ESIC Energy Storage Implementation Guide

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EPRI Project Manager

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THE ELECTRIC POWER RESEARCH INSTITUTE (EPRI) PREPARED THIS REPORT.

This is an EPRI Technical Update report. A Technical Update report is intended as an informal report of continuing research, a meeting, or a topical study. It is not a final EPRI technical report.

NOTE

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The authors would like to thank all ESIC participants for their thought leadership, and also acknowledge individuals for their roles to date. Omissions are the sole responsibility of the author.

Former ESIC chair, Eva Gardow of FirstEnergy, has demonstrated dedication from inception to execute the mission of ESIC. Without the tremendous administrative support of Karen Larsen, Lucy Cha and Christian Martinez-Ventura, execution of ESIC would not have been possible.

Leadership has also been provided by the following Working Group chairs:

Grid Services and Analysis Working Group – Udi Helman, Helman Analytics

Testing and Characterization Working Group – Jorge Araiza and Naum Pinsky, Southern California Edison

Grid Integration Working Group – Thomas Golden, Duke Energy (Former Chair)

Numerous other individuals and organizations have also played leadership roles in the development of subgroups and individual topic work products. These individuals are recognized specifically in the context of those work products.

The Energy Storage Integration Council consists of over 1200 volunteer participants from more than 600 organizations.

This publication is a corporate document that should be cited in the literature in the following manner:

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ABSTRACT

Effective implementation of utility-distribution energy storage requires recognition of factors to consider through the complete life cycle of a project. This report serves as a practical reference guide from initial planning, procurement, system deployment, operations and maintenance, and eventual decommissioning. This document provides a bridge between work performed by the participants in the Energy Storage Integration Council (ESIC) and the practical concerns of companies involved with energy storage project deployments. Development of this document was supported by the combined efforts of three ESIC working groups, and it includes contributions from utilities, energy storage vendors, and the research and consulting community. Through direct discussion, web links, citations, and a detailed bibliography, the reader has access to an up-to-date suite of publicly available resources and insights into ESIC's ongoing work in support of developing common approaches that advance the mission of ESIC.

This guide is an annually updated report that evolves with new ESIC publications and industry use of the document. ESIC is an open technical forum with a mission to advance the integration of energy storage systems (ESSs), which is guided by the vision of universally accessible, safe, secure, reliable, affordable, and environmentally responsible electricity.

Keywords
Energy storage
Energy storage deployment
ESIC
Distributed energy resources
Integrated grid

ESIC ENERGY STORAGE IMPLEMENTATION GUIDE – USER QUICK GUIDE

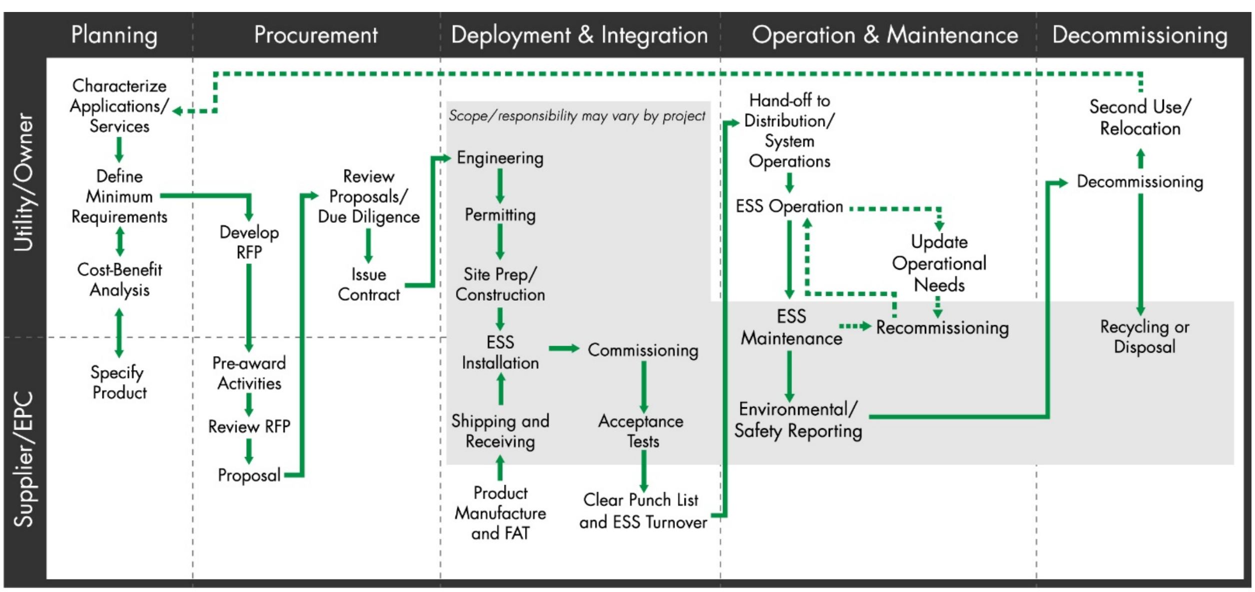
The following User Quick Guide provides a brief overview of each five chronological phases of the life cycle of an energy storage project as described in the Energy Storage Implementation Guide, including Planning, Procurement, Deployment, Operations and Maintenance (O&M), and Decommissioning. Many important items are hyperlinked in this document to help users quickly navigate to specific content in the comprehensive implementation guide. This document is developed in close coordination with other Energy Storage Integration Council (ESIC) products; these can be accessed at **epri.com/esic**.

Section 1: Introduction discusses the purpose and organization of the Implementation Guide and an overview of ESIC.

The purpose of the Implementation Guide is to:

- To serve as an evolving reference guideline for utility project managers, the suppliers they work with, and users investigating energy storage solutions
- To support the development of a practical, short-term industry research agenda to deploy safe, reliable, cost effective energy storage projects with a one- to three-year time horizon
- To identify common problems and risks that are encountered in the implementation of energy storage projects and provide a path toward resolution
- To provide an annual update on the publicly available tools of ESIC

To achieve these objectives, the Guide is organized into chapters that follow the five phases of the life cycle of an energy storage project. In each chapter, useful and publicly available tools, templates, and resources are referenced to guide users through each of those phases, with the goal of developing clear channels of communication within the project team.



Section 2: Planning describes the process for identifying grid needs, translating such needs into technical requirements, and analyzing the cost-effectiveness and viability of energy storage projects.

Characterize Applications / Services

The first phase in the planning process for an energy storage procurement is the identification of grid needs in order to characterize applications and services. From the perspective of an electric utility stakeholder, there are several ways that distribution-connected energy storage could be used to minimize, defer, or avoid costs, increase reliability, or to increase the operational efficiency of the electric power system. Additionally, there are emerging drivers resulting from the adoption of both fossil and renewable distributed generation by utilities, utility customers, and third-parties, as well as the overall drive toward a more environmentally responsible electric power sector.

Define Minimum Requirements

Identifying and assessing specific requirements of storage will ensure project managers evaluate and screen the energy storage technology's ability to meet solution requirements defined previously. Elements for developing energy storage specific project requirements include: Ownership of the Storage Asset, ESS Performance, Communication and Control System Requirements, Site Requirements and Availability, and Local Constraints.

Cost-Benefit Analysis

At this part of the planning phase, there could multiple options to meet the grid need, including conventional options. The decision makers may narrow the scope of options using a screening cost-benefit analysis. This analysis may include secondary service benefits and costs, in addition to those associated with solving the primary service. Processes such as Net Market Value, a metric that considers the net costs and net benefits of a new generator, and tools such as EPRI's StorageVET, a cloud-based energy storage valuation analysis tool, help planners perform analysis on the initial cost-effectiveness screen of the options available.

Section 3: Procurement describes the phase of the project which turns previously defined minimum requirements from the planning stage into specifications that result in a formal Request for Proposal (RFP) or Request for Offer (RFO). The project team will then review of the ESS proposals accordingly and evaluate how well individual proposed systems can meet project needs.

Develop RFP

A significant portion of developing a request for proposal is the development of the scope of work for the project. The scope of work is where the utility, or the Buyer, has the opportunity to define the objectives of the project and include specifications of the energy storage system, the energy storage product, balance of system, and other physical components and services that are required for the complete integration of the project. It should also clearly describe the expected responsibilities of each party for procuring, designing, and installing different components in the project. To clearly delineate responsibilities and interactions within each task, a Division of Responsibility (DOR) matrix should be a key supplement to the RFP. Additional ESIC guides and tools to support the development and clear communication of RFP requirements include the ESIC Energy Storage Request for Proposal Guide, ESIC Energy Storage Cost Tool and Template, and ESIC Technical Specification Template.

Review Proposals / Due Diligence

Proposal responses may include a broad spectrum of potential technologies, configurations, and potentially even supplemental value streams in addition to the core solution being sought by the utility. A well-formed RFP with established criteria for evaluating proposals can simplify the proposal review process. For example, use of the ESIC Technical Specification Template allows the buyer to evaluate and compare technical specifications from potential bidders by requesting the same set of technical information within the same reporting format. Other evaluation criteria may include cost, prior deployment experience, financial stability, and other risk mitigation considerations.

Section 4: Deployment and Integration discusses the stage after procurement contracting has been done until the project has been installed and commissioned, and subsequently handing off to operations. Since energy storage technologies are still emerging, the scope of deployment and integration has not always been fully considered in previous stages. To improve the estimates of time and cost required for implementation, it is important to address in detail the steps required at this stage.

Engineering

Site and system engineering will use contract technical specification requirements and utility and industry design codes and standards as the basis of design.

Permitting

It is important to engage local authorities having jurisdiction (AHJ) to understand permitting requirements and additional codes and standards applicable for the construction and operation of an energy storage system. Due to large gaps in standards for energy storage with respect to codes, standards, and regulations (CSR) and the lag time for AHJs adopting new CSRs, there may be a need to educate and discuss concerns and requirements for safety, nuisance, or environmental issues certain departments within an AHJ.

Site Preparation/ Construction

After a permit or notice to proceed with construction is issued, site preparation and construction can begin.

Product Manufacture and FAT

In parallel with detailed engineering and site preparation, the energy storage product will be manufactured. When the product manufacturing is complete, it is a common practice for the utility or a third party to witness a factory acceptance test (FAT) at the vendor’s manufacturing facility prior to shipment. The FAT is typically a set of quality control-related tests to help ensure that the components of the energy storage system have been built to specification prior to its leaving the factory.

Shipping and Receiving

After the energy storage system is approved for shipment, it is transported to the site. Product shipping and receiving procedures, loading unloading equipment and practices, modes of transportation and other considerations should be given careful thought. Responsibility for these tasks should be defined during procurement.

ESS Installation

ESS product installation and system integration can be performed by an electrical contractor who should be experienced in both high and low voltage systems and familiar with the local electric utility's system. However, they may be unfamiliar with energy storage technology and require sufficient training and documentation to ensure that the contractor knows about safety hazards and procedures unique to energy storage systems.

