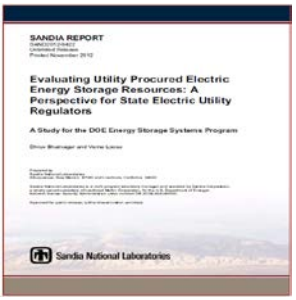
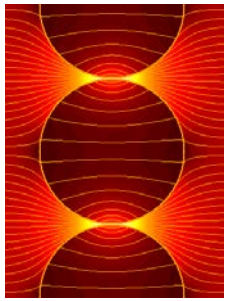




2015 U.S DOE OE Peer Review

DOE/EPRI Electricity Storage Handbook (ESHB)

in Collaboration with NRECA

Updates

Jacquelynne Hernández

Portland, Oregon (USA)

September 2015

Sandia National Laboratories

Exceptional service in the national interest

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

SAND Number: SAND2015-7774 C

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

ESHB Update -

Project Background Info

How does this project fit into the SNL Energy Storage Demonstrations?

Clean Energy States Alliance CESA

- Alaska
- California
- Connecticut
- Hawai'i
- Massachusetts
- New Hampshire
- New Mexico
- New York
- Oregon
- Pennsylvania
- Vermont

Testing and Analysis

- Cells
- Modules
- Systems
- DoD Microgrid/FOB

Optimization & Commissioning

- Safety & Standardization
- Metrics/ Standardization
- Performance Protocols

Industry Collaboration

- Enervault
- Helix
- Duke Energy
- EMA/ Singapore Power
- DOE/EPRI Electricity Storage Handbook
- Bermuda Electric/Light

ESHB - Project Rationale

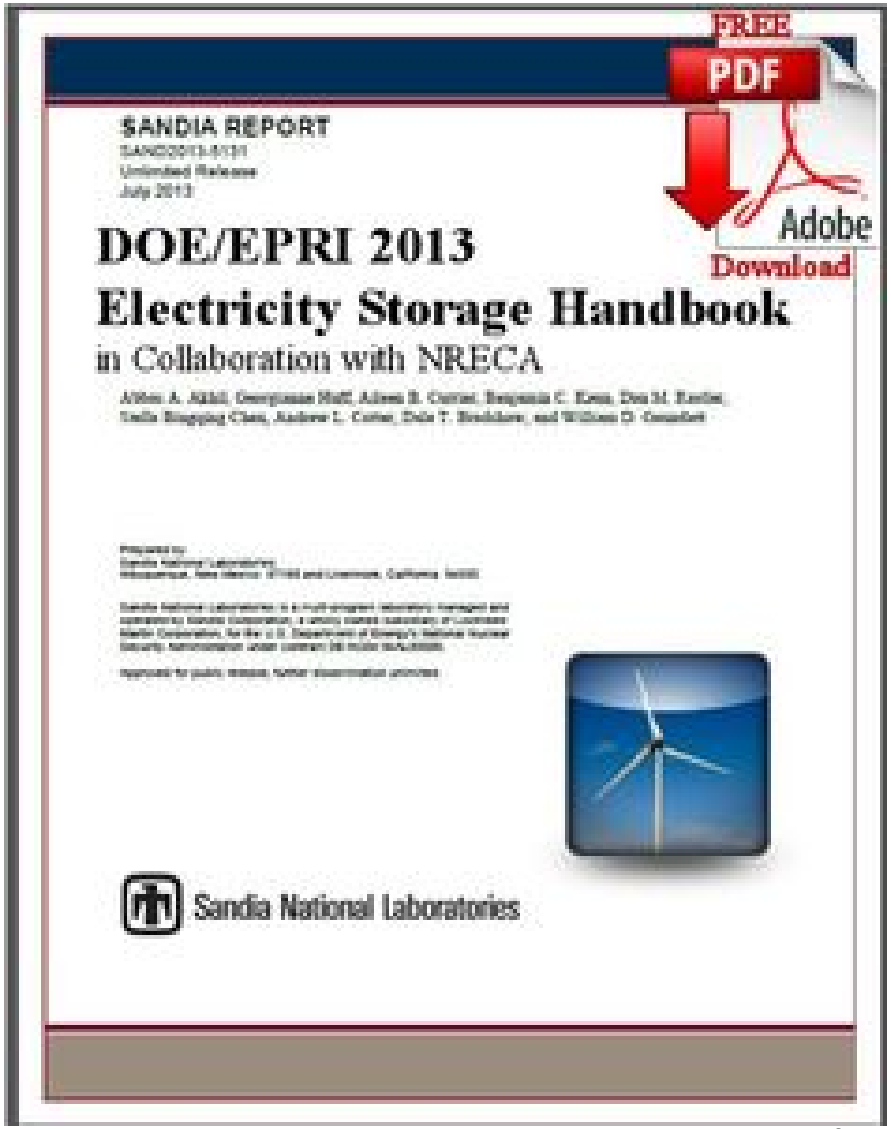
- Why are we doing it?
  - Specific and Existing problem
  - What is the problem that the project is working to solve?
  - What will this research bring to Stationary Energy Storage?
- Why is it important?

