Clean Energy States Alliance

Energy Storage Technology Advancement Partnership (ESTAP) Webinar:

Developing an Energy Storage Project: A Technical Perspective

March 8, 2017

Hosted by Todd Olinsky-Paul
ESTAP Project Director
Clean Energy States Alliance

U.S. Department of Energy

Sandia National Laboratories

Housekeeping

All participants are in "Listen-Only" mode. Select "Use Mic & Speakers" to avoid toll charges and use your computer's VOIP capabilities. Or select "Use Telephone" and enter your PIN onto your phone key pad.

Submit your questions at any time by typing in the Question Box and hitting Send.

This webinar is being recorded.

You will find a recording of this webinar, as well as all previous CESA webcasts, archived on the CESA website at

www.cesa.org/webinars

State & Federal Energy Storage Technology Advancement Partnership (ESTAP)

Todd Olinsky-Paul

Project Director

Clean Energy States Alliance (CESA)

Clean Energy States Alliance

Sandia National Laboratories

U.S. Department of Energy

Thank You:

Dr. Imre Gyuk
U.S. Department of Energy,
Office of Electricity Delivery and
Energy Reliability

Dan Borneo
Sandia National Laboratories

ESTAP is a project of CESA

Clean Energy States Alliance (CESA) is a non-profit organization providing a forum for states to work together to implement effective clean energy policies & programs:

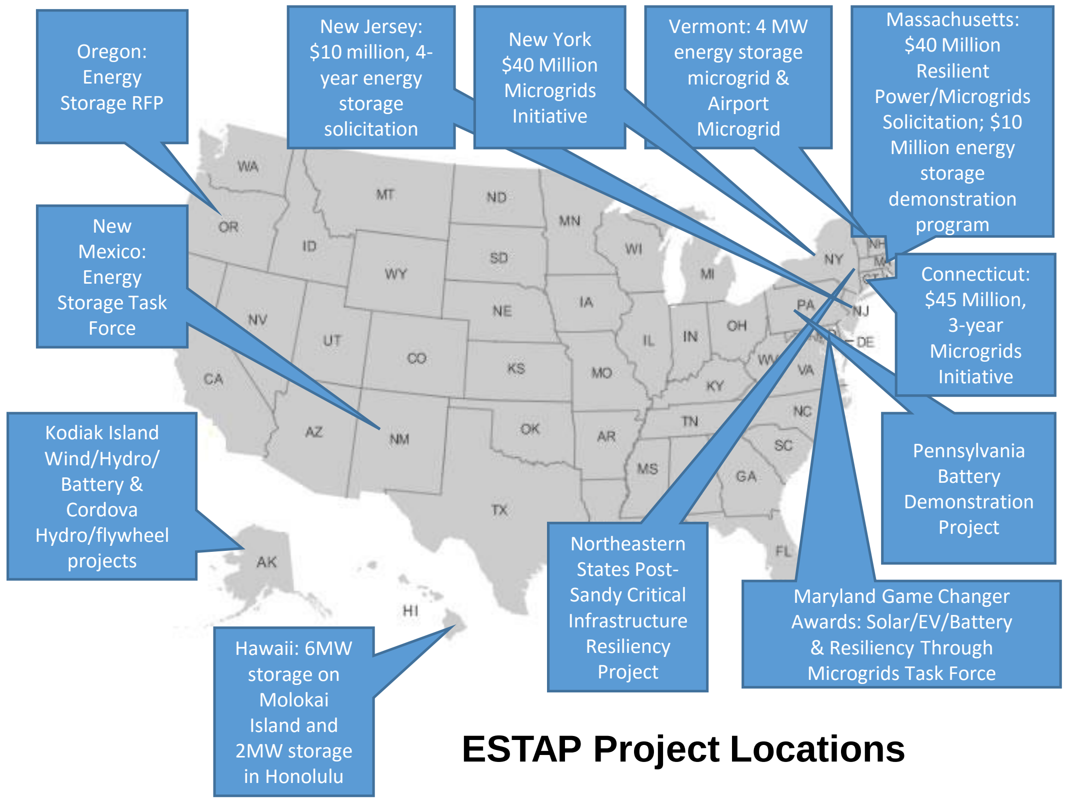
State & Federal Energy Storage Technology Advancement Partnership (ESTAP) is conducted under contract with Sandia National Laboratories, with funding from US DOE.

ESTAP Key Activities:

1. Disseminate information to stakeholders
   - ESTAP listserv >3,000 members
   - Webinars, conferences, information updates, surveys.

2. Facilitate public/private partnerships to support joint federal/state energy storage demonstration project deployment

3. Support state energy storage efforts with technical, policy and program assistance



ESTAP Project Locations

Clean Energy States Alliance

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

Energy Storage Technology Advancement Partnership

More CESA Projects

Overview

ESTAP Resource Library

ESTAP Webinars

ESTAP News

ESTAP Listserv Signup

ESTAP

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The Energy Storage Technology Advancement Partnership (ESTAP) is a federal-state funding and information sharing project, managed by CESA, that aims to accelerate the deployment of electrical energy storage technologies in the U.S.

The project's objective is to accelerate the pace of deployment of energy storage technologies in the United States through the creation of technical assistance and co-funding partnerships between states and the U.S. Department of Energy.

ESTAP conducts two key activities:

1) Disseminate information to stakeholders through:

- The ESTAP listserv (>2,000 members)
- Webinars, conferences, information updates

NEW RESOURCES

October 14, 2015
Resilience for Free: How Solar+Storage Could Protect Multifamily Affordable Housing from Power Outages at Little or No Net Cost
By Clean Energy Group

September 30, 2015
Webinar Slides: Energy Storage Market Updates, 9.30.15

UPCOMING EVENTS

December 16, 2015
ESTAP Webinar: State of the U.S. Energy Storage Industry,

More Events

LATEST NEWS

November 30, 2015
Massachusetts Takes the Lead on Resilient

Panelists

Dan Borneo, Sandia National Laboratories

Ben Schenkman, Sandia National Laboratories

Todd Olinsky-Paul, Project Director, Clean Energy States Alliance (Moderator)

Developing an Energy Storage Project – A Technical Perspective

Daniel Borneo, P.E.

Ben Schenkman

Sandia National Laboratories

CESA Webinar

March, 2017

Sandia National Laboratories

Exceptional service in the national interest

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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SANDIA Document SAND2017-0203 C

Objective:

- **As more Energy Storage (ES) projects are being implemented it is important to discuss how to successfully construct a project that is safe, reliable and cost effective. This talk will incorporate lessons learned from the portfolio of projects that Sandia is involved with and will discuss project initiation, application determination, power and energy requirements, design, and installation. It will also include other aspects of a successful ES project such as commissioning, system testing, codes and standards, data acquisition, and operations.**

Acronyms

- **PCS**-Power Control System
- **EMS**-Energy Manage System
- **DAS**-Data Acquisition System
- **ESS**-Energy Storage System
- **DBB**-Design Bid Build
- **EPC**-Engineer Procure Construct
- **DB**-Design Build
- **PPA**-Power Purchase Agreement
- **SOO**-Sequence Of Operation
- **POC**-Point Of Connection
- **LOTO**-Lock Out Tag Out
- **BOP**-Balance Of Plant
- **OAT**-Operational Acceptance Testing
- **FAT**-Function Acceptance Testing

DOE OE ES Projects Group

What We Do and Why

- Work with Utility, Industrial, State and International entities to:
  - Provide **third party independent analysis** for cells and systems
  - Support the development and implementation of **grid-tied ES** projects
  - Monitor and analyze operational ES Projects
    - Differing applications
    - Optimization
    - Operational performance
  - Develop public information programs to discuss lessons learned

- Goal
  - Inform the Public and encourage investment in ES by making sure it's safe, reliable, and cost effective.

