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EnerVault
Safe, Reliable, Cost-Effective Energy Storage

DEMONSTRATION OF ENERGY STORAGE USING A BREAKTHROUGH REDOX FLOW BATTERY TECHNOLOGY

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Disclaimer

This material is partially based upon work supported by the Department of Energy under Award Number DE-OE0000225.

This material is partially based upon work supported by the California Energy Commission under Grant Award Number PIR-10-066

This material is partially based upon work supported by NYSERDA under PON1200 Project 15880

Project Overview

- Phase 1, Dec. 2009 – Jan. 2012
  - Develop EnerVault's energy storage technology into a 21 kW utility-scale system building block
  - Complete preliminary design of the Vault-250/1000 system

- Phase 2, Feb. 2012 – Jan. 2013
  - Final design and build Vault-250/1000 beta system
  - Install and commission system
- Phase 3, Feb. 2013 – Dec. 2013
  - First Ever Design and Operation of MWh-scale Fe/Cr RFB System
  - Commission and demonstrate Vault-250/1000 system

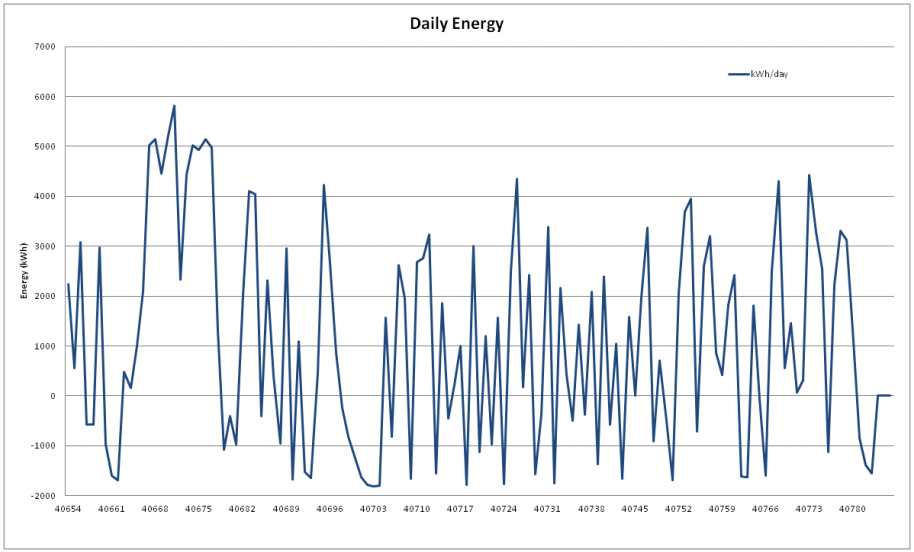
Milestones

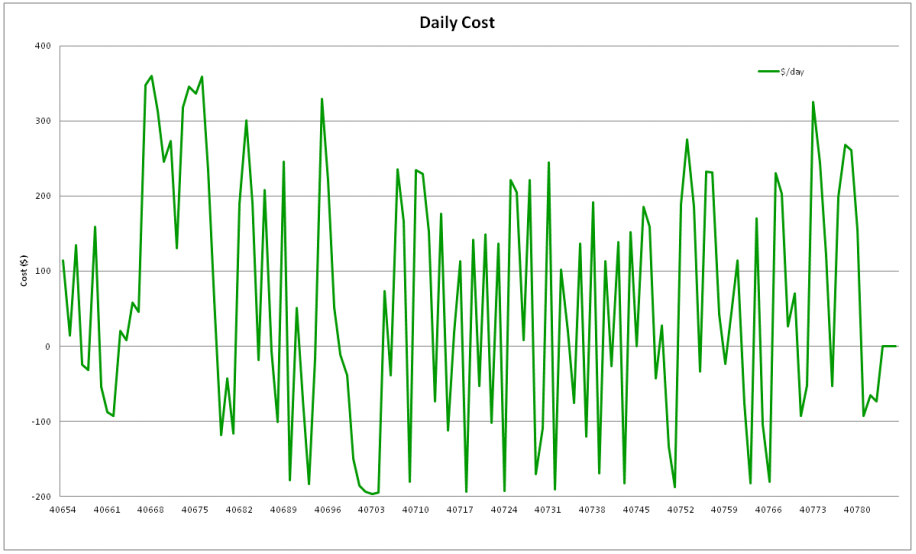
Achieve initial performance targets	Complete
2 kW prototype system	Complete
Full scale 21 kW design, Engineered Cascade™	Complete
Engineered Cascade™ demonstration	In process
Completion of Vault-250/1000 beta system	In process
Vault 250/1000 field demonstration	Scheduled 2013
Final report to DOE	Dec 2013

