# DEMONSTRATION OF ENERGY STORAGE USING A BREAKTHROUGH REDOX FLOW BATTERY TECHNOLOGY

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# 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

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# 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

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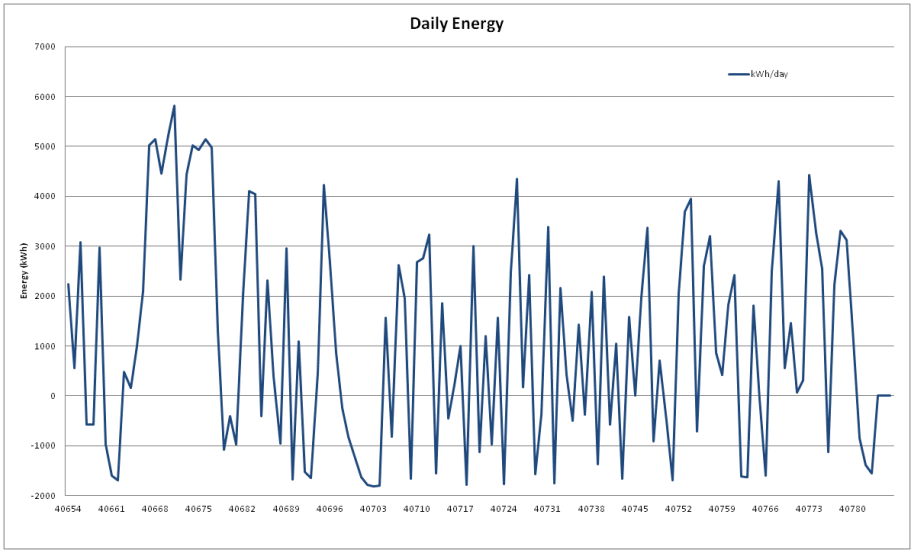
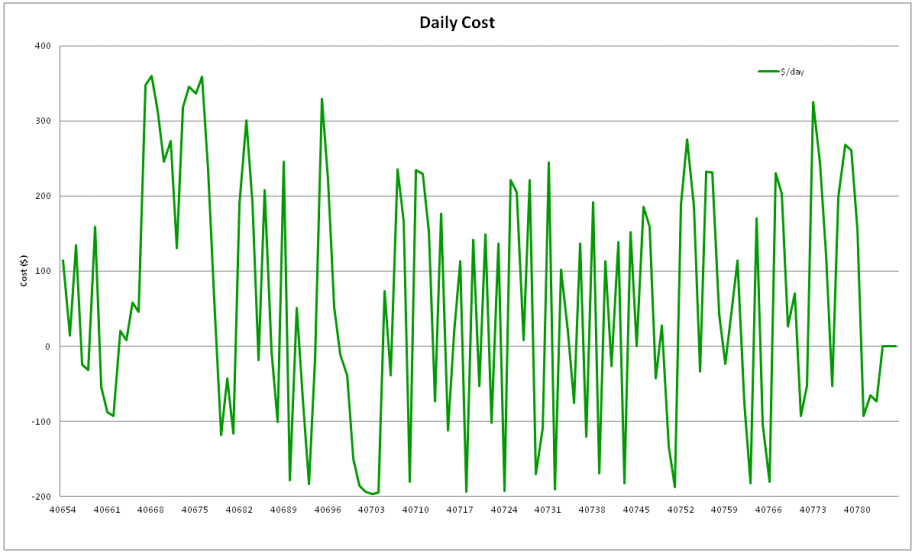
# Project Metrics and Benefits

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

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# 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

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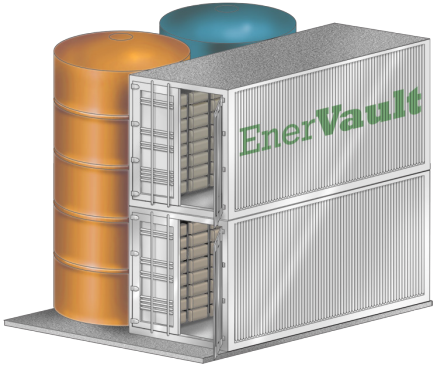
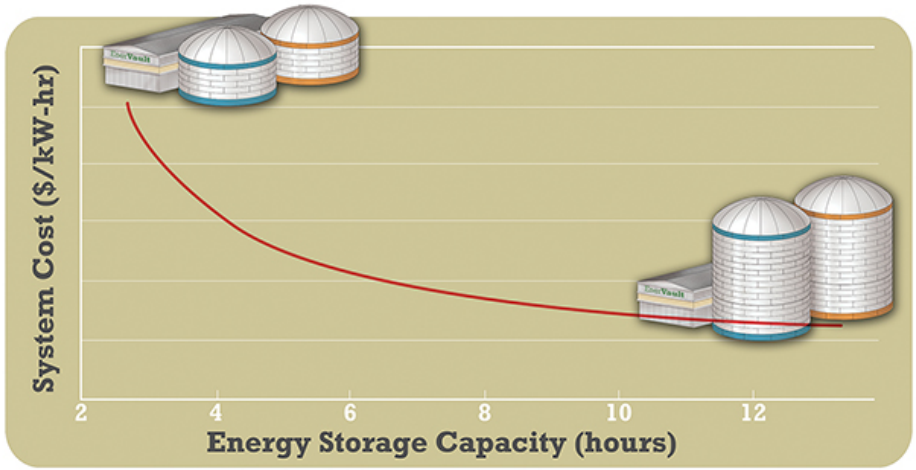
# Why Flow Batteries for Grid Scale?