DOE-OE Demonstration Projects 2016

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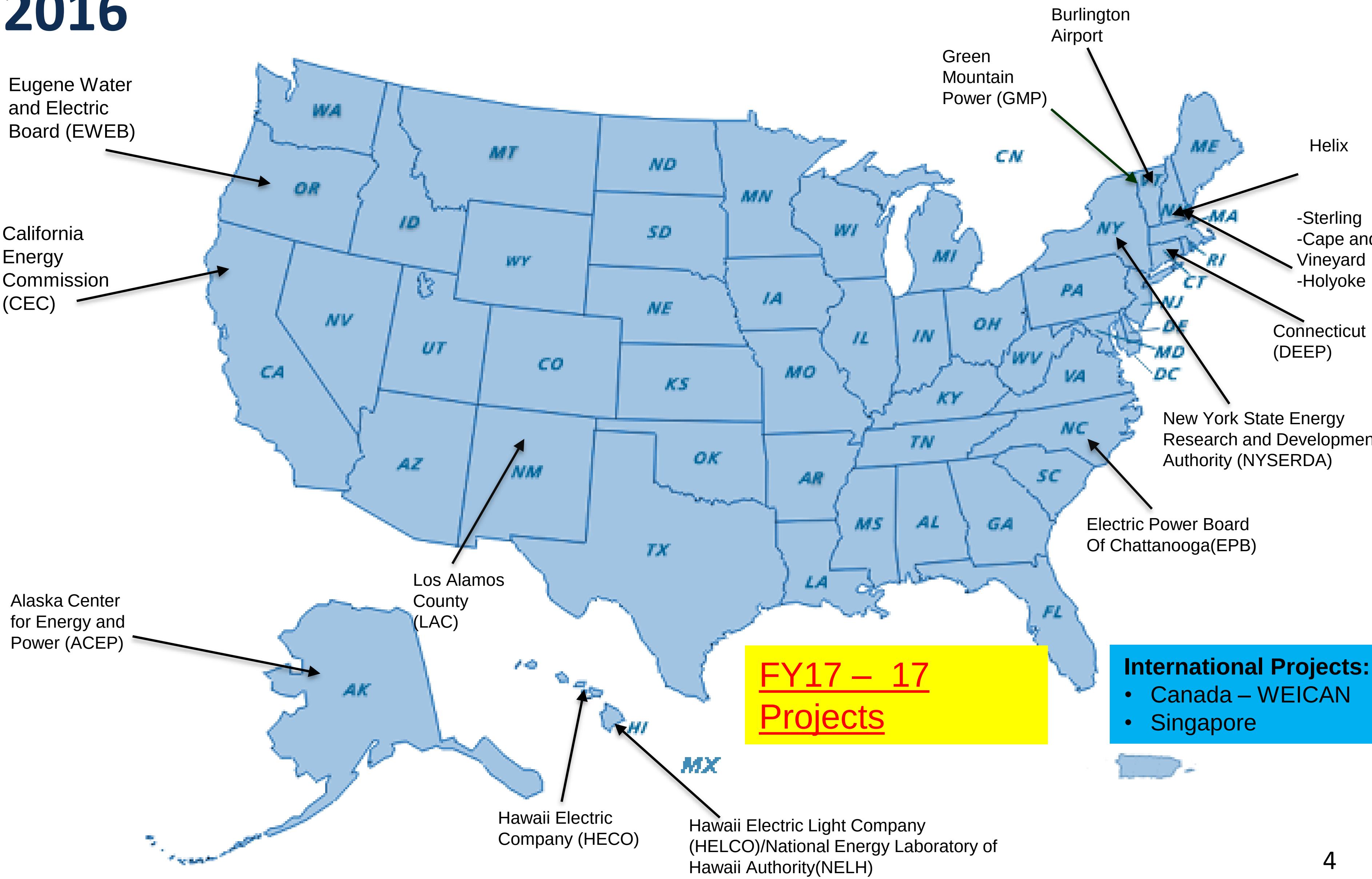

FY17 – 17 Projects

International Projects:
- Canada – WEICAN
- Singapore

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Project Programming

Problem(s) to solve, How to accomplish, Initial Analysis,

Design

Site, Interconnection, System KW/KWH, DAS, BOP, Specifications, Codes and Standards, Permitting, Cost Estimation

Procurement

System, Construction services, Integration services, Commissioning Agent

- Warranty

Construction

Installation per design, code, & specifications. Design verification.

Commissioning/ Testing

Factory tests, operational (OAT), Start-up, Functional (FAT), Shakedown, baseline measurements

Operation

- Operate, monitoring, Warranty, Predictive maintenance

Project Programming

- What are YOU trying to do:
  - Problem(s) to solve
  - Initial Analysis – Application(s), Power (KW) and Energy (KWh) requirements
  - Charge and Discharge cycle profiles
  - In-front-of (FTM) or behind (BTM) the meter
  - Own/operate or do Power Purchase Agreement (PPA)

Project Programming (cont.)

Can we show picture that I can talk to???

- Project team development
  - Owner/Owner's Engineer, Design Engineer, Construction, Commissioning Agent*, Procurement, Finance, Safety, Utility, **AHJ (trades), first responders**, **insurance**
- Project Delivery method
  - Design/Bid/Build (DBB) aka Engineer/Procure/Construct (EPC)
  - Design/Build (DB)
  - Developer (Power Purchase Agreement - PPA)