Team is meeting the challenge of developing a breakthrough energy storage technology

Project Metrics and Benefits

- Performance Metrics
  - Energy dispatched, system availability, round trip efficiency, maintenance
- Impact Metrics
  - Electricity usage and production, peak load and generation, annual dispatch, average efficiency





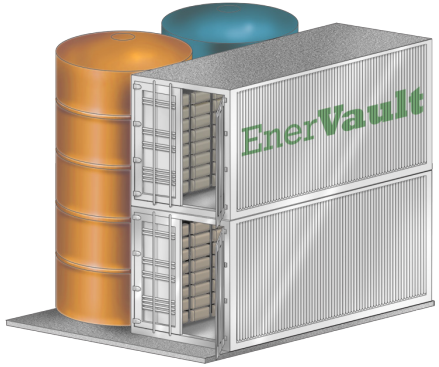
Project Activities

- EnerVault
  - Engineered Cascade™
  - Architecture and design
  - Core electrochemistry
  - Flow Battery Operations

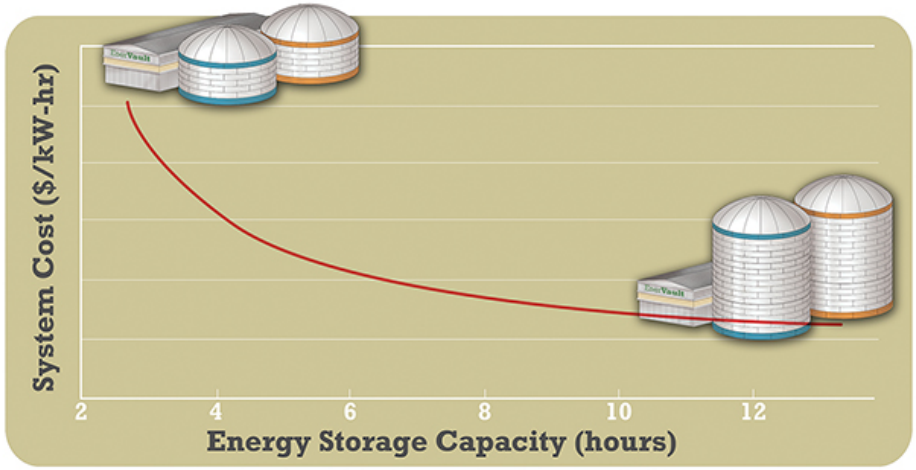
- Raytheon Ktech
  - Balance of system design and integration
  - Controls design and development
  - System fabrication
  - Testing and commissioning

Why Flow Batteries for Grid Scale?