Commissioning

After the installation and connection of an energy storage system to the distribution system, commissioning is required to ensure successful integration. The ESIC Energy Storage Commissioning Guide contains details of commissioning and site acceptance tests during the deployment and integration phase.

Acceptance Tests

Additional tests, such as performance and control functionality tests, may be required to verify the system operates as expected. The ESIC Energy Storage Test Manual with detailed test protocols that include measurement and calculation methodology, testing duty cycles, and templates for data collection can be used for acceptance testing.

Section 5: Operations and Maintenance (O&M) provides an overview of the various processes steps required over the operational life of the system. Since many of the planning assumptions for the project may evolve over time, it is important to consider both current and future needs, while assessing and communicating the inherent strengths and limitations of energy storage technology.

Handoff to Distribution / System Operations

During handoff, it is important that the distribution system and energy resource operators (and other parties with control of storage system) are well-informed and trained regarding the storage system operational software, intended use of the product, the protection systems and schemes invoked, and the planned operational profile of the storage system.

ESS Maintenance

Maintenance of any asset comes in two forms: planned and unplanned. Planned maintenance should be scheduled regularly depending on configuration, usage, and the technology of the energy storage system, with regular diagnostic checks for indicating degradation and performance expectations. Although costly, unplanned maintenance is needed when storage system malfunctions occur, which may lead to power system reliability issues. Many instances of unplanned maintenance should be avoidable through planned maintenance and diagnostics on system state of health.

Environmental / Safety Reporting

Depending on the type and size of the storage system used there may be an ongoing requirement to report chemical content, operational status, and other parameters to AHJs.

Update Operational Needs

In the case where changes in operation needs are identified, modeling and simulation efforts may help to understand both the future demand and current operating needs of the system for energy storage projects. Changes in operation outside of the warranty provision or agreed upon use-case may need to be discussed with the vendor or supplier.

Recommissioning

In both situations involving replacement of major system components, which could include firmware updates, and changes in operation outside of original scope may require recommissioning of the system. In addition to recommissioning, periodic performance testing may also be conducted to ensure compliance with warranty or to document performance over time.

Section 6: Decommissioning and End of Life discusses the consideration of issues during the last phase of the project lifecycle when the system is no longer viable. The end of life can be expected by a predetermined project end date, triggered by safety or reliability issues or caused by exceeding marginal costs relative to marginal benefit. A well-defined end of life condition for the energy storage project can ensure the safety, reliability and cost-effectiveness of the project.

Decommissioning

The cost and specifications of decommissioning should be considered throughout all phases in the life cycle. When the decision to decommission an energy storage system is made, a comprehensive decommissioning plan should be prepared to ensure a safe, efficient process.

Recycling/ Disposal or Relocation

As part of the decommissioning plan, it should be determined what will happen to the system after leaving the site. A plan could be made to recycle and dispose of the system components or, if there are components that have useful life, they could be reused at another location.

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INTRODUCTION

Purpose of this Implementation Guide

- To serve as an evolving reference guideline for utility project managers, the suppliers they work with, and users investigating energy storage solutions
- To develop a practical, short-term industry research agenda in support of safe, reliable, cost effective deployment of energy storage with a one- to three-year time horizon
- To identify common problems and risk that are encountered in the implementation of energy storage projects and provide a path toward resolution
- To provide an annual update on the publicly available tools of the Energy Storage Integration Council (ESIC)

Organization of this Guide

The objective of this document is to guide readers through the five phases of the life cycle of an energy storage project, referencing publicly available tools, templates, and other resources along the way. Each phase faces unique challenges and necessitates careful considerations to avoid project delay and miscommunication. As shown in Figure 1-1, the five chronological phases of the life cycle in this implementation guide are Planning, Procurement, Deployment and Integration, Operation and Maintenance, and Decommissioning and End of Life.

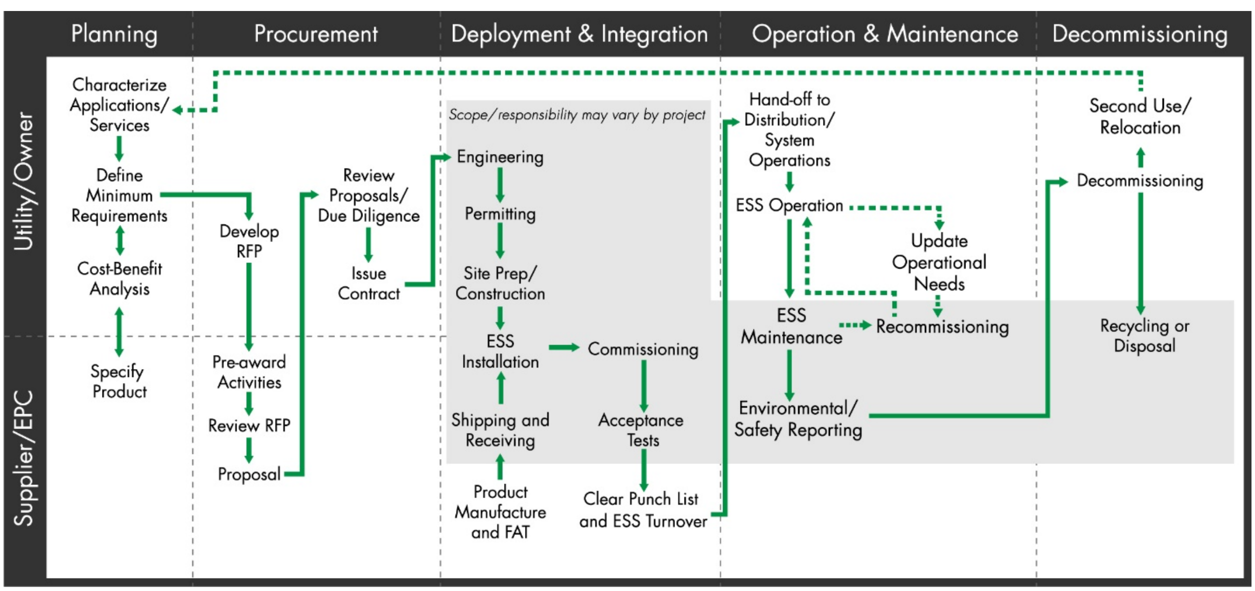

Figure 1-1
Project phase summary

This guide has been organized according to these lifecycle phases, with the section contents as follows:

- Section 2: Planning of Energy Storage – This section begins by looking at potential opportunities for ESS through the lens of grid issues and needs. It discusses both traditional issues and emerging needs and then guides readers through the process of defining an ESS application and its requirements. Subsequent subsections introduce product cost and project effectiveness analyses. The section concludes with discussion of on-site assessments for ESS, as well as frameworks, methodologies, and tools for conducting technical feasibility and impact assessments.
- Section 3: Procurement of Energy Storage – This section begins with a detailed look at developing a Request for Proposal (RFP), and the associated technical specification for the solution requested. It provides details on different considerations to include in the specification. It then discusses the evaluation of supplier proposals. It concludes with a subsection on conducting detailed technical and business case analyses and contracting.
- Section 4: Deployment and Integration of Energy Storage – This section walks readers through each step of a deploying an ESS. The section covers a broad range of topics, from required departments and specific roles to site engineering, product acceptance testing, logistics, installation, and commissioning.
- Section 5: Project Operations and Maintenance – This section discusses project operations and maintenance considerations throughout the operational life of an energy storage project.
- Section 6: Decommissioning and End of Life – This section discusses considerations that define the end of life for energy storage projects and for decommissioning an energy storage project.
- Section 7: References – This section lists references cited in the main sections of this guide. Additional references for ESIC working groups can be found in the appendices associated with them.

The following appendices provide a glossary of acronyms, an overview of the ESIC collaboration site and the ESIC work products under development, and the status of the different working groups and the various work products under development in each. The content of the appendices is summarized as follows:

- Appendix A: Acronyms and Abbreviations – This section provides a list of acronyms and abbreviations used throughout this guide.
- Appendix B: Bibliography for Energy Storage Implementation – This section provides a summary of how ESIC products can be applied throughout the implementation process and other materials that the working groups have used in the development of those work products.
- Appendix C: Additional Resources – This section provides a list of other publicly available resources that may support the implementation process.

Overview of Energy Storage Integration Council (ESIC)

This section will provide a brief overview of the Energy Storage Integration Council to highlight the importance of common approaches and terminology and describe the process by which ESIC tools, guides and templates are developed. For additional information on how ESIC operates visit www.epri.com/esic.

ESIC Description

ESIC is an open, technical forum to facilitate conversations between energy storage stakeholders, including utilities, developers, the research community, regulators to determine and communicate utility requirements for energy storage while maintaining acceptable safety and reliability characteristics. ESIC, which operates under the auspices of the Electric Power Research Institute (EPRI) is also a forum to attain consensus on definitions and common technical approaches to accelerate the development of standards as appropriate to facilitate safe and reliable deployment of energy storage. Through its collaborative process, ESIC produces publicly available guides and tools that support a wider understanding of industry requirements and standards. The ESIC forum is also a platform to discuss emerging issues and to review and provide input to efforts by other organizations that support ESIC's mission.

ESIC Mission

ESIC's mission is to advance the integration of energy storage systems through open, technical collaboration, guided by the vision of universally accessible safe, secure, reliable, affordable, environmentally responsible electricity.

ESIC Documentation and Publishing Process

Work products developed within ESIC are typically developed collaboratively by ESIC participants and EPRI staff. The documents undergo a review process, beginning with a subgroup, then working group, then general ESIC review and, finally, EPRI editorial review. At the end of this process, EPRI endeavors to publish work products developed through ESIC, which are made available to the public for free.

Work products developed outside of ESIC may be periodically reviewed in both draft and final form by ESIC. The entities that develop these products typically publish them using their own resources. However, reviews of these documents may become ESIC work products. Additionally, portions of externally developed work products may be referenced in ESIC documentation, as coordinated with the responsible party.

ESIC Working Groups

ESIC currently has three working groups: Grid Services, Testing and Characterization, and Grid Integration, as illustrated in Figure 1-2.