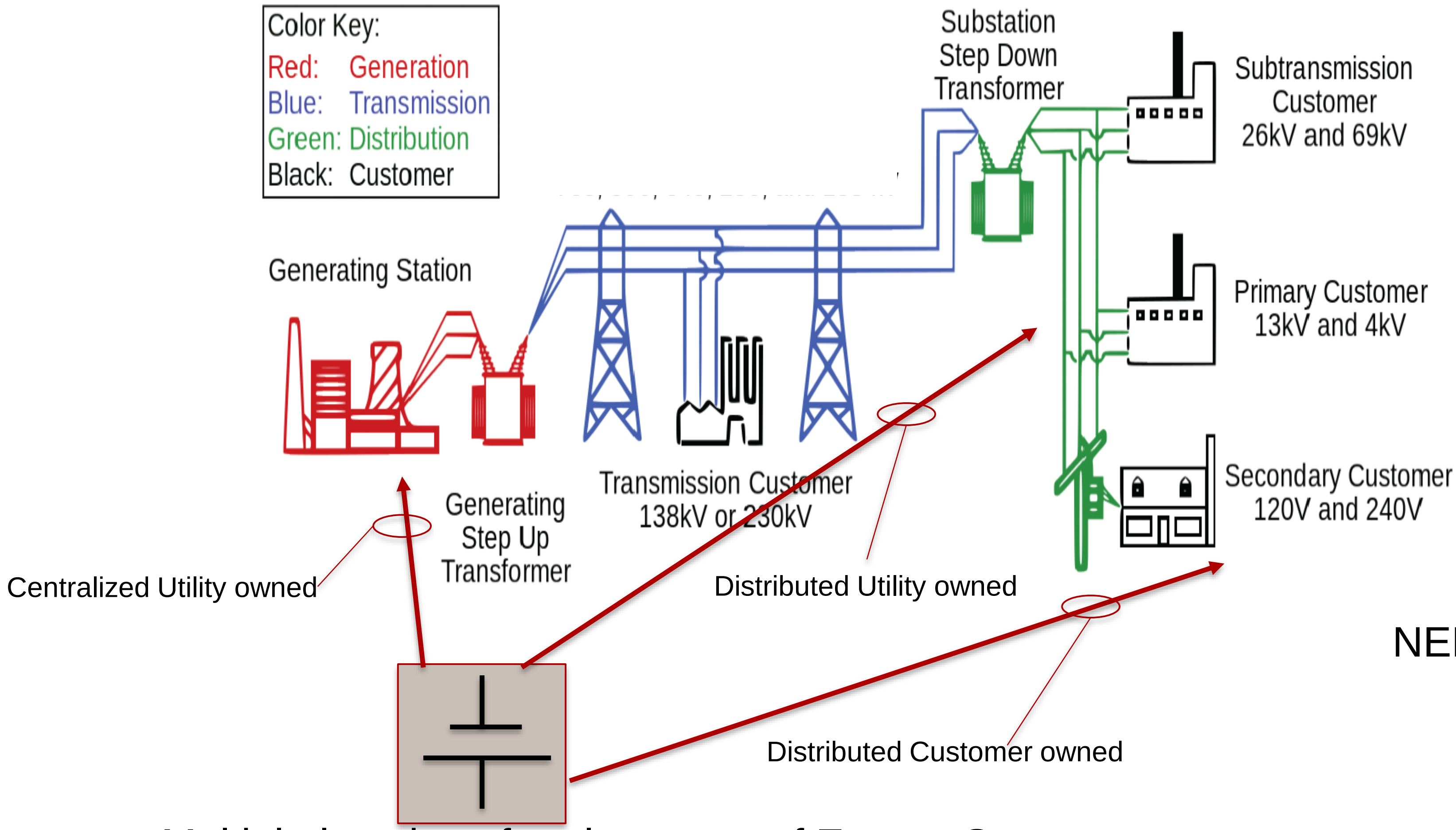
NOTE: Integrated Team with one owner.

*Commissioning agent can be Owner Maintenance (preferred)

Project Programming (cont.)

- Do you have a clear knowledge of what you want to do?
    - If NO use RFI – Request for Information about services, products, potential solutions costs, schedule, etc.
    - If YES use RFP – Request for a proposal based upon defined requirements and project details.
        - http://energy.sandia.gov/sandia-national-laboratories-develops-guidance-document-for-energy-storage-procurement/
- RFP Procurement Methods
    - Sole Source – Tried and true partner
    - Low Bid – You get what you pay for
    - Best value – Selection criteria matrix and scoring
        - Qualifications base – Most experienced for particular work
    - Unit Price or Time & Material (T&M)– Can have a not to exceed amount. Need to measure. Need to manage

The Grid Today



NERC

Multiple locations for placement of Energy Storage

Summary: Three Possible Business Models

Business Model	Pro	Con
Centralized Utility-owned or Merchant-owned storage	• Economic benefit to utility • Utility has direct control	• Little to no direct benefit to customer • How is ES monetized
Distributed utility-owned storage	• Economic benefit to utility • Resiliency benefit to customer	• How is ES monetized
Distributed customer-owned or Third-party owned storage	• Utility shifts risk of ownership • Regulated/deregulated electricity markets • Owner gets direct benefit	• Utility doesn't have direct control over operations • Owner gets direct benefit

Application and Benefits of ES in a Microgrid

- Power Quality/ Reliability/UPS: Instantaneous ride through during momentary interruptions
- Demand Reduction: Decrease peak, equipment upgrade deferral
- Energy Shifting: PV or cheap power stored and dispatched after dark or in times of high costs
- Renewable Energy and Distributed Energy support: Steady source of energy during variability caused by Renewables or other Distributed Energy Resources (DER)
- Generator Support: Load or supply to increase generator efficiency and reduce generator run time

ES SERVING MULTIPLE APPLICATIONS IS THE MOST COST EFECTIVE.

ES Cost Considerations

Capital Costs

- Design/permitting/Studies
- Site and infrastructure
- ES System - $/kW and/or $/kWh
- Balance of Plant
- Construction/Installation
- Commissioning
- Warranty

Operating Costs

- Efficiency factors
- Cycle life/replacement
- Operations
- Maintenance
- Ongoing Warranty
- Debt Service
- Disposal Cost

Project Design:
Elements of an Energy Storage System

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Storage

- Storage device
- Battery Management & Protection (BMS)
- Racking

Power Control System (PCS)

- Bi-directional Inverter
- Switchgear
- Transformer
- Data Acquisition System (DAS)

Energy management System (EMS

- Charge / Discharge
- Load Management
- Ramp rate control
- Grid Stability

Balance of Plant

- Container / Housing
- Wiring
- Climate control

NOTE: Important to have single entity responsible for the ESS integration.

Project Design (Cont.)
Modular Energy Storage Types

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Type	Storage Mechanism	Common Duration	Cycles
Capacitor	Electrical Charge	Seconds(minutes)	100,000's
Flywheel	Kinetic Energy	Seconds/Minutes	1000's- 100,000's
Battery	Electro-chemical	Minutes(hours)	100's- 1000's

Project Design (Cont.)
Battery Technologies

Type	Storage Mechanism	Common Duration	Cycles
Lead Acid / Advanced Lead Acid	Electro-chemical	Seconds to Hours	100's – 1000's
Li-ion	Electro-chemical	Seconds to hours	1000's plus
Vanadium Flow	Ion Exchange	Hours	1000's plus
Zinc Flow	Plating	Hours	1000's plus
NaS and NaNiCl	Electro Chemical	Hours	1000's plus
Aqueous Sodium	Electro Chemistry	Hours	1000's plus

Types of Lithium Batteries (NEED TO REDO COLORS FOR VISABILITY)

