:
  - Strategic shutdowns and ROC visibility with camera views day and night.
  - Critical data and control house located 100'+ from BESS.
  - First responder stations equipped with necessary tools and information.
  - Signage with clear instructions and contact information for emergencies.
- Training & Emergency Management:
  - Initial and ongoing training for local fire departments (FD) and APS Generation Emergency Management.
  - Integration of BESS into APS's existing emergency management processes with FEMA-based training.
  - Annual re-training and scenario-based exercises.
- Signage and Emergency Procedures:
  - Reflective signage stating risks and emergency contact information.

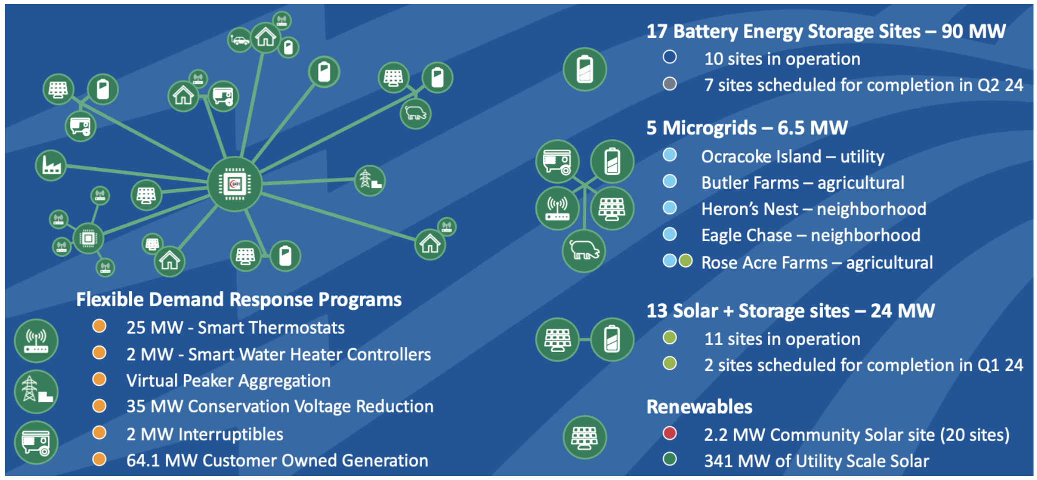
- Tactical worksheets with contact info, site plans, known hazards, expected responses, and emergency procedures.

NC Electric Cooperatives (NCEMC) – Learnings from Solar, Storage, and Microgrids

- Overview:
  - Presentation by S. Lee Ragsdale, Jr. PE, Sr VP of Energy Delivery.
  - Focus on NCEMC's experiences with solar, storage, and microgrids.
- Growth of DER on NC Electric Cooperatives:
  - Distributed Resources (DR) Programs and DER Sites:
    - Microgrids: 6.5 MW across 5 sites (Ocracoke Island, Butler Farms, Heron's Nest, Eagle Chase, Rose Acre Farms).
    - Solar + Storage Sites: 24 MW across 13 sites (11 operational, 2 scheduled for completion in Q1 2024).
    - Battery Energy Storage Sites: 90 MW across 17 sites (10 operational, 7 scheduled for completion in Q2 2024).



  - Flexible Demand Response Programs:
    - 25 MW - Smart Thermostats
    - 2 MW - Smart Water Heater Controllers
    - Virtual Peaker Aggregation
    - 35 MW Conservation Voltage Reduction
    - 2 MW Interruptibles
    - 64.1 MW Customer Owned Generation