- *Independence of system power and energy – application flexibility*



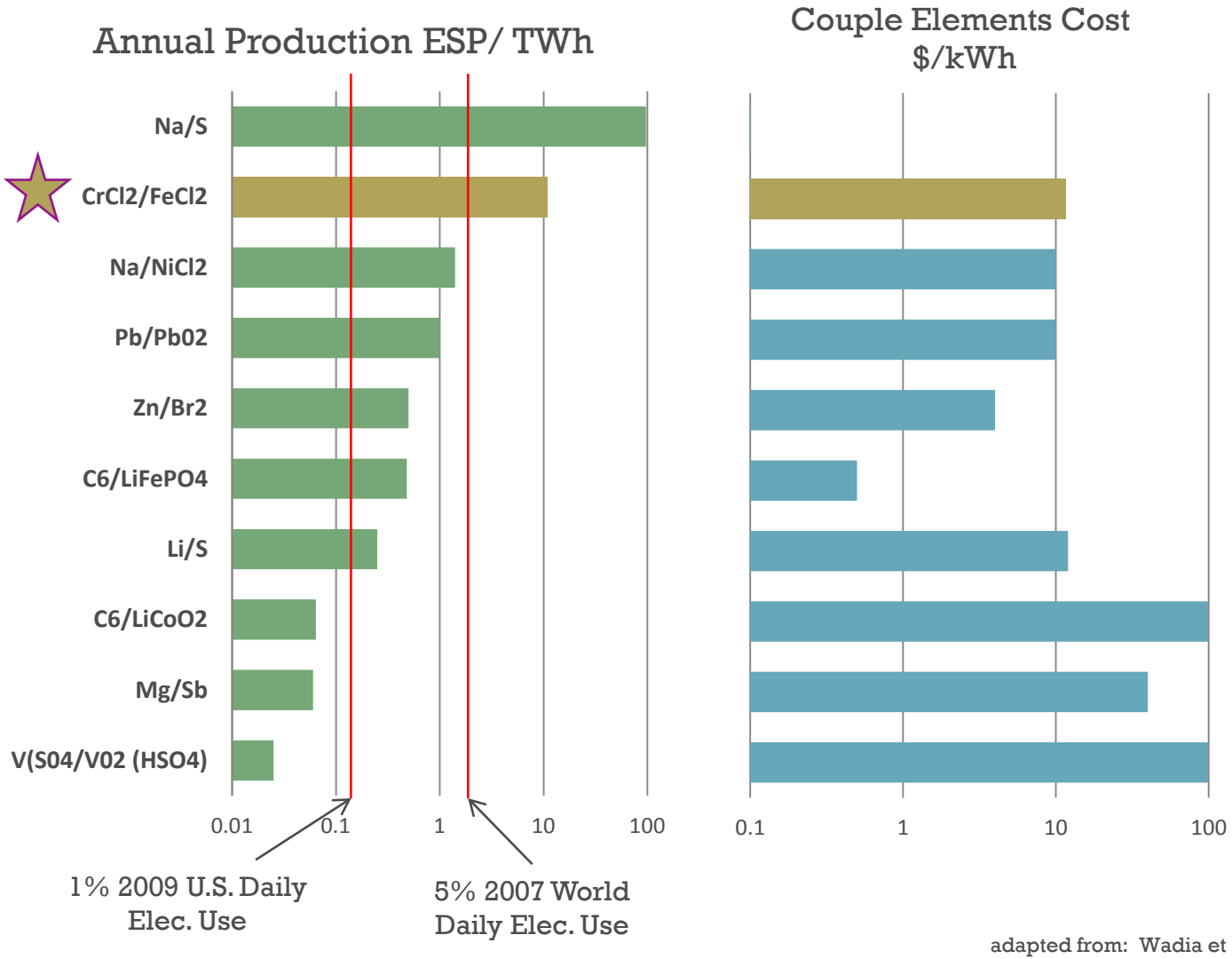
- *Economics get better at higher energy to power ratio - 3-10 hrs*
  - *Peak shaving applications*
  - *Long duration back-up*



- *System safety at high energy capacity*
  - *< 10 minutes of energy is electrically connected at one time*

Why Fe-Cr for Grid Scale?