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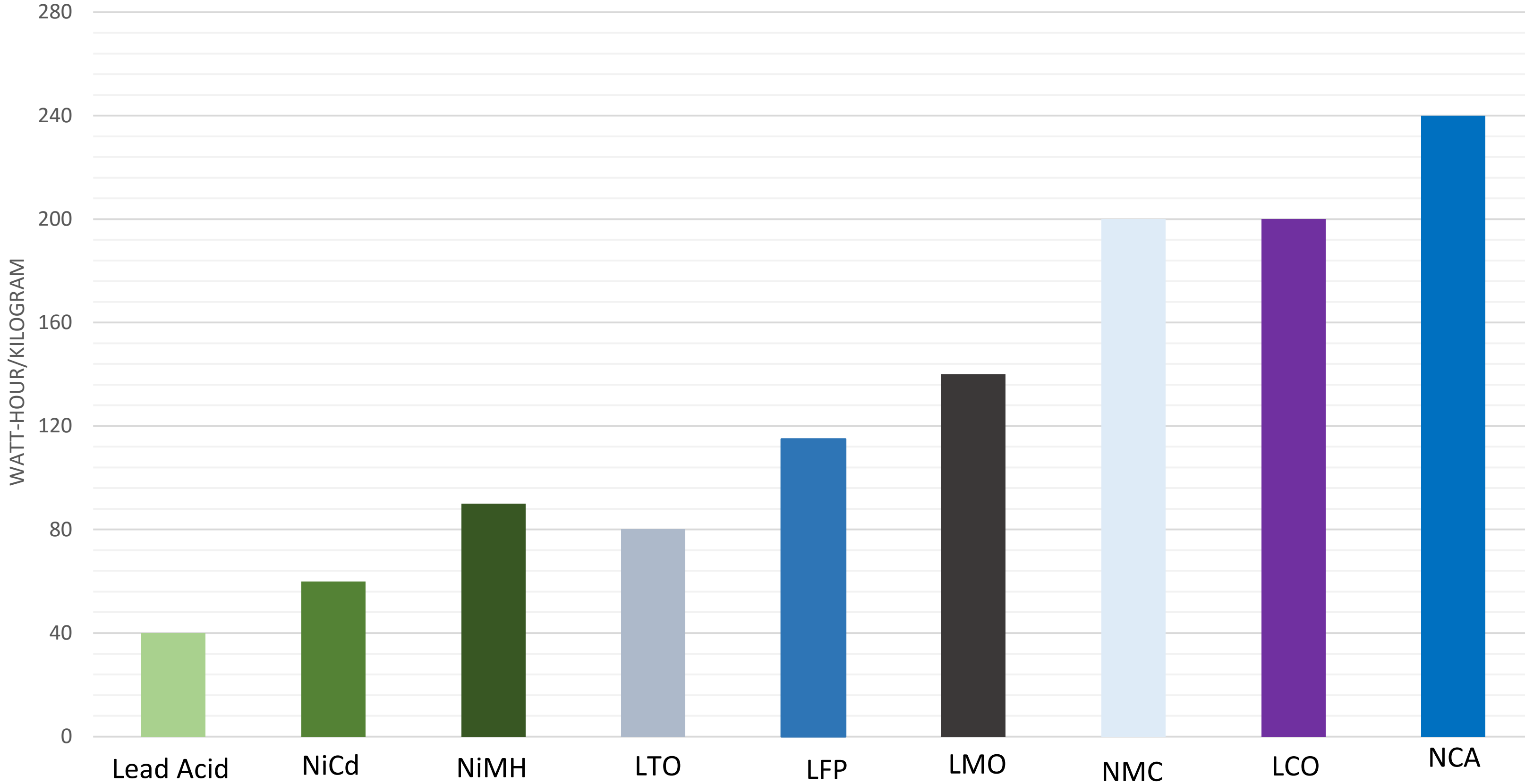
Chemical Name	Material	Abbr	Short Form/Nickname	Specific Energy	Cycle Life	Thermal Runaway	Applications	Comments
Lithium Titanate	Li4Ti5O12	LTO	Li-titanate	70-80Wh/kg	3000-7000	One of safest Li-ion batteries	1.Ideal for High Rate and High Cycle Life Applications	Long life, fast charge, wide temperature range but low specific energy and expensive. Among safetest Li-ion batteries.
Lithium Iron Phosphate	LiFePO4	LFP	Li-phosphate	90-120Wh/kg	1000-2000	270°C (518°F)	1.Portable /stationary needing high load currents and endurance	Very flat voltage discharge curve but low capacity. One of the safest Li-ions. Used for special markets. Elevated seld-discharge
Lithium Manganese Oxide	LiMn2O4	LMO	Li-manganese, or spinel	100-150Wh/kg	300-700	250°C (482°F)	Power tools, Medical Devices, Electrical powerstrains	Most safe;Lower capacity than Li-Cobalt but high specific power and long life. High power but less capacity. Commonly mixed with NMC to improve performance.
Lithium Nickle Manganese Cobalt Oxide	LiNiMnCoO2 (10-20% Co)	NMC	NMC	150-220Wh/kg	1000-2000	210°C (410°F)	Medical devices, E-bikes	Provides high capacity and high power. Serves as a hybrid cell. Favorite chemistry for many uses. Market share is increasing.
Lithium Cobalt oxide	LiCoO2 (60% Co)	LCO	Li-cobalt	150-200Wh/kg	500-1000	150°C (302°F)	Mobile phones, Laptops, digital cameras	Very high specific energy, limited specific power. Cobalt is expensive.Serves as Energy cell. Market share has stabilized.
Lithium Nickle Cobalt Aluminum Oxide	LiNiCoAlO2 (9% Co)	NCA	NCA	200-260Wh/kg	500	150°C (302°)	Medical devices, industrial electric, powertrain(Tesla)	Shares similarities with Li-Cobalt. Serves as Energy Cell

Source: “Types of Lithium Batteries- A Handy Summary” and “BU-205: Types of Lithium-ion”, Battery University

Project Design (Cont.)- Typical Specific energy of lead-, nickel- and lithium-based batteries



Typical specific energy of lead-, nickel- and lithium-based batteries.
NCA enjoys the highest specific energy; however, manganese and phosphate are superior in terms of specific power and thermal stability. Li-titanate has the best life span.
Courtesy of Cadex Source: "Types of Lithium Batteries- A Handy Summary" and "BU-205: Types of Lithium-ion", Battery University