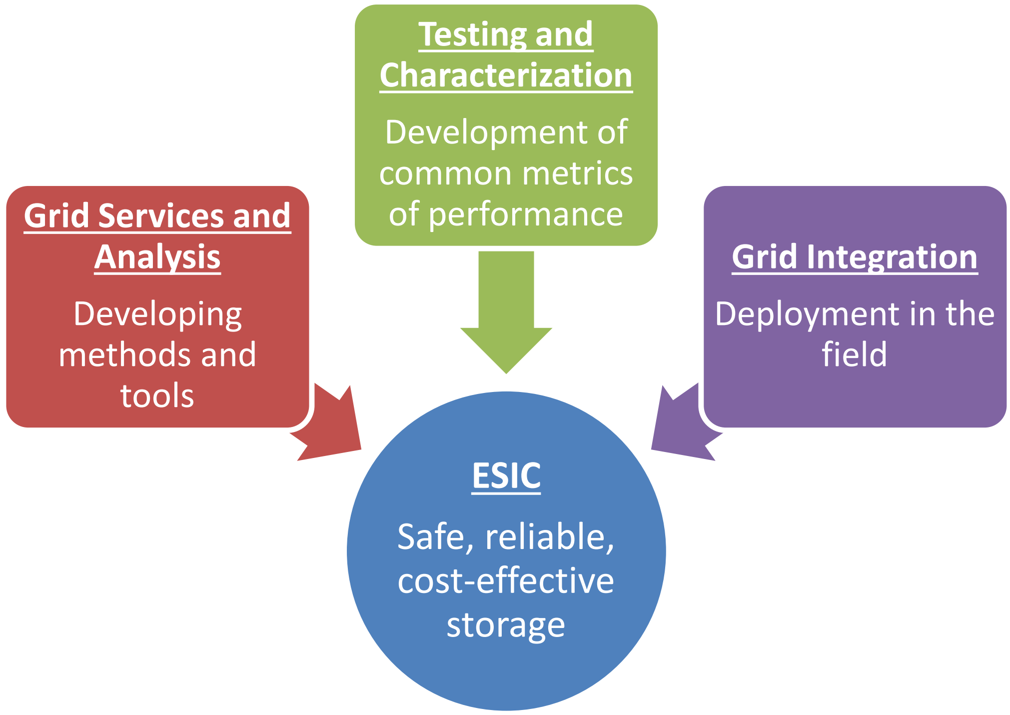

Figure 1-2
Three ESIC Working Groups

The mission of the Grid Services and Analysis Working Group (WG1) is to determine the requirements of energy storage in order to solve grid needs and provide value and to develop guidelines and definitions for analysis of energy storage system value and impacts on the power system. This working group identifies grid issues and corresponding grid services that can be addressed by energy storage. It provides practical methodologies for identifying relevant solution requirement parameters and how to derive the requirements for energy storage to meet needs and provide value. WG1 is also developing common definitions for energy storage technology models and grid services requirement and benefit calculation definitions. The group is the venue through which the industry provides guidance to an EPRI-led project, funded by the California Energy Commission, to develop a publicly available cloud-based energy storage valuation tool, called the Storage Valuation Estimation Tool (StorageVET).

The mission of the Testing and Characterization Working Group (WG2) is to consistently characterize the technical characteristics of fully integrated energy storage products relevant to utility requirements. This entails identifying common terminology and definitions for energy storage product performance and technical characteristics. It also involves defining or facilitating the creation of test procedures to consistently verify energy storage characteristics, in a technology neutral way, that are relevant to utility application requirements.

The mission of the Grid Integration Working Group (WG3) is to provide practical guidance for the implementation of energy storage in the field. The Working Group aims to provide utility project deployment and integration guidelines. This entails procurement, commissioning, communication and control and safety guidelines.

2
PLANNING OF ENERGY STORAGE

This section covers the first phase of energy storage project implementation: planning. This phase begins with the identification and definition of grid needs and translates those needs into requirements. The objective is to provide an analytical framework on which to base a decision on whether or not to proceed with an energy storage procurement project.

The planning process for energy storage requires an understanding of the current processes for planning and a detailed evaluation of power system needs, criteria, and alternatives, as well as an overall cost-benefit analysis.

Planning an energy storage procurement project involves several phases:

- **Characterizing** applications and services
- **Defining** minimum solution requirements
- **Identifying** and **assessing** specific requirements of storage
- **Evaluating** the technical and economic feasibility of storage

The planning process is often referred to as developing a use case. The use case framework can support a system planner by helping to identify the technical objectives, the elements (humans, devices, etc.), and their step-by-step interactions as a project moves toward implementation. Use cases can be general or very detailed, depending on the need, but they are most valuable when they are most practical. With this in mind, the ESIC Grid Services and Analysis Working Group (WG1) is collecting publicly available use cases from energy storage deployments to build a reference library of realistic energy storage deployment scenarios and to understand the requirements to achieve specific objectives.

Characterizing Applications and Services Relevant to Distribution-Connected Storage

The first phase in the planning process for an energy storage procurement is the identification of grid needs in order to characterize applications and services. Project managers can begin by asking the following questions:

- What need am I trying to satisfy?
- Is energy storage an option for addressing this need?

From the perspective of an electric utility stakeholder, there are several ways that distribution-connected energy storage could be used to minimize, defer, or avoid costs; increase reliability, or to increase the operational efficiency of the electric power system. There are both fixed and variable costs inherent to generating, transmitting, and delivering safe and reliable electric power. Factors affecting these costs include the following:

- load growth-driven T&D capacity investments
- load growth-driven generation capacity investments

- renewable-driven T&D capital investments
- contingency-driven T&D capacity investments
- bulk system operations (energy and ancillary services)
- local power quality and reliability issues

Additionally, there are emerging drivers resulting from the adoption of both fossil and renewable distributed generation by utilities, utility customers, and third-parties, as well as the overall drive toward a more environmentally responsible electric power sector. These include the following:

- distribution feeder-level photovoltaic (PV) hosting capacity limitations
- distribution level resiliency to weather (and other contingency) events, enabled by distributed energy resources (DER)
- renewables ramping and aggregated impact on bulk electricity needs for flexibility

Defining Minimum Solution Requirements

An important initial step in the consideration of energy storage systems in the utility planning process is to define the grid services and the specific required impacts to achieve a solution. To begin, planning criteria must be identified and quantified, first accounting for the scope and timeframe for stakeholder decision making. Planning scenarios must be developed and their impacts, relative to the technical criteria, understood. Possible violations of planning or operating criteria are identified through an analytical method appropriate for the domain and issue. Then, any violations are characterized (e.g. exceeding normal or emergency load ratings). Finally, from characterized violations, the technical impacts to correct a violation may be derived. Solution requirements should be "resource neutral," that is, not specific to one type of energy storage or even energy storage in general. For example, in a case where capacity limits of distribution assets are exceeded in the planning horizon, solutions requirements would include, at a minimum, the capabilities of power, energy, and availability for the energy storage (or other) resource to maintain the asset below its peak load limit.

The phases described for defining grid services are illustrated in Figure 2-1 below.

Figure 2-1
Defining grid services (technology-neutral solution requirements)

While it may be most logical for a distribution-connected ESS to focus on providing distribution level services, it may be feasible for these systems to provide services upstream to the bulk electricity system, affecting the planning and operations of generation and transmission.

The process of defining grid services can be relatively straightforward on a conceptual level, but in order to define grid services driven by emerging grid needs, planners and operators need supporting methods, models, and data to assess standard modes of operations, exceptions, violations, and the resulting solutions and/or requirements. EPRI's Integrated Grid Cost-Benefit

Analysis Framework [1] lays out a number of considerations for modeling processes and interdependencies. Additional grid service definitions are applied in the EPRI-led modeling tool, the Storage Valuation Estimation Tool (StorageVET®) [2], a web-hosted energy storage valuation tool (more at www.storagevet.com). The ESIC Grid Services and Analysis Working Group (WG1) contributed to review of StorageVET, and the working group is also developing a technical guidelines document for energy storage modeling.

Identifying and Assessing Specific Requirements of Storage

In practice, the array of options under consideration should first be evaluated and screened according to their ability to provide a solution and meet other compliance criteria. When the options under consideration do not appear to provide a solution, it can be worthwhile to reassess the options bearing in mind that new technologies might not fit into existing solution categories. As a framework, there could be two broad categories of feasible technology and service combinations, such as the following:

- Conventional Utility Options – e.g. generators, wires, transformers, voltage regulators, capacitors, protection equipment, feeder reconfiguration, etc.
- Emerging Options – e.g. storage, demand response, smart inverters, distributed generation (renewable or fossil), hybrid solutions, microgrids, etc.

After the minimum technical requirements for the grid solution have been defined, planners should note which of the solution parameters are important in the context of an energy storage based solution. In the case of distribution-connected energy storage used to provide distribution peak load management for the deferral of a transformer upgrade, it is important to consider the expected load shape and load growth rate of the feeder in order to understand how much power and energy a storage solution would need to support a given transformer or circuit on the highest peak day to maintain reliability under the planning criteria. This information may improve the planner's confidence for energy storage as an alternative solution to a higher capacity transformer. This contrasts with historical approaches that may dictate a need to specify a transformer upgrade, re-conductoring, or other "wires-based" solution, which do not take into account peak duration requirement.

The process for developing energy storage specific requirements is relatively immature currently, due to the nascent stage of utility energy storage deployments. As experience is gained, best practices should emerge and support a clearer process for meeting requirements. At this stage, it is important to identify and document relevant considerations for establishing requirements of energy storage products and implementation, as well as enabling infrastructure for validating the asserted value, by application of energy storage systems. Elements for developing energy storage project requirements are illustrated in Figure 2-2 and include ownership assignment, ESS system performance, communications and control system requirements, location requirements (including protection requirements) and site availability, and local constraints.

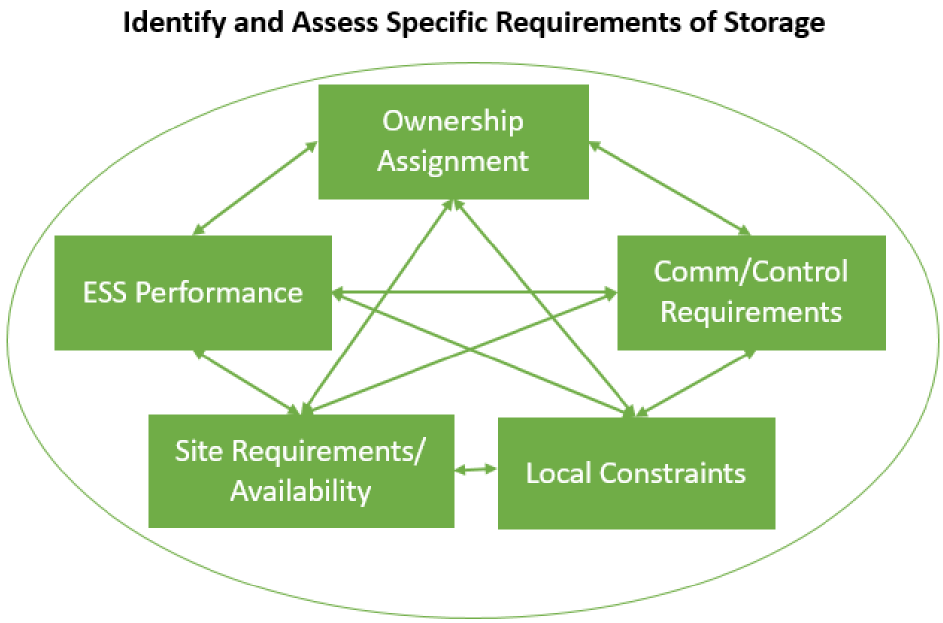

Figure 2-2
Development of energy storage project requirements

Each of these required solution elements is interrelated, so it is currently a challenge to develop a serial, step-by-step approach to setting requirements that will be generally applicable to a broad cross-section of stakeholders, accommodating specific requirements of the utility internal owners of the storage system. The order of operations may depend on the scope of consideration and control for the decision-making stakeholder(s), as well as degrees of freedom for the analyses. For example, a storage solution may be constrained by the existing utility distribution controls infrastructure. The storage use case may be substantially different if integrated with a utility Distributed Energy Resource Management System (DERMS), versus a case where the utility does not have any grid edge monitoring and control. In the latter case, the energy storage system may be relied on to provide substantially more sophisticated control.