- Renewables:
  - 2.2 MW Community Solar site (20 sites)
  - 341 MW of Utility Scale Solar
- Recent Encounter from Arba S+S:
  - Initial studies required inrush mitigation and permitted staging in transformers.
  - Online measurements found voltage routinely exceeded the 6% requirement.
  - Site was built with larger transformers than initially studied.
  - Staggered energization was inadequate; NCEC will install a Point On Wave recloser to mitigate inrush current concerns.
- Microgrid Fleet:
  - Various microgrids with diverse components like solar arrays, diesel generators, and storage units.
  - Each microgrid designed for specific needs and resilience.
  - Details (below)
  - Tideland EMC:
    - Components:
      - Smart Devices: Ecobee & Carina
      - Storage: 500 kW, 1 MWh
      - Solar Array: 15 kW
      - Diesel Generator: 3 MW
    - Features:
      - Utility-based microgrid.
      - Long, exposed feeder susceptible to high winds and storms.
      - Peak loads correspond with costly demand peaks.
      - Equipped with a microgrid controller.
  - South River EMC:

    - Components:
        - Storage: 250 kW, 735 kWh
        - Solar Array: 20 kW
        - Diesel Generator: 100 kW
        - Swine-Waste Generator: 185 kW
    - Features:
        - Member-consumer owned assets.
        - Commercial operation with renewable generation.
        - Supported by the local community.
        - Equipped with a microgrid controller.
- Rose Acre Farms (Tideland EMC):
    - Components:
        - Storage: 2.5 MW, 5 MWh
        - Solar Array: 2 MW
        - Diesel Generators: 25 units, 250 kW each
    - Features:
        - Member-consumer owned assets.
        - Commercial operation with renewable generation.
        - Emphasis on corporate sustainability.
        - Equipped with a microgrid controller.
- Brunswick EMC:
    - Components:
        - Smart Devices: Ecobee & Carina
        - Storage: 230 kW, 255 kWh
        - Solar Array: 62 kW
    - Features:
        - Sustainable community.
        - Microgrid controller.
        - Developer and customer-owned assets.
        - Serving 33 homes with 3kW solar each.
- Wake EMC:
    - Components:
        - Storage: 558 kW, 1 MWh
        - Propane Generator: 300 kW (grid-tied)
    - Features:
        - Resilient neighborhood with 36-hour backup power.
        - Provides grid services.
        - Equipped with a microgrid controller.

        - Serving 31 homes.
- Eagle Chase Microgrid:
    - Resilient neighborhood with 36-hour backup power.
    - Successful operation maintained power during a significant outage event.
    - Components include a 558 kW - 1 MWh Tesla battery bank and a 300 kW propane generator.
- Rose Acre Farms Microgrid:
    - Phases include solar + storage and future microgrid expansion.
    - Components include Tesla Megapacks, diesel generators, and a solar array.
    - Successful testing in 2023 demonstrated resilience and reliability.
- Site Selection Considerations:
    - Adequate area (~¼ acre for a 2.5 MW BESS site).
    - Accessibility for maintenance and vendor access.
    - Environmental considerations to avoid wetlands and endangered species.
    - Soil quality for site stability and cost efficiency.
- Integrated T&D Operations and Planning:
    - Advanced data analytics for DER modeling and scaling.
    - Use of digital twins and hardware-in-the-loop models.
    - Enhanced situational awareness to improve DER visibility.
    - Coordination of DER management across multiple Distribution System Operators (DSOs).
    - Deployment throughout NC to benefit co-op members at scale.
- Site Selection – Electrical
    - POD Shoulder Load:
        - Peak load at the point of delivery (POD) should be greater than the size of the distributed energy resources (DER).
    - Relaying/Metering supports load and back-feed calculations to ensure accurate data and safe operations.
    - RTAC and Communications:
        - Direct Transfer Trip
        - Charge and discharge limits
        - Direct VARs (Volt-Ampere Reactive) from DER
        - Single-mode fiber installation costing approximately $40k per mile
    - Express Feeder:
        - Preferred but not required
        - 600 Amps at 12.47 kV equates to 12.96 MVA