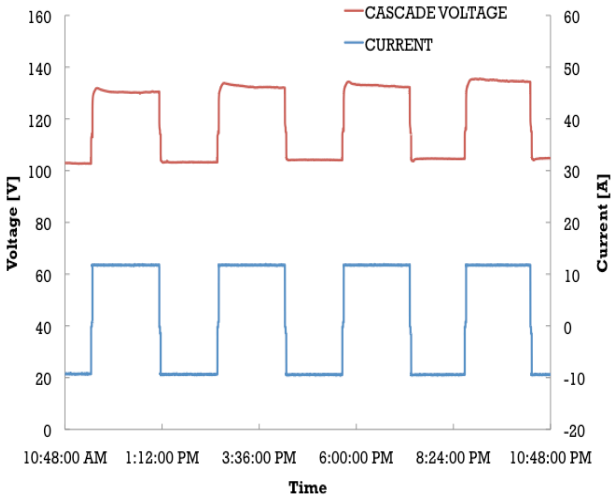
- Abundant, high production volume = low cost



adapted from: Wadia et al., *J. Power Sources* **196**(2011)1593-1598

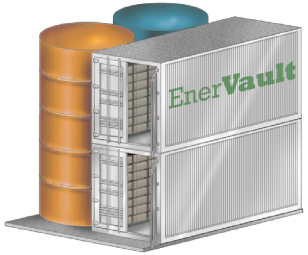
Program Progress

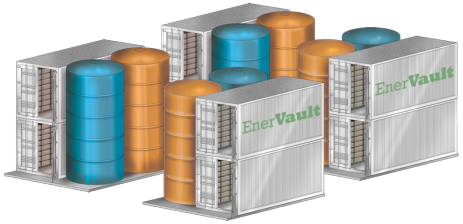
- Multiple kW-Scale test systems operating:
  - 2 kW; 7 kW; 21 kW
- Cell stack manufacturing started; long lead system components on order
- Detailed system design and BMS software development nearly complete
- Refining operating conditions on large test systems

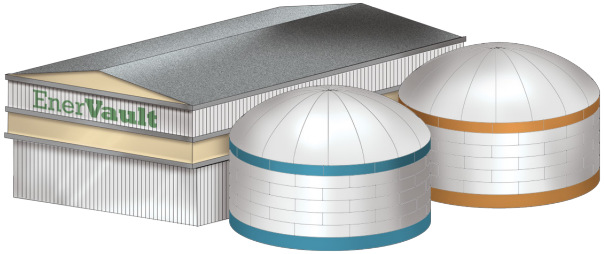


Future Applications and Impact

- Modular, tailored solutions for multiple applications







Market	Distributed Renewable Energy	Commercial & Industrial	Utilities and Grid
App's	Time Shifting	Demand Management Extended Emergency Backup	Renewable Integration Demand Management T & D Deferral Energy Arbitrage
Power Range	250 kW to 5 MW	250 kW to 5 MW	500 kW to 100 MW
Energy Range	3 to 6 hours	3 to 12 hours	3 to 8 hours

The Future

- Flow batteries provide grid-scale storage
  - 50 MW – 250 MWh system
  - Serving time shifting needs at the load centers

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Developing a Novel Redox Flow Battery for Grid Applications

A Combination of Public and Private Support

Product Development

2009 → 2013

Bench 2 W → Prototype 2-5 kW → Alpha 21 kW → Beta 250 kW

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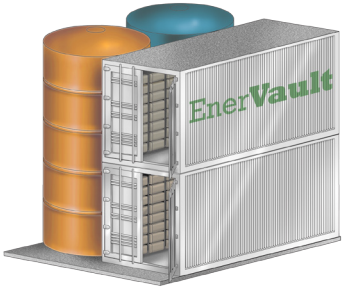


Test System Development

Able 2 kW | Bravo 5 kW | Charlie 7 kW | Delta 7 kW | Echo 21 kW

Project Support

NYSERDA

California Energy Commission

U.S. Department of Energy – ARRA Storage Demo

EnerVault Corporation

nyserda Energy. Innovation. Solutions.