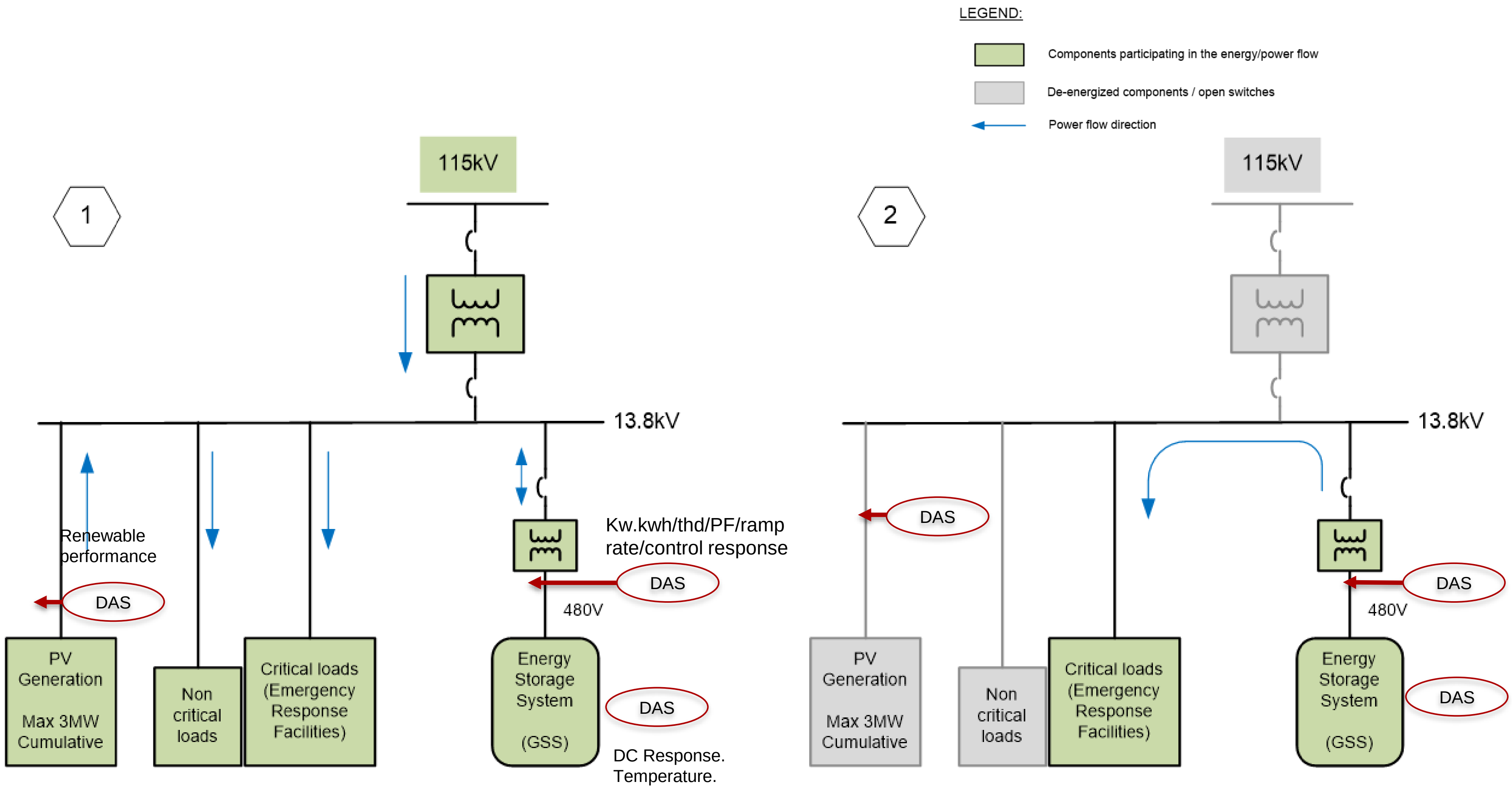
Project Design (Cont.)

- ➢ Could be a prior, separate Procurement (DBB or EPC) or
- ➢ Could be part of the procurement (DB or PPA)
- Site infrastructure
  - Equipment pad or building
  - Grounding
  - Building inspector
- Point of connection – 1- lines, detail drawings
  - Main & Aux Transformers
  - Electrical distribution switchgear and panels
  - Fault current and Arc flash calculations
  - Protection coordination
  - Power Control System (PCS) AC/DC bi-directional inverter
- Balance of Plant
  - HVAC
  - Fire protect
  - DAS

Project Design (cont.)

- Understand the applications and design ES Appropriately
  - Optimize the kW and kWh
  - Some technologies better suited for certain applications
  - Environmental concerns (extreme heat or cold)
  - Develop Sequence of Operations (SOO) based on Applications
- Energy Management System (EMS) -Design the controller to perform the various applications (Stack) and integrate with DER
  - Centralized vs. Decentralized controller
- Does system have (need) necessary certifications
  - UL listed - If not, need to get buy-in from AHJ
- What codes and standards are required to install ES
  - Local and National
  - IEEE Standards
- Data Acquisition System (DAS)
  - What information is required – V, I, KW, KWh, PF, Ramp rate, Temperature, charge/discharge info; Time stamp

Project Design (Cont.)
Overview of DAS connections



SMLD operating modes Courtesy of NEC

Data Acquisition System (DAS) A Closer Look

- DAS important part of overall management of system and performance
  - Monitor battery performance
    - Did it turn on/off as specified
    - Capacity fade over time – Does it meet Contract obligations
    - How much energy was consumed and delivered
- Important aspects of a DAS
  - Remote access to data
  - Time stamp of data/ command signal (Applications)
  - Sampling rate- Frequency regulation – Faster than signal
  - 30+ day on board memory to back-up transfer of data

- General Monitoring Parameters for ESS and balance of plant
  - AC Voltage (V) and Current (I)
  - KVA/KW / Power Factor (PF)
  - KWh in and out (efficiency)
  - Balance of plant monitoring
  - System and ambient temperature
  - State of Charge (SOC)
  - Frequency of ESS
  - May want DC
  - System (V/I/KW/KWh)
    - Cell voltages and temperature

Codes and Standards

Application	Standard Org	Standard	Standard Title
ESS Commisioning	ANSI	Z535	Safety Alerting Standards
ESS Commisioning	IEEE	450	Recommended Practice for Maintenance, Testing and Replacement of VRLA Batteries for Stationary Applications
ESS Commisioning	IEEE	1106	Recommended Practice for Installation, Maintenance, Testing and Replacement of Vented NiCd Batteries for Stationary Applications
ESS Commisioning	IEEE	1188	Recommended Practice for Maintenance, Testing and Replacement of VRLA Batteries for Stationary Applications
ESS Commisioning	IEEE	1578-2007	Recommended Practice for Stationary Battery Electrolyte Spill Containment and Management
ESS Commisioning	IEEE	1657	Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries
ESS Installation	AS	2676-1983	Installation and Maintenance of Batteries in Buildings
ESS Installation	AS	4777-1-2005	Grid Connection of Energy Systems via Inverters
ESS Installation	IEC	62935	Planning and Installation of Electrical Energy Storage Systems
ESS Installation	IEEE	519-1992	Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems
ESS Installation	IEEE	1145-1999	Recommended Practice for Installation and Maintenance of Nickel-Cadmium Batteries for Photovoltaic Systems
ESS Installation	IEEE	1187-2013	Recommended Practice for Installation Design and Installation of VRLA Batteries for Stationary Applications
ESS Installation	ICC		International Building Code
ESS Installation	ICC		International Fire Code
ESS Installation	ICC		International Wildland Urban-Interface Code
ESS Installation	IEEE	937	Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for PV Systems
ESS Installation	IEEE	1184	Guide for Batteries for UPS Systems
ESS Installation	IEEE/ASHRAE	1635-2012	Guide for the Ventilation aand Thermal Management of Batteries for Stationary Applications
ESS Installation	IEEE	1547	Standard for Interconnecting Distributed Resources with Electric Power Systems
ESS Installation	IEEE	C2-2012-2012	National Electrical Safety Code (NESC)
ESS Installation	NFPA	70-2017	National Electrical Code (NEC) (Updated section on Energy Storage)
ESS Installation	NFPA	70E-2012	Standard for Electrical Safety in the Workplace
ESS Installation	NFPA	400-2013	Hazardous Material Code
ESS Installation	IEC	62485-2	Safety Requirements for Stationary Batteries
ESS Installation	UL	96A	Installation Requirements for Lightning Protection Systems
ESS System	ANSI	C84-1	Electric Power Systems and Equipment
ESS System	IEC	62040-1 Ed.1	UPS General and Safety Requirements in operator access areas
ESS System	IEC	62040-1 Ed.2	UPS General and Safety Requirements installed in restricted access locations
ESS System	IEC	62257-9-5	Small renewable energy and hybrid systems for rural electrification - protection against electrical hazards
ESS System	IEC	62257-9-1	Small renewable energy and hybrid systems for rural electrification - Micropower systems
ESS System	IEC	62932-2-1	Flow Battery Systems for Stationary Applications - performance requirements and methods of tests
ESS System	IEEE	485	Lead-Acid Batteries for Stationary Applications
ESS System	IEEE	1375	Guide for the Protection of Stationary Battery Systems
ESS System	IEEE	1491	Guide for Selection and Use of BMS in Stationary Applications
ESS System	NFPA	111-2013	Standard on Stored Electrical Energy Emergency and Standby Power Systems
ESS System	NFPA	791-2014	Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation
ESS System	UL	1741	Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy
ESS System	UL	1778	Uninterruptible Power Sources
ESS System	UL	9540	Outline for Investigation for Safety for Energy Storage Systems and Equipment