Ownership of the Storage Asset: As part of the definition of technical requirements, a key initial step is to determine and assign ownership of the storage system. Systems can be owned by the utility or by a third party, i.e., an independent power producer, where only services or capacity are purchased. This is a crucial step in that downstream requirements and specifications can vary depending on ownership. If the utility owns the asset, there still may be differences in requirements because the asset could be managed through the transmission, distribution, generation or another business unit. A case in point would be the infrastructure and interconnection requirements; a storage system assigned as a substation may be constructed, controlled, and operated differently than one designated as a distribution asset. Ownership designation also needs to be considered from a broader, future standpoint in terms of placement of multiple units and a growing emphasis on distributed technologies in general. Additional considerations affected by the ownership decision include asset financial classification within the utility accounting system, warranty enforcement, site access, maintenance assignment, response to alarms and storage disposition, removal or relocation, to name but a few.

ESS System Performance: When defining storage technical characteristics, it is important to have consistent terminology and definitions. ESIC WG2 has developed a Technical Specification Template to support clear and consistent communication of function and performance parameters. Additionally, benchmarks for reporting ESS performance have not been consistent, so ESIC has been working to develop a common measurement method and compliance tests performed. The ESIC Test Manual [3] includes testing protocols for characterizing performance metrics and validating functional requirements.

Communication and Control System Requirements: Requirements documents can ultimately establish the framework of the intended communication and controls for storage projects, key to successful commissioning and downstream operation. These efforts are non-trivial as they require coordination with many internal stakeholders to ensure legacy systems interface with new distributed systems in a robust, cost efficient, and secure manner. The framework, depending on the complexity of what is required from the storage system, needs to detail specific system and user requirements. Successful integration of storage often hinges on up front analysis and documentation of the requirements in a prescribed documentation effort, similar to an IT based requirements document. Identification of communications, control, and cybersecurity requirements and functional definitions are in progress in the Grid Integration Working Group (WG3). In 2016, EPRI updated Common Functions for Smart Inverters [4] with support of ESIC and other industry stakeholders. This can be used to communicate system control functionality. In 2017, EPRI has been working to identify protocol mapping gaps and opportunities and will propose updates to the DNP3 standard.

Site Requirements and Availability: Some considerations when siting a system may include space requirements, type of location (e.g. rural, residential, urban, commercial and industrial), safety, applicable codes and standards, existing interconnection infrastructure, proximity to emergency response, permitting, physical access requirements, noise, appearance, or community outreach. No formal work has been done in this area within ESIC, but it is a research topic within the EPRI Energy Storage Program.

Local Constraints: To date, ESIC has not significantly addressed guidelines for analysis of local constraints relevant to energy storage, but work is under way at EPRI and other organizations to perform robust analyses to assess these operational considerations in a process similar to a PV hosting analysis. Guidelines are expected to be drawn from those experiences and implemented in future work. Without such analyses, coordination issues may have the potential to result in negative side effects to the local grid.

After defining and assessing storage specific requirements, a request for information (RFI) can be issued to understand the available storage technology that satisfies the project's needs. Responses can give insight as to whether a solution is likely to meet space, schedule, or minimum technical requirements. Additionally, energy storage products are now emerging with varying levels of technical readiness and independent evaluation. To screen readiness of a technology, utilities may request a summary of experience or list of field deployments with use case descriptions as part of an RFI. For technologies without extensive field data to reference, some utilities are performing demonstration or test projects to evaluate the storage products in terms of performance and compliance to safety and other relevant standards. The ESIC Request for Proposal Guide [5] can be used to support RFI development.

Evaluating Feasibility and Cost-Effectiveness of Storage and Alternatives

After the need has been defined and solution criteria established, there may be multiple options available for meeting the need. To identify the best solution, decision makers may further narrow the scope of options using a screening cost-benefit analysis. This analysis may include secondary service benefits and costs, in addition to those associated with solving the primary service. The scope of benefits considered in the analysis could be restricted by regulatory or business model considerations; however, it is important to note the potential evolution of regulatory, policy, and business models over the life of a long-term asset. Options may have different sets of potential benefits to consider, depending on the owner, location, and technology capabilities. These benefits can be considered in addition to a purely cost-based analysis, which is the historical approach for the distribution planning process with “wires-only” solutions.

Analyses of emerging non-wires alternatives are often compared with use of the conventional utility alternative based on solution requirements only. However, it is increasingly necessary to expand the scope of the analysis to incorporate requirements specific to emerging options, which often contain strengths and limitations similar to energy storage, such as location specific benefits, limited duration, or fast response. The ability to address grid services varies by resource and could be most reliably and cost effectively addressed by a combination of resources.

There is already a process for considering non-reliability benefits in the procurement of generation for resource adequacy or capacity, with a metric called Net Market Value (NMV) [6]. NMV is a metric that considers the net cost of a new generator, considering the levelized difference in fixed and variable costs of the generator versus the expected net benefits of that generator to provide energy and ancillary services. The NMV metric helps planners to determine what type of generator to purchase in the future (e.g. simple cycle, combined cycle, or base load generation), each with different fixed and variable cost structures. Similar analytical approaches are needed to consider the full potential scope of both economic and reliability benefits of energy storage and other distributed energy resources (DER).

Currently, there are no widely accepted tools and methods for performing cost-benefit analysis across multiple resources in the scope of the distribution system. However, these tools and methods are under development at EPRI and other organizations. In 2015, EPRI, along with its modeling partners and supported by the ESIC, kicked off the development of StorageVET [2], a cloud-based energy storage valuation analysis tool. The modeling team is using ESIC as a key venue for industrial guidance on modeling energy storage use case and technology. Common approaches for developing methods, models, and data requirements for energy storage are under development in the ESIC Grid Services and Analysis Working Group. As a result, the StorageVET model strives to address stakeholders’ challenges and incorporate a common modeling approach in its analysis infrastructure.

After assessing options and their relative cost-benefit trade-offs, the planner may be ready to perform deeper due diligence of the technical solutions or to communicate the solution needs to solution providers through the development of a technical specification. This could be accomplished through a request for quote (RFQ), request for offers (RFO), or request for proposals (RFP) process. The next phase, where the utility communicates needs and reviews options from the market, is covered in the next section, Procurement of Energy Storage.

General Considerations: Team Building, Participation, and Utility Department Roles

Early in the project, it is important to communicate and evaluate requirements with a broad set of internal stakeholders. One common theme of utility survey respondents with energy storage deployment experience was the importance of early buy-in, training, and documentation for the different utility departments and roles. The first step of getting buy-in is clarification of which specific stakeholders are responsible for the decisions pertaining to regulatory and environmental compliance, safety, permitting, integration, operation, and planned/unplanned maintenance. Utility stakeholders and their respective areas of concern should be identified, along with the key concerns or interests they may have regarding a new energy storage project. Stakeholders from utility IT, field communications, system operations, metering, substations, protection and design, among others, could have key roles, and significant outreach to all parties is required.

To this end, the Grid Integration Working Group (WG3) has identified key stakeholders and functions to guide thinking in development of the project team. Refinement of the portfolio of resources will proceed with time, technology adoption, and through maintaining this broad survey of the industry and tracking of best practices as new deployments occur. Indeed, the process is likely to change and become more uniform as energy storage becomes more common. Specifically, as key characteristics of energy storage systems are standardized, there will likely be fewer unique interactions with projects than when they are first-of-a-kind. In the near term, it will be important to understand and precisely define the requirements for each stakeholder.

Planning Resources

ESIC and EPRI provide access to a range of helpful resources for energy storage project planning, as outlined in Table 2-1.

Table 2-1
Useful Resources for Energy Storage Planning

Resource	Application in Planning
The Integrated Grid Phase II: Development of a Benefit-Cost Framework [6]	Provides a methodology for benefit-cost analysis.
ESIC Technical Specification Template [7]	Provides an understanding of the degree of detail needed in developing storage requirements.
ESIC Energy Storage Test Manual 2017 [3]	Provides insights on recommended testing for storage systems.
ESIC Energy Storage Request for Proposals Guide [5]	Use elements of RFP Template to support creation of RFI.
Common Functions for Smart Inverters, 4th Edition [4]	Lists inverter functional requirements based on use case.
StorageVET [2]	Publicly available web-based tool for cost-benefit analysis; confirm storage can meet general solution requirements.
DOE/EPRI Electricity Storage Handbook [8]	Chapter 1 addresses a range of use cases. Chapter 2 surveys technologies. Chapter 3 provides an approach to evaluating storage.

3
PROCUREMENT OF ENERGY STORAGE

Introduction to Procurement

The procurement phase of energy storage implementation begins after the planning process yields a set of minimum requirements for an energy storage project. Assuming the planning process found that a cost-effective project is viable, that process would result in a set of requirements so that project would meet or exceed a defined need. From this stage, those requirements can be distilled into major subgroups, including:

- Interconnection requirements
- ESS performance requirements
- Communication and control requirements
- Location requirements

The planning process also provides a decision platform that can lead to the selection of specific technologies, sizes, locations, and capabilities, and a decision to present the requirements determined through the planning process to the market for a solution. The exact process used in determining the procurement process will depend on the specific needs and requirements of the utility. In general, the steps of the procurement process, described in some detail below, are:

- Development of a Request for Proposal (RFP) or Request for Offer (RFO)
- Review of Energy Storage System Proposals/Due Diligence

In time, it should be possible for a utility to access a guide that would describe the procurement process for an energy storage project in steps as well defined and laid out as the procurement process for more established technologies, such as transformers, but the rapid emergence of energy storage and the quickly changing nature of the technology often means that energy storage solicitations are used to test the viability and availability of current products and solutions.