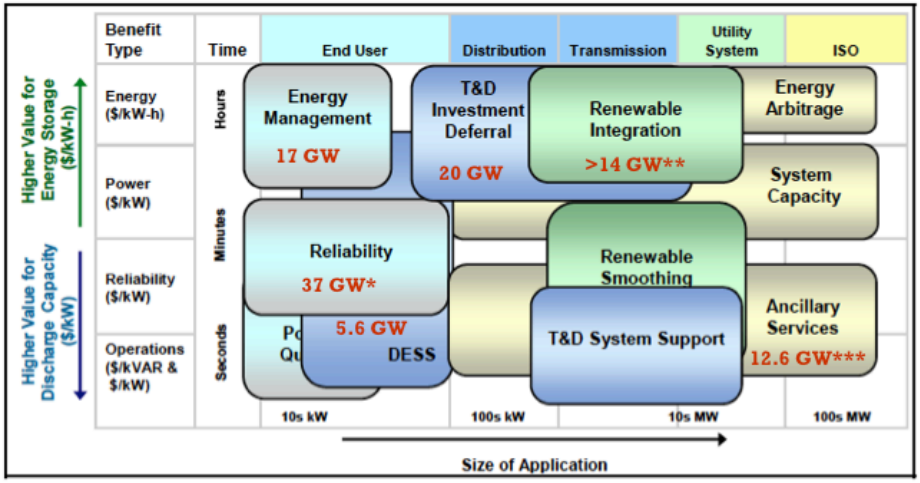
U.S. DEPARTMENT OF ENERGY

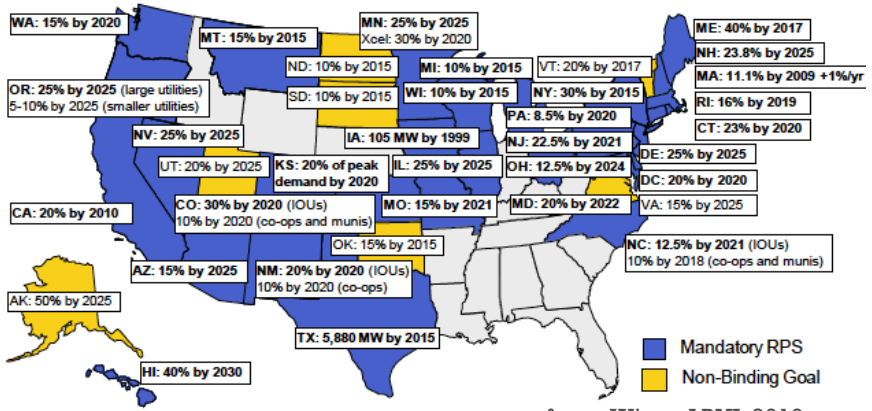
STATE OF CALIFORNIA ENERGY COMMISSION

Program Impact

- **Reduce the cost of sure and secure electricity**
  - reduced blackouts
  - improve grid stability
  - optimize existing T&D network
- **Cleaner, healthier environment**
  - provide clean peak electricity generated w/in distribution network
  - retire OTC plants (CA leading)
- **Electricity price predictability**
  - transform renewable but variable sources into dispatchable resources
  - state RPS become price hedge
- **US jobs**
  - KEMA: over 110,000 jobs

Source: *Electric Energy Storage Technology Options: A White Paper Primer on Applications, Costs and Benefits.* EPRI, Palo Alto, CA, 2010. 1020676.





from: Wiser, LBNL 2010

Summary

- Our project is the first MWh scale Fe/Cr redox flow battery demonstration in the US
- EnerVault Engineered Cascade™ design validated
- Scale-up testing underway
- Detailed system design is nearly complete
- Development, integration and build of Vault-250/1000 is underway
- Successful demonstration of the Vault-250/1000 system in this application provides pathway to broad deployment for smart grid and renewable generation

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