Courtesy of PNNL/Sandia, edited by Schenkman/Borneo. for exhaustive list see David Conover's **http://www.sandia.gov/ess/publications/SAND2016-5977R.pdfz**

Additional C&S' List Courtesy of Laurie Florence, UL ADD UL 1642 -

Document No.	Title
ANSI UL 1973	Batteries for use in Light Electric Rail (LER) and stationary
UL 3001	Distributed Energy Generation and Storage Systems
IEEE 3575	Guide for the Protection of Stationary Battery Systems
IEEE 1679	Recommended Practice for the Characterization and Evaluation of Emerging Energy Storage Technologies in Stationary Applications
IEC CD 62619	Secondary cells and batteries containing alkaline or other non-acid electrolytes. Safety requirements for secondary lithium cells and batteries, for use in industrial applications (under development)
IEC NP 62897	Stationary Energy Storage Systems with Lithium Batteries –Safety Requirements (under development)

Commissioning Activities During Design

- Identify commissioning owner and roles and responsibilities across team
  - Energy Storage (ES) System integrator – (**Important position**)
  - Engineering designer – (**ES installation and balance of plant)**
  - Inspectors /EHS representatives/First Responders/Insurance
  - Operations and Maintenance (commissioning agent?)
  - Utility Representative – (**Point Of Connection**)
  - ES Equipment Vendor
  - Construction contractor (Depending on Procurement Strategy)
  - Commissioning Agent if not maintenance
- Review equipment specifications and applicable codes & standards
  - what is the KW/KWh rating, why?
  - Parameters that system needs to meet
  - Develop equipment list of items that will be commissioned
- Develop and/or review the system Sequence Of Operations (SOO)
- Review and/or establish ESH requirements
  - What safety systems need to be installed
  - Develop Site Incident Prevention Plan-Authorization POC, LOTO, Hot-work

Procurement

- Did anything change for the decisions made in the programing phase? To refresh:
  - Do we have a clear knowledge of what we want to do?
    - If NO use RFI – A means to collect information about services, products, potential solutions and to understand the capability of potential vendors
    - If YES RFP – Is a request for a proposal based upon defined requirements and project details.
      - http://energy.sandia.gov/sandia-national-laboratories-develops-guidance-document-for-energy-storage-procurement/
  - RFP Procurement Methods
    - Sole Source
    - Low Bid
    - Best value
    - Qualifications base
    - Negotiated
  - Performance Clause – Project and System

Construction

- Construction Management
  - Manage to Safety, Scope, Schedule, & Budget
- Design and Shop Drawings
  - Measure twice cut once
- Design Verification – Is is built as it was designed/specified
- Coordination Meetings
- Change order Process
  - Who initiates, who authorizes, who pays
- Contingency plans and work arounds
  - When things don't go as planned
- Implement Lock-out/Tag-out process

SAFETY SAFETY SAFETY

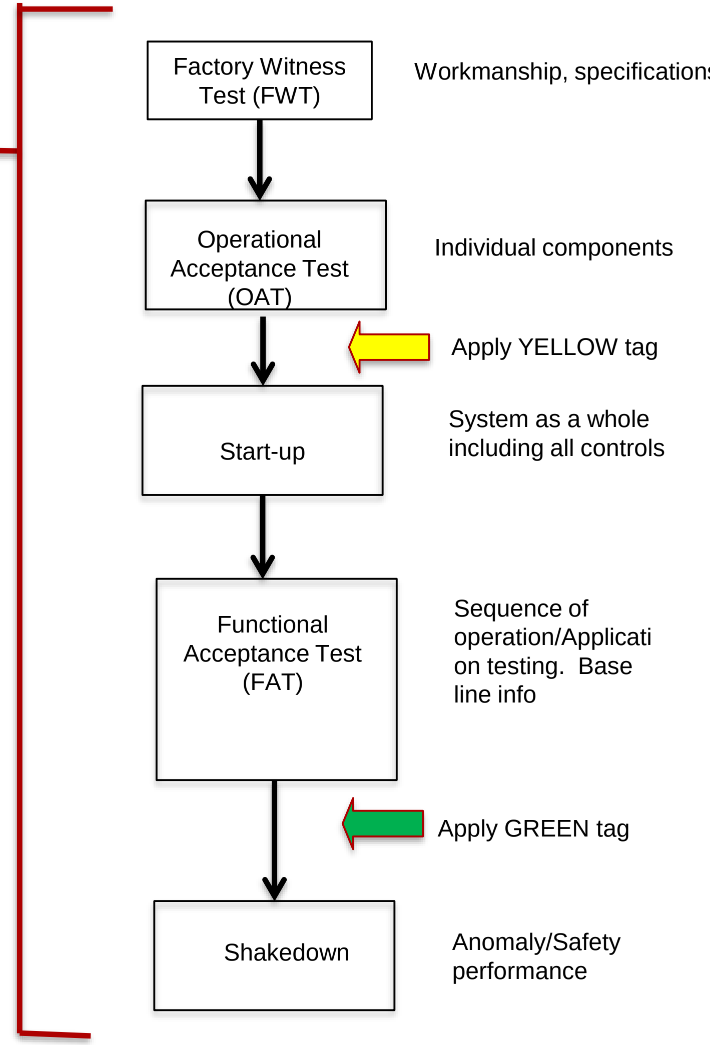
Commissioning Activities during Construction

- Factory Acceptance Tests
  - Test Application - More than on/off, charge/discharge
- Develop start-up procedures
  - Use equipment list, equipment manuals, SOO and operating specifications
- Develop testing procedures
  - Based on SOO and applications
  - PNNL/Sandia Testing Protocol
    - **http://www.sandia.gov/ess/publications/SAND2016-3078R.pdf**
- Develop installation review checklists and perform inspections
  - Design Verification – Installed as designed & specified;
  - Code adherence
  - Punchlist items noted
- Develop Training and emergency response procedures
  - MSDS

Commissioning/Testing Process

COMMISSIONING

GOAL: To Ensure a **Safe and Reliable** System is Installed as designed and is verified operational.



NOTES on Tags

Tags act as gates to advance events for the owner in the following manner:

(**Pick** a **Color**)
YELLOW Tag: Construction owned, Owner-Operated
GREEN Tag: Owner owned/operated. Hand off from construction to operations. System completed

The yellow tag is removed once a green tag is applied.
The green tag may be removed at the owner's discretion AFTER the project is completed and signed off.

Commissioning Process- Operational Acceptance Testing (OAT)

Do the Individual components of the system operate?