Development of Request for Proposal/Offer

The first step of a procurement is for the customer – in this case, an electric utility – to align the defined storage requirements to the procurement vehicle, whether it is a RFP or an RFO. In this document, however, the approach is assumed to be a Request for Proposal (RFP). It is important that whatever solution is requested can meet all the requirements to attain the desired value and to ensure that the solution does not create negative side effects or fail to comply with other requirements.

In additional to the technical requirements developed during the planning phase, more detailed specifications and requirements need to be defined for an RFP. As mentioned in the planning section, in order to further develop those specifications, it is important to determine the ownership of the storage system. Both utility owned or third party owned structures may be viable options for addressing the grid needs. There may be substantial differences in the information requested in an RFP issued under each of those two ownership scenarios. This section focuses on RFP under a utility owned project. Even within a utility owned project, the differences in the utility corporate structure can change the RFP requirements. This section focuses on RFP under a utility owned project.

ESIC's Grid Integration Working Group (WG3) has developed the ESIC Energy Storage Request for Proposal Guide [5] that details key elements an RFP may include. An outline of the template is below.

- Introduction
  - Purpose and Background
  - Project Description
  - Definition of Terms and Acronyms
- Proposal Process Overview
  - Confidentiality
  - Pre-bid Qualifications
  - Schedule
  - Notice of Intent to Bid
  - Pre-Bid Information Session and Communications
  - Proposal Preparation and Submission
  - Participation Requirements
  - Evaluation Criteria, Proposal Evaluation Matrix
  - Disclosure of Proponents
- Scope of Work
  - Scope of Supply
  - Division of Responsibility Matrix
  - Deliverables/Submittals
  - Technical Specification – Buyer Requirements
  - Communication and Control Integration Specification
  - Performance Requirements
  - Warranty
  - Owner Standards
  - Safety/Codes, Regulations and Standards
- Required Proposal Submittals: Project- Specific Elements
  - Pricing
  - Technical Specification – Bidder Offering
  - Drawings
  - Project Schedule
  - List of Project Clarifications, Assumptions, Exclusions, and Exceptions
  - Subcontracting Plan
  - Diverse Supplier Statement
  - List of Major Equipment Suppliers
- Required Proposal; Submittals: Company Qualifications
  - Statement of Knowledge, Experience and References
  - Safety Plan and Record
  - Financial Statement
  - Conflicts of Interest
  - Legal Claims
  - Business Ethics Statement
  - Non-Disclosure Agreement
- Requirement Proposal Submittals: Contracting
  - Contract Terms and Conditions
  - Bidder Exclusions and Exceptions

Details for each section of the RFP can be found in the ESIC RFP Guide. Due to the evolving nature of energy storage projects, special attention should be focused on the Scope of Work (SOW) section of an RFP, so the next section in this Implementation Guide provides important insights into the purpose and nature of the SOW.

Scope of Work

Understanding the full scope of work for an energy storage project is an important component of the utility RFP. In the SOW, the utility can determine and define the parties responsible for procuring and installing specific portion of the project, illustrating what a supplier or a third-party vendor would be accountable for. This SOW may include the energy storage product, balance of system, other physical components and services that are required for the complete integration of the project. The SOW needs to be as specific as possible, detailing the demarcation point for all wiring, including controls, power, and auxiliary power. Timing considerations need to be documented so that the project installation proceeds without interference between different parties working at the site. Additionally, there is increased focus on end of life recycling and repurposing and RFPs are often requesting information about these topics upfront.

The requested SOW may include both equipment and services associated with a fully integrated solution:

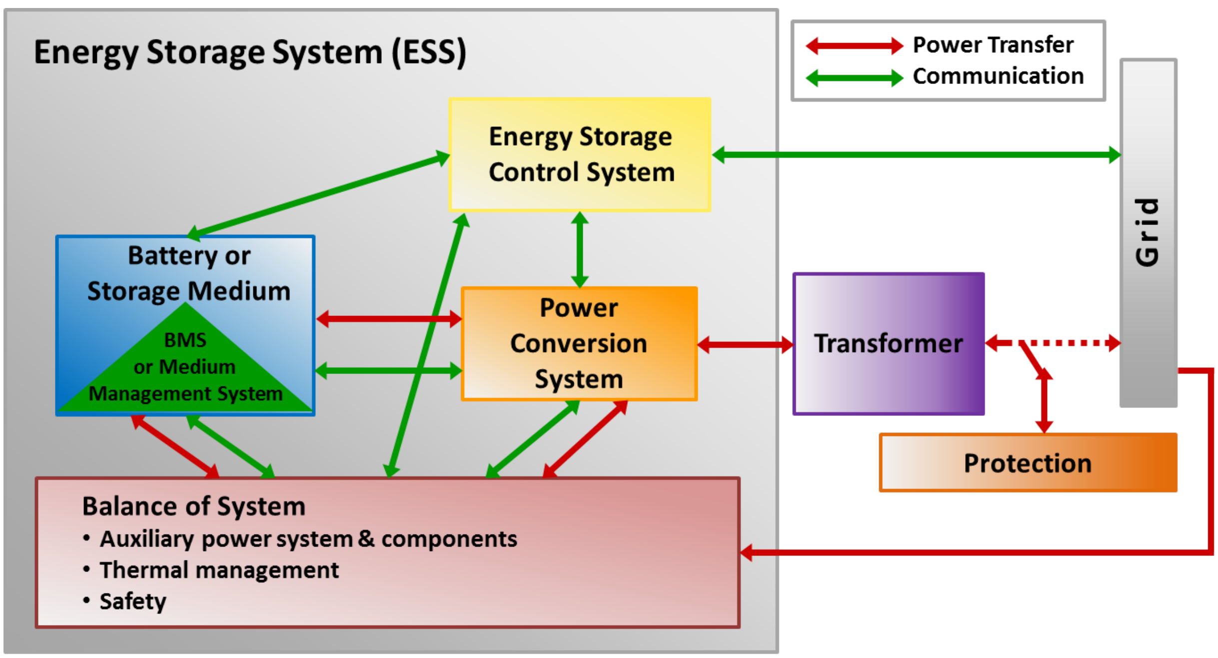

Figure 3-1
Interrelationships in planning an integrated storage solution

A Division of Responsibility (DOR) matrix can supplement the SOW and provide additional details and clearer distinction on the interactions among different groups within the project. This is especially important when multiple responsible parties are involved.

The template can be found in the ESIC Energy Storage Request for Proposal Guide [5], which aims to aid communication and clarify responsibilities during the RFP process.

Table 3-1
Example of a Division of Responsibility Matrix

Task Description	Design Criteria	Detailed Design	Purchase Specification	Procure or Supply	Installation	Testing/ Commissioning
ESS EQUIPMENT						
Battery (cells, trays, racks, containers, other)						
Battery (or storage medium) management system (BMS)						
Power conversion system (PCS, including inverter(s), controls, external communications)						
ESS control system (interfaces, controllers, communications, others)						
ESS mechanical and structural commodities						
ESS raceway, wire, commodities						
ESS shipping/transportation (note where transfer of ownership occurs, i.e. Inco Terms)						
ESS rigging and offloading						
ESS spare parts						
Balance of plant space parts						
PREPARATION/STRUCTURAL WORK (SITE/BUILDING)						
Foundation or building (new or modifications)						
Excavation and grading						
Site access road						
Fencing						
Finishing (gravel)						
Site Restoration						
MECHANICAL SYSTEMS WORK						
Heating, ventilating, and air conditioning						
Fire protection						
Safety systems (e.g., spill protection, other)						
Materials (Anchor bolts, steel structures, other commodities)						
Painting and coating (if required)						

Technical Specification – Buyer Requirements

The solution requirements determined during the planning stage should be translated into a set of technical specifications in the RFP, which can be either extremely detailed or very broad to suit the project's needs. The level of details desired from the technical specification is also affected by the utility's experience level with energy storage integration.

The ESIC Technical Specification Template [7] can facilitate the communication of technical information between the utility and potential bidders. The template can serve as a starting point to define a list of desired specifications from the suppliers for the following categories. Some generation considerations for energy storage projects are described in Table 3-2 below.

Table 3-2
General Considerations for Technical Specifications

Categories	General Considerations
Facility and ESS Performance	Setting minimum requirements and general target parameters for your project will ensure more effective responses to the project solution needs. Conversely, over-specifying performance requirements can overly restrict respondents from proposing innovative solutions. Striking a balance and clearly distinguishing "needs" versus "wants" is helpful for the supplier community to make viable offers.
Installation	The specifications should address project site size and other characteristics. Physical protection schemes and devices that will be integrated with the installation need to be considered, such as transportation, containment, physical security, and clearances. The structural characteristics of the site may require thorough analysis to understand the extent of site development needed to accommodate the storage system.
Interconnection	Interface requirements to connect either to a utility-specified transformer or to the voltage level at the chosen site. The interconnection protection scheme and devices that will be integrated with the installation need to be considered. The capacity or power quality related constraints should be considered.
Balance of System	Auxiliary load requirements for the energy storage technology should be stated, including pumps, heaters, chillers, fans, or controls. The power source, whether fed directly from the ESS, a dedicated power source, or a combination of the two, should be considered. These loads can affect overall facility efficiency, power output, and energy calculations
Controls and Communication	Communication, control, and cybersecurity requirements are increasingly important in the integrated grid. Refer to ESIC's *Common Functions for Smart Inverters, 4th Edition* [4] for current guidelines.
Mechanical and Environmental	Ambient conditions of the project site, weather-affected load conditions of the system, sound emissions of the system should be considered.
Safety	Safety measures required to meet project's needs should be illustrated clearly in this section, which could also include a list of applicable codes, standards and regulations (CSR), fire protection requirements, hazard protection requirements, and contractor safety requirements.
Operations and Maintenance	Startup and shutdown characteristics should be defined, to determine whether the ESS satisfies the criteria for intended use. Planned maintenance requirements should be taken into account, as well as estimates of the potential impact of unplanned maintenance.

Review of Energy Storage Proposals

Once the scope of work and technical specifications have been developed and an RFP issued, the utility can expect to receive proposals from potential suppliers. At this stage, due to the diversity of the energy storage asset class, the proposals may include a broad spectrum of potential technologies, configurations, and potentially even supplemental value streams in addition to the core solution being sought by the utility. This is in part a function of the range of solutions requested by the utility. It is, therefore, important for the utility to have methods and tools to compare and assess the diversity of different project options in order to arrive at a uniform "apples to apples" comparison of the proposals. Depending on the scope of the RFP and the grid needs under consideration, the utility may also need to consider conventional options or other DERs as potential solutions.

EPRI has developed a generic analytical methodology for assessing the costs and benefits of DERs, "The Integrated Grid Phase II: Development of a Benefit-Cost Framework" [6]. Through ESIC, this methodology is being further refined for distribution-connected energy storage. The near-term vision is to work with industry stakeholders to develop generic methodologies along with modeling tool and data requirements guidelines for electric utilities to assess a broad range of energy storage technology options on a consistent basis. Due to the specific considerations of individual utilities, it is anticipated that a utility would consider and adapt these guidelines to fit their specific situation and existing toolset.