ESHB Update -
Project Overview

DOE/EPRI Electricity Storage Handbook

- resource for making decisions
- emerging technologies and applications
- electrical energy storage stakeholders

- Evolution of the Handbook
- Genesis in 2003
- Collaborative effort in 2013



ESHB Update Background

We are using the proper framework to deliver to industry a much needed tool with the ESHB. We provide basic information to help the user develop perspective, understand the type questions to ask, and to be confident in the answers provided.

Definition: A framework is a model. It is a hypothetical description of a complex entity or process. The description includes the underlying structure for a group of components or elements that work interactively to support an issue or concept such that one responding to questions or problems delivers consistent output, answers, or potential solutions.

ESHB Update - Project Rationale

Why are we doing it?

- Updates 2013 iteration handbook
- Fills an industry-wide need
- Establishes single-point resource
- Describes the services and applications of energy storage
  - in/on the grid
  - the current storage technologies
  - commercial status
  - system costs
  - performance metrics

ESHB Update Project Rationale

Why is it important?

The Handbook is jointly sponsored by the U.S. Department of Energy that capitalizes on a partnership with the Electric Power Research Institute in collaboration with the National Rural Electric Cooperative Association.

Fills an industry-wide need for a single-point resource to describe the services and applications of energy storage in the grid, the current storage technologies and their commercial status, system costs, and performance metrics.

ESHB Update Project Basic

JUST THE FACTS:

- The Handbook is organized into four chapters and appendices. Roadmaps are provided at the end of this section to aid in navigation of the Handbook

Chapter 1: Electricity Storage Services and Benefits

- Reviews 14 services and functional uses, including electricity storage services to the grid, ancillary services, grid system services and functional uses, end user/utility customer functional services and renewables integration that electricity storage provides to the grid as a generation, transmission and distribution (T&D), and customer-side resource.
- Brief review of simultaneous use of electricity storage for multiple applications (stacked).

Chapter 2: Electricity Storage Technologies: Cost, Performance, Maturity

- principles of operation for pumped hydro and Compressed Air Energy Storage (CAES) and the electrochemistry for a family of currently available battery technologies.
- Technology sections include capital and levelized cost of energy (LCOE) charts based on the responses of a first-of-a-kind, comprehensive survey of more than 40 vendors.

Chapter 3: Methods/Tools for Evaluating Electricity Storage

- Screening-level and advanced production cost, electric stability, and financial tools that can be used to evaluate the impact of electricity storage in the grid.
- An appendix to this chapter provides a summary of specific evaluation tools currently available.

Chapter 4: Storage Systems Procurement and Installation

- An overview of procurement options based on approaches used both in the past and for current projects.
- Sections in this chapter address purchasing options, safety, interconnection and communication, warranty, and disposal issues. Further details on noteworthy past and present storage projects and a worldwide storage project database initiated by the DOE are presented in a related appendix.

References and Appendices

- A glossary of select terms and an extensive reference database of reports published by DOE, EPRI, NRECA, and industry sources are among the supporting appendices provided at the end of the Handbook. References for material in the text are provided in footnotes

Current Status

E-mail from G. Huff/ August 12, 2015

In the last two years, we made a few minor updates to the handbook. Among those revisions include:

- subchapter highlighting tools available to use to evaluate a storage solution from a modeling and simulation standpoint,
- additional information regarding ES models and tools in Appendix A,
- clarifications and expansions of three energy and power cost components,
- expanded derivation of the Total Plant Cost (TPC) and referenced costs that are components of the TPC,
- additional explanation of equipment costs.
- webpage for input http://www.sandia.gov/ess/handbook.php

As we are gearing up to make some major modifications/ updates to the handbook, I would like to ask for you to lend us your expertise in providing guidance.