US DOE Office of Electricity – Energy Storage: Transformation Planning

- Opportunity and Risk in Energy Storage:
    - Opportunity: Rapid growth in energy storage deployment, with significant projections for the coming years.
    - Risk: Not all supply chains are secure or competitive, highlighting the need for a secure and domestic ecosystem for energy storage components.
    - NREL analysis: significant higher post-IRA storage growth (>200 GW by 2040)
    - Congressional Direction: “the Department is encouraged to seek a broad spectrum of battery chemistries not wholly exclusive to lithium-ion based battery technology”
- The Growing Storage Industry Landscape:
    - Storage Deployment Projections: Significant increase in storage deployment, predominantly driven by lithium-ion technology.
    - Supply Chain Risk Assessment:
        - Identifies critical components and materials, highlighting which are secure and competitive in the global market.
        - Emphasis on developing a secure domestic supply chain for materials like lithium, cobalt, nickel, and others.
- DOE Storage Highlights:
    - Technology Progressions: From basic research and development to commercial operations, including stages of technology readiness and manufacturing.
    - DOE Roles:
        - Basic Research: Conducted by DOE, academia, and national labs.
        - Applied R&D: Managed by programs like ARPA-E and various DOE offices focused on different energy sectors.
        - Deployment and Scale-Up: Supported by the Loan Programs Office and other DOE initiatives.
        - Technical Assistance: Provided through various DOE offices for policy and implementation support.
- Developing an Ecosystem Feedback Loop:
    - IRA Incentives: Introduce supply chain and deployment questions earlier in the R&D process.
        - Domestic content: “Can it be sourced and manufactured here?”
        - Energy community: “Can it be beneficially deployed for targeted communities?”

- Scenario Planning: Identifying long-term targets and engaging with the industry to plan for future needs.
- Common Long-Term Targets: Setting specific goals for manufacturing capacity, cost reductions, efficiency improvements, and deployment capacity by 2030-2035.

- DOE Storage Year in Review (2023):
  - Expanding Innovations:
    - Significant investments in various battery technologies and energy storage innovation hubs – DOE announcements:
      - Announces $125 Million for Research to Enable Next-Generation Batteries and Energy Storage
      - DOE Announces $264 Million for Basic Research in Support of Energy Earthshots™
      - Funding Opportunity Announcement (FOA) worth $15 million to tackle pre-competitive technology R&D barriers (SI 2030: Technology Liftoff)
      - Announces Energy Storage Innovations Prize Winners (10 teams)
        - 5 "Storage Innovations Champions" to receive $50,000 each
        - 5 "Storage Innovations Finalists" to receive $10,000 each
    - Progress on alternative battery chemistries and power electronics ($30 Million):
      - Zinc Battery Research at PNNL
      - Zinc Manganese Dioxide Batteries for Long Duration Energy Storage (LDES) Systems
      - Redox Flow Batteries (RFBs)
      - Aqueous Organic Flow Battery
      - Sodium-Based Batteries
      - Energy Storage Power Electronics Program
  - Bankability and Scaling:
    - Initiatives to support solid-state and flow battery manufacturing, conditional loan commitments, and battery materials processing grants.
      - Department of Energy Announces $16 Million to Boost Domestic Capabilities in Solid-State and Flow Battery Manufacturing
      - LPO Announces Conditional Commitment for Loan to KORE Power, Inc. to Increase Domestic Battery Manufacturing
      - Biden-Harris Administration Announces $3.5 Billion to Strengthen Domestic Battery Manufacturing

        - Biden-Harris Administration Announces $325 Million For Long-Duration Energy Storage Projects to Increase Grid Resilience and Protect America's Communities
        - Energy Department Awards $19 Million for Long-Duration Energy Storage in Remote Communities and Military Housing
        - Rapid Operational Validation Initiative (ROVI) worth $2 Million: Energy Department Selects Six National Laboratories to Validate Battery Energy Storage Performance
        - Long-duration energy storage demonstrations and validation projects worth $30 Million
    - Decisionmakers and Workforce:
        - Reports and assessments to guide technology strategy, safety, reliability, and community capacity building.
        - Capacity-building initiatives for regulators and collaborations with international partners.
- Enhanced Engagement:
    - National Consortium for the Advancement of Long-Duration Energy Storage (LDES) Technologies.
    - Collaborative efforts to address issues in LDES commercialization, such as investor confidence, market planning, interconnection, standardization, and safety.