- Verify and test that the individual electrical, mechanical components of the system are ready for start-up
  - Meggering, torqueing, rotation/phasing, covers and barriers
- Verify that the controls are in place and test operation
    - Point to point check
- Verify electrical protection and relays are coordinated, tested and are operational
- Verify and test that all safety systems are installed and operating.
  - Temperature, leak, security, fire alarm, flow, pressure
- Verify and test that all communication systems are operating
- Emergency procedures are in place and Lock/out tag out process implemented
- **Tag and sign off – System is ready to operate**

Note: Is 3rd party testing required?

Commissioning Process– Start-up

Do the components operate as a system?

- Using start-up procedures, operate all components as a system
  - Record base-line data
    - Voltage, currents, temperatures, flows, pressures
    - Perform initial IR scan
    - Capacity
    - Efficiency KWh out/ KWh in
  - Record and repair punch list items

✓ Does Automatic and remote control operate as required

✓ Is Data Acquisition system operating, recording data and transmitting/Saving as required

Commissioning Process- Functional Acceptance Test (FAT)

- Using Testing plans and procedures test to insure systems performs the functions/applications for which it was designed.
  - Are all components and sub-systems operating in unison
  - Do controls operate as intended
  - Is communication system sending and receiving data as intended- type and frequency. Are anomalies being annunciated
  - Is data collected adequate to determine system performance
  - Record and repair punchlist items
  - Is training complete for operators, maintenance and first responders
  - Is operation and maintenance plan in place
  - Is warranty in place
  - Is emergency response procedures in place- 1-800 number in the event of an emergency
  - Log additional baseline data

✓ **Tag and sign off that system is now owned and operated by customer/owner**

Commissioning Process-Shakedown

When any site utility is interrupted, and then restored (e.g., electricity, gas, water, data, communication, etc.), does the system operate in such a manner as to protect the people, the environment, the equipment, and the facilities?

- *Turn off major utilities serving project.*
  - Determine if safety systems work as designed or needed.
  - Evaluate if systems fail in a safe mode.
  - Assess if back-up systems operate as needed.
  - Do alarms serve the purpose

- *Turn on major utilities*

  Determine if the systems come up in a safe manner.

  Assess if backup systems turn on in a safe/ready mode.

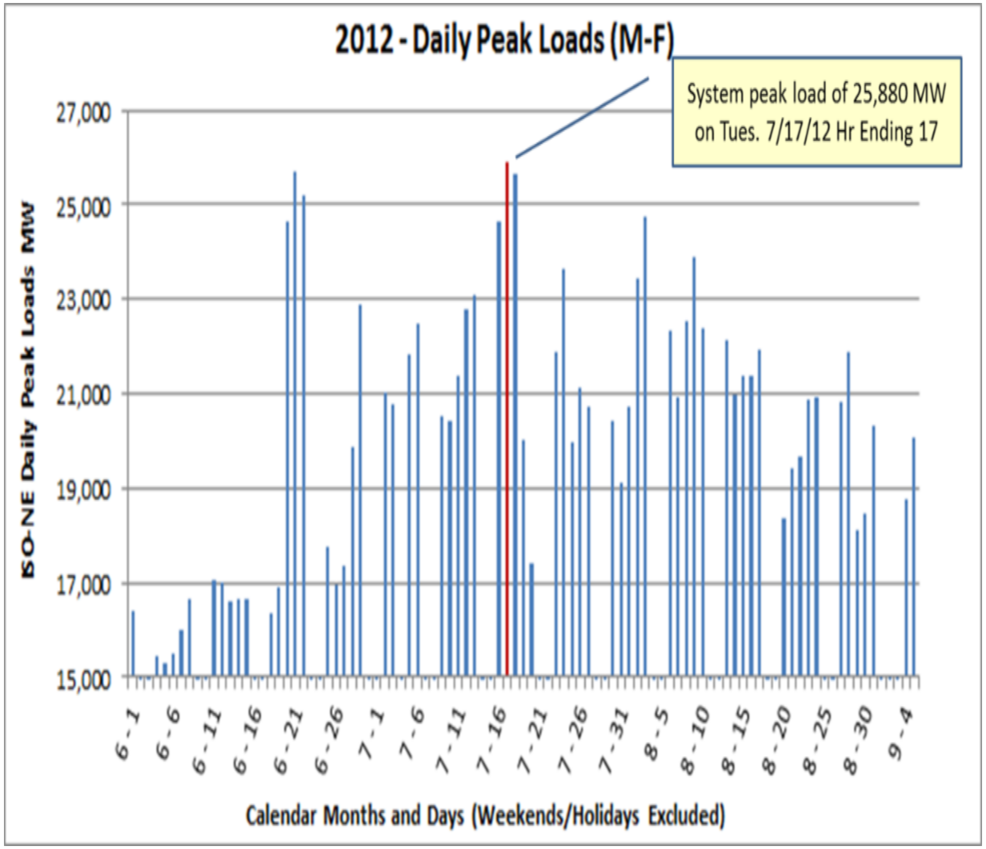
Operation

- Additional Operator training
- Application review
- DAS System in Play
  - System Performance
  - Monitor capacity fade
  - Predictive maintenance
  - Remote access and on site storage (min 30 days)
  - Is system being operated as designed
- Who to call and what to do in the event of an emergency
- Warranty
  - Who takes care of what and when
  - 1-800 number

Case Studies

Case 1: Green Mountain Power ES

- 4MW/ 3.4 MWh Li-ion/Lead acid & @MW PV (limited by 2MW inverter)
- GMP capacity and transmission obligation is $80-90 million/year, based on one annual capacity peak and 12 monthly transmission peaks
  - Capacity portion (one annual peak) is $30 - $40 million/year, will triple by 2018
  - Transmission portion (12 monthly peaks) is $50 - $60 million/year now, will increase as transmission gets built in NE

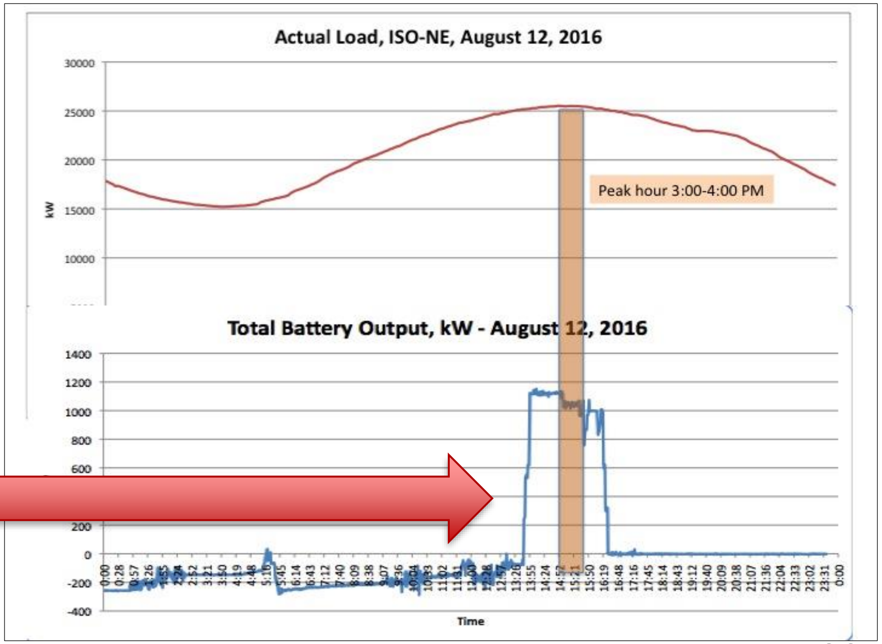


GMP calculates it will soon be paying $150 million/year to NE-ISO based on 12 hours/year.