Outside of the cost-benefit analysis of different proposals, there may be other business considerations for an electric utility to make decisions regarding procurement. These may include prior deployment experience, financial stability, and other risk management considerations.

Additional Project Technical and Economic Considerations

After the initial short-listing of top candidates or the final choice of a proposed energy storage project is made by the electric utility, there may be internal or external due diligence that occurs to help ensure that a project meets all requirements and is expected to be cost effective. This may include connecting with various internal stakeholders identified early in the planning process to ensure that all requirements are met by a specific offering. Any exceptions to the specifications by proposers should be carefully noted, examined, and clarified if needed prior to contracting of an energy storage project. The final purchase agreement should reflect all exceptions, if allowable, and have clear stage gates, performance metrics and contract terms to penalize non-conformance to schedules in order to ensure that the project schedule and budget is realized without delays or overruns.

Selection of the storage system vendor and identification of scope of work for both parties should, at this point, allow firm definition of the project budget. It is important to closely review internal labor costs at this point since significant effort will be needed from numerous parties in ensuring design and installation efforts. Numerous departments will potentially be engaged and affecting the budget, and all aspects of integration need to be assessed from a labor and equipment cost perspective. These departments could include metering, protection, distribution planning, IT/OT, communication and control, distribution operations, distribution engineering, network operations, environmental compliance, and regulatory compliance, as well as overall project management.

Procurement Resources

ESIC, as well as EPRI and the U.S. Department of Energy (DOE), provide a range of resources to assist in preparing for and conducting an energy storage procurement process. Table 3-3 highlights the key applications for each resource.

Table 3-3
Useful Resources for Energy Storage Procurement

Resource	Application in Procurement
ESIC Energy Storage Request for Proposal Guide [5]	Use elements of RFP Template to support creation of Scope of Work.
ESIC Technical Specification Template [7]	Buyers can communicate minimum or preferred technical and project requirements, and sellers can communicate proposed system specifications.
DOR Matrix (See Appendix B or ESIC Energy Storage Request for Proposal Guide [5]	Supplement SOW to clarify interactions and responsibilities between multiple parties with overlapping roles within a project.
The Integrated Grid Phase II: Development of a Benefit-Cost Framework [6]	Provides a methodology framework for benefit-cost analysis.
Common Functions for Smart Inverters, 4th Edition [4]	List inverter functional requirements based on use case.
ESIC Energy Storage Safety Guide 2017 [9]	Describe safety requirements in procurement (e.g. failure modes and effects analysis, codes and standards compliance).
DOE OE Energy Storage Systems Safety Roadmap: Focus on Codes and Standards [10]	Sandia National Laboratory and Pacific Northwest National Laboratory publish a monthly update of codes and standards changes and active development. In developing an RFP, it is important to understand the latest codes and standards to assess project requirements and potential cost and schedule implications of requiring certain codes and standards.
DOE/EPRI Electricity Storage Handbook in Collaboration with the National Rural Electric Cooperative Association [8]	Chapter 4 describes different ownership and procurement business models and Appendix C has a sample RFP.

4
DEPLOYMENT AND INTEGRATION OF ENERGY STORAGE

Introduction to Deployment and Integration

The Deployment and Integration phase of an energy storage project occurs after the procurement contracting of energy storage has taken place and work begins toward the integration of the project. This phase ends when a project has been installed and commissioned, with the subsequent hand off to operations.

Picking up from the Procurement phase, it is assumed at this point that the scope of work has been defined for the parties developing the energy storage project. However, prior experience has shown this is not always the case. Sometimes the complete scope of energy storage project deployment and integration is not fully considered in advance; in other cases, some steps of the process have been underestimated. Incomplete specifications have resulted in project delays because of a lack of up front involvement with all the utility groups with a stake in the energy storage system and its integration with the power system.

The subsections of this section will review identified steps associated with the deployment and integration of energy storage projects:

- Site and System Engineering
- Permitting and Applicable Codes and Standards
- Site Preparation and Construction
- Factory Acceptance Testing
- Product Shipping and Receiving
- Product Installation, Connection, and Integration
- Project Commissioning and Site Acceptance Testing

Engineering

The contract executed during procurement should have included the utility and industry design standards and codes the facility must meet. These along with the other technical specifications will be used as the basis of design during the engineering process. In this subsection, engineering is separated into site engineering and system engineering. For both engineering categories, detailed plans for the project may be reviewed by multiple stakeholders, including outside permitting agencies and utility teams responsible for protection engineering, distribution planning, standards engineering, SCADA engineering, Environmental Health & Safety (EH&S), and information technology (IT). Design reviews throughout the engineering process ensure the supplier and utility are aligned, helping to avoid delays associated with design changes.

Site Engineering

Before project site construction can begin, the energy storage project site must be engineered and specified for accommodating the procured energy storage product. Considerations for site engineering include, but are not limited to:

- Equipment access during construction and project operations (e.g. cranes, maintenance trucks)
- Operational and maintenance access
- Work clearances and ergonomic considerations
- Fire barriers
- Noise barriers
- Containment
- Egress
- Flood zones
- Seismic zones
- Physical security and access (e.g. fencing, key/card reader access, security cameras)
- Control building or enclosure
- Building design vs. containerized system
- Equipment foundations
- Build out for future capacity

System Engineering

Aside from the physical site engineering, the electrical and communication interface between the energy storage system and the utility system needs to be considered and addressed. System engineering considerations include, but are not limited to:

- Transformers – Configuration of any step-up or isolation transformers to match the voltage level at the point of connection and the wiring configuration (e.g. wye, delta) of the grid.
- Grounding requirements – ESS equipment grounding recommendations from the manufactures may differ from utility standards. Grounding design may also impact the transformer configuration.
- Protective devices – In general, there are a number of protection issues to consider for energy storage and DER. Protection issues primarily concern issues of safety and reliability of the distribution system under fault conditions, but they also may concern the protection of the ESS itself. Protection includes the functionality of the PCS (e.g. response to abnormal voltage and frequency), as well as the configuration and settings of utility system protection (e.g. circuit breaker, fuse, relay, recloser, etc.) and potential impacts to utility protections schemes. The protection considerations will be different depending on the specific use cases intended for a given ESS installation. For example, in some cases, the utility may want the ESS to shut down in the presence of abnormal conditions, which may be easily accomplished with the storage PCS functionality, recloser, or an external breaker. In other cases, the ESS may be expected to support the electric power system in the presence of some abnormal

conditions and not others, which can add more value to the ESS asset, but may also complicate implementation.

- Power feed for auxiliary loads – these circuits should consider the effects of upstream protection gear and be designed such that any circuit isolation associated with the storage system does not kill power to the auxiliary systems.
- Metering and monitoring requirements – This may include requirements from the utility, ISO (if applicable), and equipment manufacturers.
- Communication and control – This is a critical component of a successfully operating facility and, therefore, it is important to have well defined specifications and division of responsibility in early phases. There are typically two different levels of communication and control: one within the ESS envelope and the other between the ESS and utility interface. Since storage is not as widely deployed as other generation or distribution assets, there may be significant work in integrating into the utility infrastructure such as programming new interface screens and navigating through network and security requirements. Previous projects have shown that integrating storage systems into legacy SCADA systems presents specific challenges that require thorough investigation. It is also important to include provisions for vendors to access their equipment and data log files for diagnostics and troubleshooting. This can be challenging due to cybersecurity requirements, and therefore project planners should involve internal stakeholders related to cybersecurity early in the project planning process
- ESS design – The ESS may be a packaged system with the vendor providing an integrated product up to the AC output of the PCS, or the system may be designed by the supplier using components from several different manufacturers. If the latter, there will be additional engineering required to ensure all the devices are properly interfaced, and coordination and design reviews with all parties will be critical during the engineering phase.

Permitting and Applicable Codes and Standards

In parallel to detailed site engineering and drawings by internal utility stakeholders, the utility may need to engage local authorities having jurisdiction (AHJ) for any required permits to construct and operate the energy storage project. Some permitting actions may need to start with incomplete engineering documents, due to the long potential timeframe a permitting action can require. These AHJ may include the local zoning, local fire marshal, and other local planning authorities (county or municipal). In other cases, the utility itself may be the primary or sole AHJ for the project. Even if self-permitting, it is good to engage with the local emergency responders so they are informed of the project and know how to respond.

Because of a large number of gaps in standards for energy storage with respect to codes, standards, and regulations (CSR), there may be a need to provide training and discuss concerns and requirements for safety, nuisance, or environmental issues one at a time with the relevant AHJ, much earlier in the process, during project initiation and throughout the planning phase. Safety issues, as they pertain to the permitting process, are being considered within ESIC and through the Department of Energy (DOE) and Sandia National Laboratories, which are taking a leadership role to define gaps and action plans for safety of energy storage systems [10]. Awareness of these new energy storage codes and standards and their adoption by local AHJs may become critical for mitigating risk of permitting schedule and costs.

Site Preparation and Construction

When the site engineering and permitting process is completed, site preparation may begin. This work is often performed by a local construction firm, which may or may not be part of a general contractor (GC) or engineering, procurement, and construction (EPC) firm that was involved in the design and permitting stages. The site preparation and construction safety hazards and other concerns are likely related to location or environmental conditions.

Factory Acceptance Testing

While the previous steps of site preparation and utility side considerations are under way, the equipment vendor(s) are manufacturing and preparing the ESS product. It is likely that the vendor will also be closely engaged with those previous steps to support the utility with the ESS-specific questions of the internal and external stakeholders.

When the energy storage product manufacturing process is complete, it is a common practice for the utility or a third party to witness a factory acceptance test (FAT) at the vendor's manufacturing facility prior to shipment. The FAT is typically a set of quality control-related tests to help ensure that the components of the energy storage system have been built to specification prior to its leaving the factory. A FAT may be a semi-standardized process, but it likely will be augmented for specific considerations of a manufacturer, product, utility, and project. It is also likely that separate manufacturers will be building the components and that a FAT of the assembled system is impractical. This is primarily used as a risk management stage gate for the project. It may be important to utilize the FAT to ensure proper communication integration amongst various suppliers' control systems if separate vendor control systems are being integrated at the site.

Within ESIC, the discussion and development of considerations for a FAT protocol is taking place in the Testing and Characterization Working Group (WG2), which can review test procedures it is developing to identify a subset of test procedures that may be appropriate for a FAT. FAT protocols have been developed and published by EPRI and other organizations for specific energy storage projects.