ESHB Update - Improvements

Ready Reference Resource Guide (3RG)

Overview Summary of Existing Document

ESHB Update - Improvements

Energy Storage Handbook

ESHB 3RG

Table of Contents

Topic	Core Discipline	3RG Page(s)	ESHB Full
Introduction		3	
ESHB Chapter 1 Summary	Storage Services & Benefits	4-5	1-28
ESHB Chapter 2 Summary	Storage Technologies	6-7	29-111
ESHB Chapter 3 Summary	Methods and Tools for Evaluating	8-9	112-123
ESHB Chapter 4 Summary	Storage Systems Procurement & Installation	10-11	124-144
ESHB Appendices Summary		12-13	
ESHB Road maps		14-16	

Topic
Core Discipline
3RG Pages
Full ESHG Reference

ESHB Update:

Improvements & Future Work

- **Thermal Energy Storage**

  Dale Bradshaw, NRECA

Scope

Great River Energy (GRE), a Minnesota-based generation and transmission (G&T) electric cooperative, evaluated ten dynamically dispatched hot water heaters to determine the benefits of grid-interactive energy thermal storage (GETS). The overall goals were to validate and verify the GETS technology and determine their value in demand reduction and for providing such ancillary services to the Midcontinent Independent System Operator (MISO) electricity market.

Steffes Data on Temperature, Power, and Energy for an Individual Water Heater

ESHB Update:

Improvements & Future Work

Flywheels Basics – *Don Bender SNL/CA*

Grid-Connected Power Management	Industry	Applications
	Frequency Regulation	Flywheels are used to provide frequency regulation services at two 20 MW facilities
Industrial and Commercial Power Management		
	Transit	Flywheels produced by Calnetix and URENCO have been demonstrated in a number of transit systems for trackside energy recovery.
	Mining	The Usibili mine in Healy, Alaska uses a 40-ton flywheel to smooth the demand for electricity from a 6 MW dragline
Pulsed Power		
	Electromagnetic Aircraft Launch	80 MW flywheel alternators are being developed to launch aircraft from the next generation of aircraft carriers
Uninterruptible Power Supplies		The global market for UPS systems is on the order of $10B per year. Rotary systems account for about 5% of the total UPS market. Among large systems (>2MW), rotary UPS account for 35% of the world market
Mobile		
	Materials Handling	Flywheels recover energy and reduce emissions from raising and lowering loads with Rubber Tired Gantry Cranes at container terminals
	Motorsport	Flywheel hybrid powertrains were used successfully in the Audi R18 e-Tron LMP1s that won at Le Mans in 2012, 2013 and 2014

ESHB Update:

Improvements & Future Work

Safety: ESS Grid-Level Testing& Analysis – *David Rosewater*

Complex System Complex Investigation

- Challenges to Testing
  - Large systems present a challenge to testing
    - Multiple labs may be required for testing
    - Environmental chamber limitations
    - Availability of samples for testing
    - Fire Testing
    - Lab safety
  - Unique/New chemistries may present a challenge
- Challenges to construction review
  - Stakeholders unfamiliar with process
  - FMEA
  - Functional Safety
  - Components without appropriate
    - Certifications/ratings
    - Determine cells are within operating region
  - Obtaining necessary information to
  - determine compliance

Hazard Analysis Approaches

CAST *Causal Analysis using System Theory*

STPA
Systems Theoretic Process Analysis

STAMP
Systems Theoretic Accident Model and Process

Nancy Leveson

ESHB Update:

Improvements & Future Work

EPRI Energy Storage Integration Council (ESIC)

ESIC Mission : A **forum** in which electric utilities guide a discussion with energy storage vendors, government organizations, and other stakeholders to develop reliable, safe, and cost-effective energy storage options for the utility industry.