VALUE OF STORAGE?

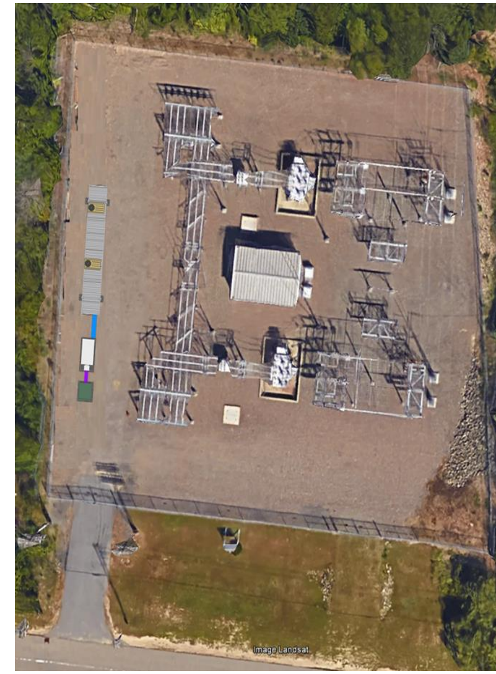
- GMP calculates the value of storage at $300,000 - $500,000 /MW/year for peak demand shaving, plus revenue from frequency regulation
- GMP site overall is valued up to $1 million/MW/year (Solar has other value streams from RECs, generation etc.)
- Batteries cost around $5-6 million
- GMP is anticipating a **5-10 year** payback
- **And by the way, this system also provides backup power to a school that is a designated emergency shelter**

GMP system discharge during annual demand peak: 1 hour = $200,000 savings



Case 2: Sterling, Massachusetts ES for Capacity and Transmission Cost Reductions, Arbitrage, Resiliency

- 2 MW / 3.9 mWh lithium ion battery project, connected with 3.4 MW solar PV
- Islanding capability to support municipal emergency facility
- SMLD awarded a $1,463,194 resilient power grant by the Massachusetts Department of Energy Resources (DOER) to purchase 1 MW of energy storage, which, together with existing 3.4 MW solar, would provide backup power to the town's police station and emergency dispatch center
- SMLD believed more storage capacity would enable it to provide cost savings
- DOE-OE provided funds, technical support to expand the project and demonstrate the business case

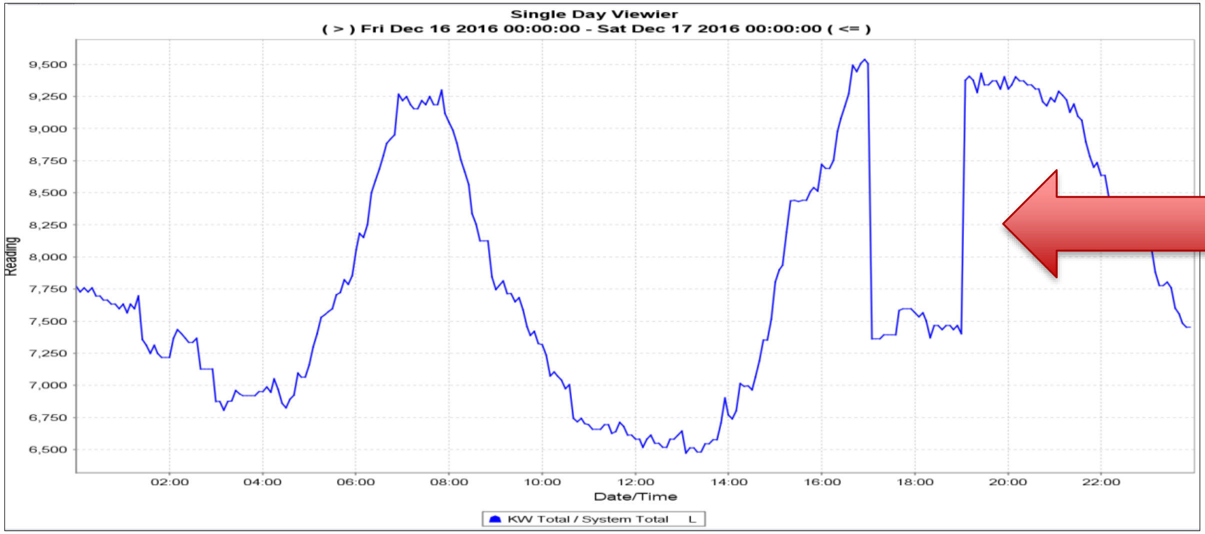


Value of Storage?

For a 1 MW, 1 MWh system:

- Arbitrage = $13,321.20/year
- Frequency regulation = $60,476.04/year
- RNS savings = $98,707.00/year
- FCM savings = $115,572/year (2017-2018 pricing)
- Resiliency savings = $40,819/event

Total value for 2 MW/2 MWh system: ~$657,790 / year (Payback < 5 years)



Transmission savings demonstrated: Battery discharge on December 16, 2016 reduces SMLD's peak demand during regional monthly peak hour

Lessons Learned

- Semiconductors follow Moore's Law; Batteries follow Murphy's Law:
  - What can go wrong WILL!

  THEREFORE: Have a contingency Plan
    - Schedule float
    - Work arounds if system is on a critical path
- Be aware of length of time to get permitting, contracts, in place
- Are EPA studies required
- Commissioning plan always gets pushed off until it becomes a gate
- Building Inspector, Fire department, need to be involved in the programing phase
- Understand equipment build lead-time and define a detailed schedule to adhere to.
  - Manage it
- Performance Clause:
  - Performance and Schedule

  Remember one finger pointing, three pointing back. Need to have clear understanding of who does what, and by when

Summary

- Start with the end in mind
  - Owner, Applications, operations, monitoring
- Energy Storage
  - Abilities
    - Firm renewables intermittency and power quality.
    - Demand reduction and energy shifting
    - Eliminate capacity constraints and reduce capacity and transmission payments
    - Possibilities exist to decrease generator run-time using ES
    - ES as a UPS+ other apps may justify capital expenditure

    NOTE: Utilities can aggregate customer owned batteries to alleviate grid problems
  - Challenges of Energy Storage
    - Need to continue to drive down costs
    - Need to settle on Safety requirements for ESS installation
    - Need better understanding of optimization and how to use one ES System for multiple applications.
    - Still not certain of capacity fade and lifetime reliability – Time is the only true measure

The 'Ol Farmer takes up fishing

Mention of our SNL Sponsor – DOE/OE - Grid Energy Storage Program, managed by **Dr. Imre Gyuk**

Thank You!

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Clean Energy States Alliance

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U.S. DEPARTMENT OF ENERGY

Upcoming Webinars

Comparing the Abilities of Energy Storage, PV, and Other Distributed Energy Resources to Provide Grid Services
Monday, March 13, 3-4:30pm ET

Solar+Storage for Low- and Moderate-Income Communities
Thursday, March 16, 1-2pm ET

Solar+Storage Industry Perspectives: JLM Energy
Wednesday, March 22, 2-3pm ET

Tools for Building More Resilient Communities with Solar+Storage
Thursday, April 6, 1-2pm ET

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