Product Shipping and Receiving

After the energy storage system is approved for shipment, it is transported to the utility site. There are a number of considerations in this process, including loading and unloading equipment and practices, modes of transportation, weight, dimension limits for containers, and existence of regulations associated with shipping energy storage (including hazardous materials as applicable by technology). Clear terms for equipment delivery and logistics are important considerations since they can have cost implications. Occasionally, the equipment delivery might not coincide with the exact start of equipment installation and temporary storage fees may need to be incurred. Responsibility should be assigned for costs such as warehouse storage fees, materials handling equipment rental fees, storage container rental fees, and labor fees. Also, the chain of custody of the equipment needs to be carefully considered in order to make sure that the responsibility and insurance aspects are covered.

For loading and unloading, as generally for shipping, it is important to consider any weight or dimension limits for any employed mode of transportation, as well as the availability of cranes or forklifts as needed at the project site. Additionally, the project site must be able to accommodate any required lifting equipment and delivery vehicle ingress and egress.

Regulations for safety of items being shipped are managed by several authorities, including the U.S. Department of Transportation (USDOT) for shipments by road, potentially Homeland Security and International Maritime Dangerous Goods (IMDG) for shipments by sea, and International Air Transport Association (IATA) for shipments by air.

For hazardous materials, a set of tests has been developed through the United Nations; for example, these tests are a consideration for regulating shipment of lithium-based batteries [11]. Similar tests may be applicable for other energy storage technologies that are energized during transport.

Provisions for temporary storage also need to be factored in if equipment deliveries are not perfectly sequenced with subsequent installation tasks.

ESS Product Installation and System Integration

ESS product installation and system integration can be performed by a local electrical contractor, which, like the site preparation and construction, may be part of a larger GC or EPC organization. The electrical contractors should be experienced in both high and low voltage systems and familiar with the local electric utility's system, but they may be unfamiliar with energy storage technology. As a result, sufficient training and documentation is important to ensure that the contractor knows about safety hazards and procedures unique to energy storage systems. The previously mentioned CSR publications and vendor specific operation manuals are good resources to familiarize the contractors.

ESS product installation processes may vary widely depending on the size, configuration, and technology used. Most likely, many components will be shipped separately, resulting in extensive on site assembly by the manufacturer. Alternatively, a smaller, pre-engineered, modular product could be fully or almost fully assembled and ready to be wired.

Project Commissioning

After the installation and connection of an energy storage system to the distribution system, a commissioning phase is required to ensure successful integration. Commissioning is defined as, "A process that assures that a component, subsystem, or system will meet the intent of the designer and the user." [12] These tests are intended to address the following list of typical concerns:

1. Was the system installed correctly and remains within specification?
2. Is the utility switchgear and protection equipment operating as designed?
3. Are the communication and control systems fully operational?
4. Are all safety systems properly installed and operational?

In defining the commissioning effort, it is important to identify the personnel involved and the timing of their involvement. Typical commissioning efforts involve numerous entities and many personnel and the unavailability of key personnel can derail the commissioning time schedule.

ESIC has published commissioning guidelines that detail commissioning during the deployment and integration phase. Additionally, the Commissioning Guide [13] addresses commissioning considerations throughout the project life cycle, such schedule, cost, and responsibility.

Site Acceptance Testing

In addition to ensuring the proper integration of the energy storage system into the utility system through commissioning, performance and functional tests may be required to verify the system operates as specified. Any tests required for acceptance and associated penalties for non-compliance should be established during the procurement phase so the buyer and seller's expectations are aligned. This includes defining how the tests will be performed. ESIC Testing and Characterization Working Group (WG2) has developed a Test Manual [3] with a full outline of potential functional and performance tests that a utility may request to perform and a comprehensive set of detailed test protocols that include measurement and calculation methodology, testing duty cycles, and templates for data collection [3]. This manual is being continuously updated thru ESIC with new test protocols being added.

Deployment and Integration Resources

Table 4-1
Useful resources for energy storage deployment and integration

Resource	Application in Deployment and Integration
ESIC Technical Specification Template	Information collected during procurement can be used to support site engineering, interconnection and protection studies, and the permitting process.
ESIC Energy Storage Test Manual	Follow test protocols during commissioning or acceptance testing to verify system performance and functionality.
ESIC Energy Storage Safety Guide	Understand safety considerations during this project phase.
ESIC Energy Storage Commissioning Guide	List of tests and design and construction verification activities; links to examples of commissioning procedures.

5
PROJECT OPERATIONS AND MAINTENANCE

Introduction to Operations and Maintenance

The Operations and Maintenance phase of an energy storage project begins when the system has been commissioned and approved for use in the operations of the electric utility. This phase continues until the end of the project's operational life, which could be 10 to 20 years after installation or even longer. This should be the longest phase of an energy storage project implementation, and many of the planning assumptions for the project may evolve over time. Depending on a number factors, grid needs may change and availability of new solutions – technology options or novel approaches – may arise.

As a result, in the early phases of project development, it is important to consider both current and future needs, while assessing and communicating the inherent strengths and limitations of energy storage technology.

Additionally, the maintenance – both planned and unplanned – of an energy storage system is another ongoing consideration. It is also important to consider the relationship between the operations of the energy storage system, which are expected to evolve over time, and maintenance requirements, as well as the impact that specific use-cases could have on the life of the storage system.

The following steps are associated with project operations and maintenance:

- Handoff to Distribution/System Operations
- ESS Maintenance
- Environmental and Safety Reporting
- Update Operational Needs (as required)
- Recommissioning (as required)

Handoff to Distribution/System Operations

At the start of the ESS project's operations, it is important that the distribution system and distributed energy resource operators (and other parties with control of storage system) are well informed and trained regarding the storage system operational software, intended use of the project, the protection systems and schemes employed, and the planned operational profile of the storage system. This coordination should be planned and tested early in the project formulation. Operators should understand the differences between energy storage and conventional utility assets. For instance, energy storage is limited by timing interdependencies, that is, before energy can be dispatched from storage, a corresponding quantity of energy must have been stored.

The details of the coordination will vary depending on the existing utility communications and control infrastructure (e.g. whether or not a Distributed Energy Resources Management System or DERMS is being used) and on the size and level of aggregation of the energy storage deployment.

Maintenance

Maintenance of any asset comes in two forms: planned and unplanned. Planned maintenance may be scheduled relative to time, level of usage, and other factors, similar to how a car is cared for (e.g. oil change every 3 months or 3,000 miles). Depending on the configuration and technology employed in an energy storage project, regular diagnostic checks may be able to identify issues with degradation of the ESS and enable a technician to strategically replace components, rather than replacing an entire system. Provisioning of spare parts that require more frequent replacement (e.g. air filters) should be considered as part of the initial product delivery. The spare part inventory, replenishment plans, and storage location(s) need to be actively managed.

Due to the relative lack of industry operational experience with integrated energy storage devices, the maintenance requirements are not fully understood. From the perspective of the utility, this uncertainty may be mitigated by warranties or service contracts with the supplier or a third party. Many storage technologies are advanced and complicated, so it is likely that domain experts will need to be available to service those pieces of equipment. The utility will likely need to consider the availability of technicians for servicing the ESS throughout the life of the project.

Unplanned maintenance is typically costlier, because it may require unanticipated service calls or prolonged loss of service. Additionally, if unplanned maintenance events occur when the storage system is expected to perform a service and is unavailable, this could result in power system reliability issues and/or financial penalties to the entity responsible for successful energy storage operation. Unplanned maintenance is a consideration for design of warranties and service contracts. Many instances of unplanned maintenance should be avoidable through planned maintenance and diagnostics on system state of health. The responsibility and methodology for determining system state of health should be established during the procurement process. This includes identifying what data points will be needed, how the data will be collected and transmitted, who will monitor the status of data, and what triggers maintenance or further investigation.

If maintenance includes any replacement of major system components, such as battery cells or PCS, the system should be recommissioned to verify proper operation.

Environmental and Safety Reporting

Depending on the type and size of the storage system used there may be an ongoing requirement to report chemical content, operational status, and other parameters to AHJs. These requirements should be clearly identified in the original permitting process, and steps should be taken that so ongoing responsibilities are institutionalized to ensure that change of personnel does not result in missed reports and subsequent fines. In particular, refer to the EPA's Emergency Planning and Community Right-to-Know Act (EPCRA) requirements [14].

Update Operational Needs

Because energy storage operational approaches are likely to evolve, it is important to have a flexible view of how the system will be used, with consideration given to how it may support other portions of the electric grid beyond the distribution system where it is connected. This implies that the capability to have firmware updates and extend interoperability with additional control systems may be helpful to maximize the value of the energy storage over its operational life. It should be noted, however, that firmware updates may well trigger retesting of the system protection and integration features and associated conformance to any interconnection agreements.

Modeling and simulation efforts may help provide an understanding of a system's future demand and current operating needs for energy storage projects. Production simulations are increasingly performed with a 5- to 10-year look-ahead for the bulk electricity system for the purpose of generation resource adequacy planning and to understand the impacts of higher penetrations of renewables. Power flow models used on the distribution system are also used to better predict grid needs and improve operational approaches with existing assets. Efforts are currently under way to advance the state of the art for energy storage operational modeling. The methodologies and associated modeling tool requirements are being considered by the ESIC Grid Services and Analysis Working Group (WG1).

Changes in operation outside of the warranty provision or agreed upon use-case may need to be discussed with the vendor or supplier. Additionally, depending on the performance and functional testing during commissioning, the changes may require the system be recommissioned for its new intended purpose.

Recommissioning

Similar to commissioning, recommissioning is performed to confirm the system is behaving as intended, but recommissioning is typically triggered by a major change in the system, such as a change in operational need or the replacement of major components, as discussed earlier in this section. The ESIC Energy Storage Commissioning Guide [13] may be used to as a reference for test and procedures for recommissioning; however, the scope may be more limited than the initial commissioning if only a portion of the system changed.

Next Steps

As previously mentioned, guidelines for operational best practices for energy storage are still being developed because commercial deployment and publicly available experiences are still in the early stages. Through continued demonstrations and commercial deployments, guidelines may be tested and further augmented with real world data.

Operations and Maintenance Resources

Table 5-1
Useful resources for energy storage operations and maintenance

Resource	Application in Operations and Maintenance
ESIC Energy Storage Test Manual [3]	Use test protocol for extended performance testing or recommissioning
StorageVET [2]	Understand cost-benefit and dispatch impacts due to changes such as load forecast, grid services, market pricing. It may also help in identifying when to schedule O&M to reduce potential impact revenue impact.

6
DECOMMISSIONING AND END OF LIFE

Introduction

The final phase of energy storage project implementation is Decommissioning and End of Life. This phase occurs at the end of the Operations and Maintenance phase when the project is no longer viable, either due to a predetermined project end date, safety or reliability issues, or because the marginal costs of continued operation exceed marginal benefits.