Background

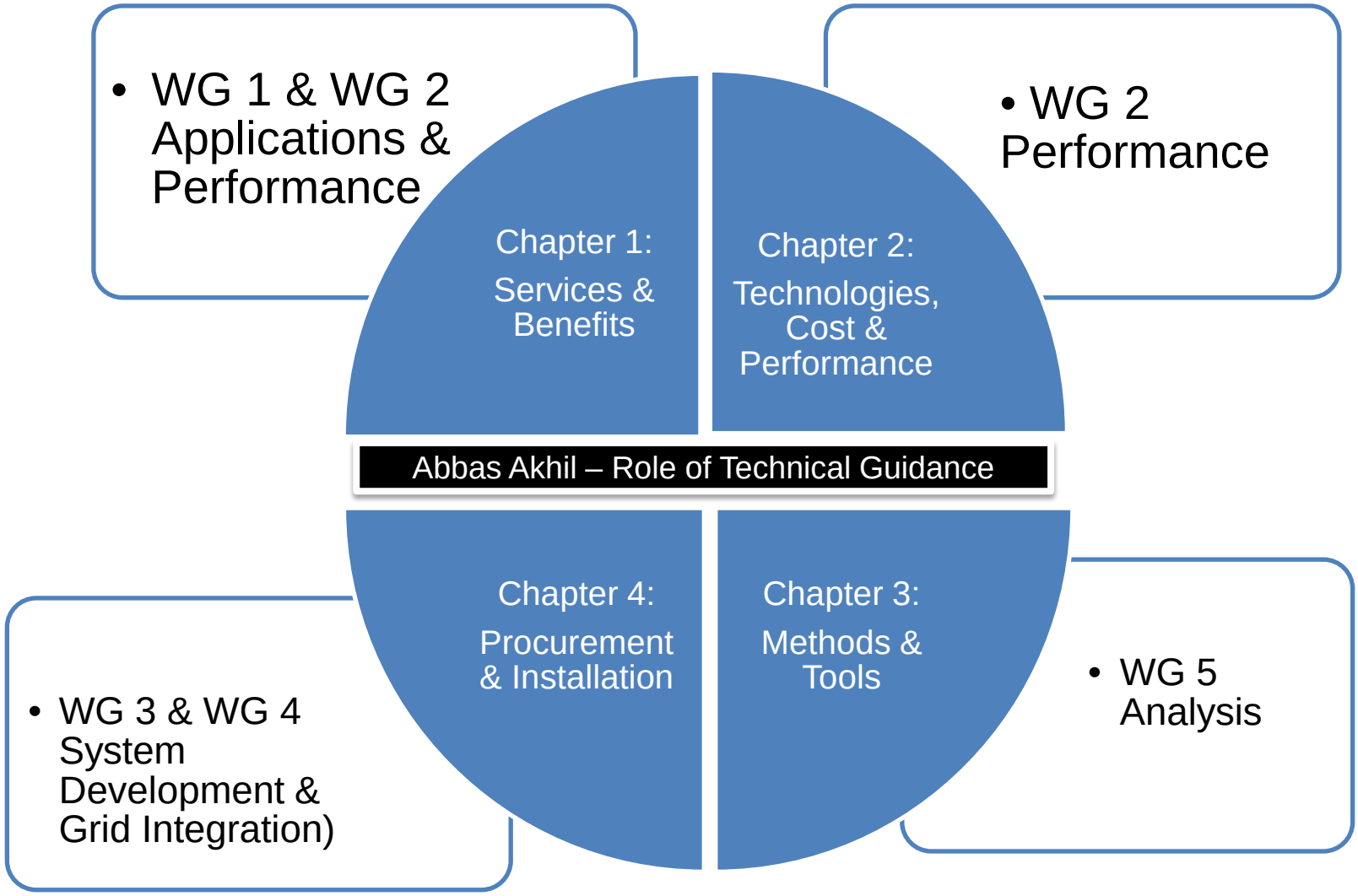
The initial focus of ESIC is to find common solutions to definition and deployment for distribution system-connected energy storage system, encompassing the utility scope from customer meter to 69kV

ESIC Working Groups Overview

- **WG 1 - Applications:** The Applications working group is focused on **developing the functional and technical requirements of energy storage in distribution-connected use cases.**
  - Chair: Bruno Prestat, Électricité de France (EdF)
- **WG 2 - Performance:** The Performance group focuses on development of **common metrics of performance for energy storage system, test protocols**, and reference duty cycles to understand fully integrated energy storage system performance on a consistent basis.
  - Chair: Naum Pinsky, Southern California Edison (SCE)
- **WG 3 - System Development:** The System Development group is focused on developing common approaches to component and **system standardization, technical specification, safety,** and communications and control.
  - Chair: Ryan Franks, National Electrical Manufacturers Association (NEMA)
- **WG 4 - Grid Integration:** This group is focusing on installation and commissioning of storage for grid purposes. The group focuses on the actual **deployment and usage of storage**, they also are responsible for controls, dispatch, and protection of storage once installed.
  - Chair: Thomas Golden, Duke Energy
- **WG 5 - Analysis:** This group is focusing on developing methods and defining data and model requirements for considering energy storage in **planning and operations processes**. This group is focusing on installation and commissioning of storage for grid purposes.
- Chair: Udi Helman, Helman Analytics

ESHB Update - Improvements

Interconnections of ESHB and ESIC Working Groups



ESHB –Future Work

Thermal Energy Storage Insights and Results	Dale Bradshaw
Flywheels	Don Bender
Energy Storage System Costs Revisions	Haresh Kamath
Energy Storage Safety: Standards/Best Practices	David Rosewater
ESIC Collaborations	Abbas Akhil

Contact Information

Thank you to DOE/OE for the funding to complete this project and for your attention!

If you have questions, contact

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