The Decommissioning phase could be overlooked early in the project because it is expected to occur many years in the future. However, having a decommissioning at the beginning of the planning process can help to ensure that a project's end of life is a smooth process. Some considerations include:

- Decommissioning issues during prior project phases
- Definition of end of life
- Alternatives for end of life

Decommissioning Issues during Prior Project Phases

It is important to consider decommissioning at the front end of the project. Below are some specific considerations as a starting point, which can be further augmented through discussion in the Grid Integration Working Group (WG3):

- **Planning** – The costs of decommissioning, as well as expected salvage value, should be considered in the cost-benefit analysis for a project. For a project with a long life and relatively small decommissioning cost, decommissioning may be immaterial to the upfront planning decisions. However, uncertain costs and reliability could result in an unexpectedly high decommissioning cost and a liability for the utility.
- **Procurement** – Safe and environmentally compliant decommissioning should be considered part of the "scope of supply" for the vendor, utility, or a third party. Additionally, the energy storage system could be either an asset or liability at end of life, depending on the costs of disposing of certain components and the value of recycling, refurbishment, or reuse of other components.
- **Deployment and Integration** – During the deployment and integration phase, consideration of the decommissioning process may inform better site engineering and development decisions that could support improved site flexibility to increase salvage value or decrease cost of decommissioning. Additionally, the decommissioning plan could be relevant for environmental compliance and permitting.
- **Operations and Maintenance** – Similar to operating and maintaining a car, the choices made for operating and maintaining an energy storage system will impact the timing of end-of-life conditions, as well as the costs associated for the project. Operators should be aware of the costs and benefits of different choices and be informed of the likely costs or benefits

associated with decommissioning the project. Front end permitting may dictate actions on decommissioning that need to be memorialized to ensure compliance.

End of Life Conditions

At the beginning of a project, an end-of-life condition should be defined for energy storage projects to ensure the safety, reliability, and cost effectiveness of the project. For energy storage technologies, especially batteries, these conditions may be defined by a threshold for energy storage capacity (kWh) as a percentage of nameplate or a roundtrip efficiency threshold. However, in practice, the end-of-life conditions may be defined by a major maintenance event that operators determine is not worth the cost of repair (like a new transmission for an old car) or if there is a perceived safety risk. Close communication between the energy storage supplier and the utility may help to support decision making around this topic. Another option to decommissioning could include re-specifying the project to perform less demanding tasks that are less taxing on the plant and may extend its life with lower maintenance costs

Decommissioning Plan

When the decision to decommission an energy storage system is made, a well-defined decommissioning plan can help ensure a safe, efficient process. The Commissioning Guidelines, Section 6 outlines the key steps and considerations in a successful decommissioning plan [13]. Additionally, EPRI has published a report on battery disposal and recycling details some considerations for handling battery-based systems during decommissioning [15].

Decommissioning Resources

Table 6-1
Useful resources for energy storage decommissioning

Resource	Application in Decommissioning
ESIC Energy Storage Commissioning Guide [13]	Understand key components of a decommissioning plan.
Electric Utility Battery Disposal and Recycling [15]	Reference for disposal and recycling of lithium ion battery systems.

7
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A
ACRONYMS AND ABBREVIATIONS

AHJ	authorities having jurisdiction
CAISO	California Independent System Operator
CEC	California Energy Commission
CONE	cost of new entry
CPUC	California Public Utilities Commission
CSR	codes, standards, and regulations
DER	distributed energy resource
DERMS	distributed energy resources management system
DOE	U.S. Department of Energy
EH&S	Environmental Health & Safety
EMS	emergency management system
EPC	engineering, procurement, and construction
EPRI	Electric Power Research Institute
ESIC	Energy Storage Integration Council
ESS	energy storage systems
FAT	factory acceptance test
IATA	International Air Transport Association
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMDG	International Maritime Dangerous Goods
IT	information technology
MSDS	Materials Safety Data Sheet
NAATBatt	National Alliance for Advanced Transportation Batteries
NEC	National Electrical Code
NERC	North American Electric Reliability Corporation

NIST	National Institute of Standards and Technology
NISTIR	National Institute of Standards and Technology Interagency Report
NMV	net market value
NRECA	National Rural Electric Cooperative Association
NREL	National Renewable Energy Laboratory
PCS	power conditioning system
PNNL	Pacific Northwest National Laboratory
PV	photovoltaic
RFI	request for information
RFO	request for offers
RFP	request for proposal
RFQ	request for quote
SCADA	supervisory control and data acquisition
SOW	scope of work
T&D	transmission and distribution
TCOES	total cost of ownership for energy storage
USDOT	U.S. Department of Transportation
WECC	Western Electricity Coordinating Council
WG1	ESIC Working Group 1 – Grid Services and Analysis
WG2	ESIC Working Group 2 – Testing and Characterization
WG3	ESIC Working Group 3 – Grid Integration

B
BIBLIOGRAPHY FOR ENERGY STORAGE IMPLEMENTATION

ESIC Product Guide

The table below provides an overview of ESIC work products linked to specific functional objectives by stakeholder through the process of energy storage project implementation. Working drafts of ESIC publications are available through the ESIC collaboration website; access may be obtained through the ESIC website.

Table B-1
ESIC Product Guide

Phase	Tool	Stakeholder	Objective	How to use
Planning	Technical Specification Template	Distribution Planning Engineer, Standards Engineer, SCADA Engineer, Operators, Protection Engineer	Understand technical performance characteristics that could feed into simulation tools	Include template in an RFI to suppliers
	Safety Guidelines	EH&S Engineer	Think through safety issues that could occur within project life from an early on project stage; Define minimum safety or environmental requirements	Read guidelines and communicate requirements and/or considerations for project management team
	StorageVET	Distribution Planning Engineer	Screen for cost-effectiveness and compare alternatives to see which can meet the technical requirements and anticipated project economics	Run simulations using information from RFI or based on minimum technical requirements Identify Secondary Services
	Common Functions for Smart Inverters – 4th Edition	Distribution Planning Engineer, Standards Engineer, SCADA Engineer, Operators, Storage Supplier, Utility Project Manager	Describe smart inverter functionality found across the industry in an easy-to-read format. A common understanding across the industry is important for successful interoperability.	Read for a common understanding of how smart inverter functionality is implemented in the industry.

Phase	Tool	Stakeholder	Objective	How to use
	Cost Tool	Utility Project Manager, Distribution Planning Engineer	Understand all cost components that should be considered in a cost-benefit analysis	Include tool in request for budgetary quote Use as a checklist to ensure total scope of work is accounted for
	Commissioning Guide	Utility Project Manager	Understand which aspects of commissioning should be considered during this phase	Read and use as a checklist for commissioning tasks; engage other departments as necessary
Procurement	Technical Specification Template	Distribution Planning Engineer, Standards Engineer, SCADA Engineer, Protection Engineer, Operators, Storage Supplier	Clear communication of utility requirements and understanding what suppliers are offering	Utility – Develop the technical requirements and issue as part of RFP; Review and confirm proposal meets utility standards and operational guidelines Supplier – Respond with requested information
	Test Manual	Utility Project Manager, Field Engineer, Protection Engineer, Storage Supplier	Clear communication of how utilities will test and ensure adherence to contractual performance requirements	Utility – Identify which tests procedures will be used for acceptance testing Supplier – Review and understand test procedures and how certain specifications will be verified
	Cost Tool	Utility Procurement team, Storage Supplier	Clear communication of costs and understanding what suppliers are offering	Utility – Clarify required scope/cost inclusion, exclusions Supplier – Specify costs for required scope

Phase	Tool	Stakeholder	Objective	How to use
	StorageVET	Distribution Planning Engineer	Comparison of cost-benefit between proposals	Run simulations using information from RFP
	Safety Guidelines	EH&S Engineer, Storage Supplier	Define EH&S requirements or specifications to include in RFP; Understand how to evaluate and compare proposals from an EH&S perspective	Utility - Include lists of standards in RFP (Table 4-1, 4-2) Supplier– Review to understand utility expectations for FEMA and SSA
	Commissioning Guide	Utility Project Manager	Understand which aspects of commissioning should be considered during this phase	Use as a checklist for commissioning tasks; engage other departments as necessary
Deployment and Integration	Test Manual	Distribution Engineer, Storage Supplier	Execute performance, functional and other acceptance tests	Use detailed prescriptive procedures
	Safety Guidelines	EH&S Engineer, Storage Supplier	Incorporate safety into design, installation and commissioning	Review standards in Table 4-3, 4-4 and other considerations highlighted in Section 3.3
	Commissioning Guide	Utility Project Manager	Well executed commissioning plan and procedures	Use as a checklist for commissioning tasks
Operations and Maintenance	StorageVET	Distribution Engineer	Support decisions to operate and maintain system to maximize performance, revenue and system life	Run simulations to understand: • Impacts to system life based on operational changes • When to schedule maintenance based on system commitments and potential revenue losses

Phase	Tool	Stakeholder	Objective	How to use
	Test Manual	Field Engineer, Storage Supplier	Re-execute tests to confirm compliance to performance or warranty term or to verify performance after major maintenance or equipment replacement	Use detailed prescriptive procedures
	Safety Guidelines	Transmission or Distribution Engineer	Understand safety related to operating and maintaining system	Review standards in Table 4-3 and other considerations highlighted in Section 3.4
Decommissioning and End of Life	Commissioning Guide	Utility Project Manager, Distribution Engineer, EH&S Engineer	Understand the decommissioning process and create a decommissioning plan	Use decommissioning plan steps section as an outline/checklist in development of a detailed plan. Review other considerations for decommissioning.

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C
ADDITIONAL RESOURCES

The following is a list of other publicly available documents that may guide projects through the implementation process. ESIC compiled the list based on gathered user input and has not fully vetted the documents below. The intent is to share provide available resources to support project planners and engineers during implementation of future energy storage projects.

"Recommended Practice: Safety, operation and performance of grid-connected energy storage systems." DNV-GL. DNVGL-RP-0043. December 2015

"Property Loss Prevention Data Sheets." FM Global. FMDS0533. January 2017

"Use case methodology - Part 2: Definition of the templates for use cases, actor list and requirements list" International Electrotechnical Commission. IEC 62559-2. April 2017

"Energy Storage System Safety: Plan Review and Inspection Checklist." Pacific Northwest National Laboratory and Sandia National Laboratories. PNNL-SA-124486 / SAND2017-3066 R. March 2017

"A Good Practice Guide on Electrical Energy Storage" EA Technology. December 2014

"Qualifying Capacity and Effective Flexible Capacity Calculation Methodologies for Energy Storage and Supply-Side Demand Response Resources" Resource Adequacy Proceeding R.11-10-023 California Public Utilities Commission. September 2013

"Joint Workshop Report and Framework Multiple-Use Applications for Energy Storage" CPUC Rulemaking 15-03-011 and CAISO ESDER 2 Stakeholder Initiative. California Energy Commission. May 2017

"Energy Storage Handbook." K&L Gates. October 2017

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