- *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*

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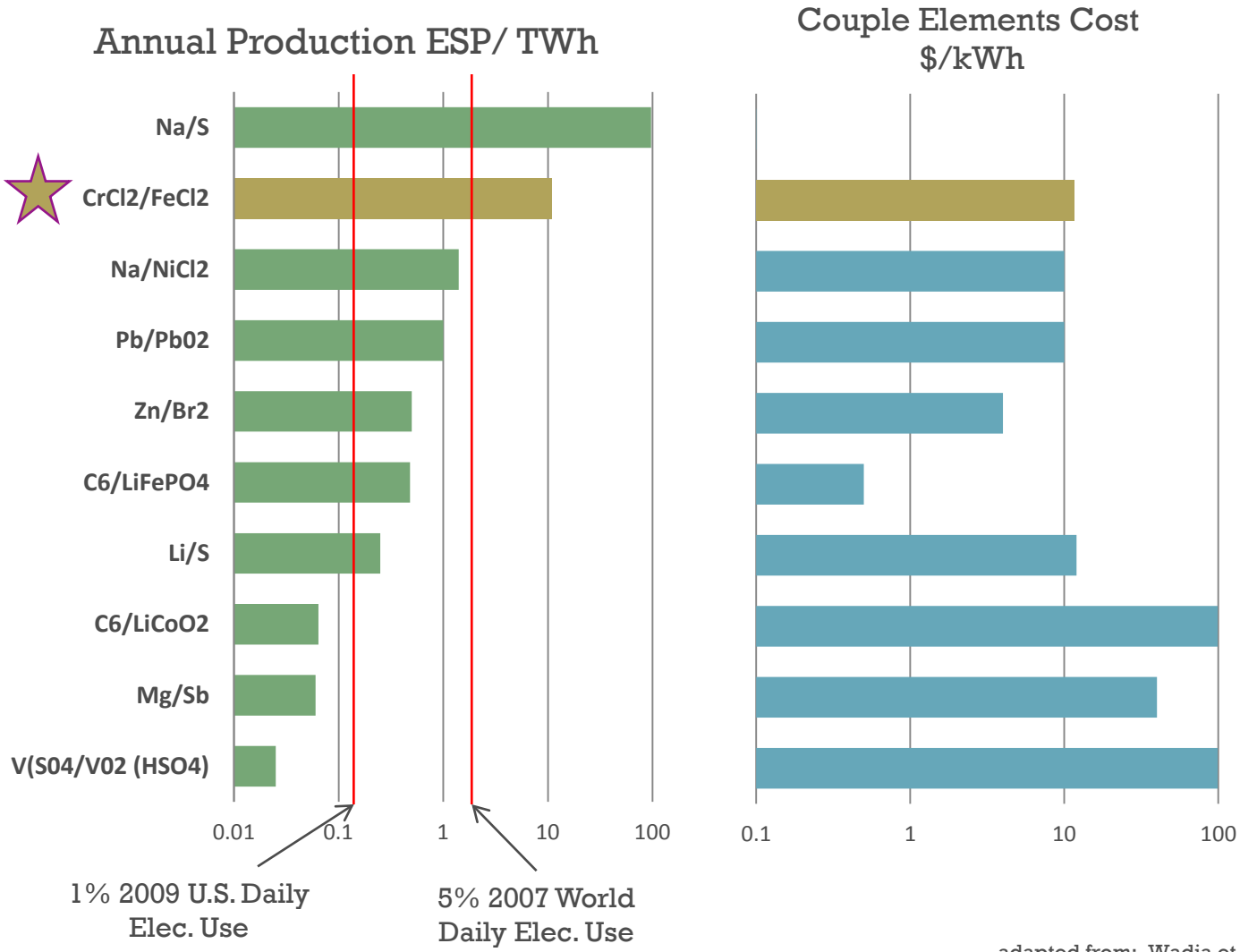
# Why Fe-Cr for Grid Scale?

- Abundant, high production volume = low cost



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

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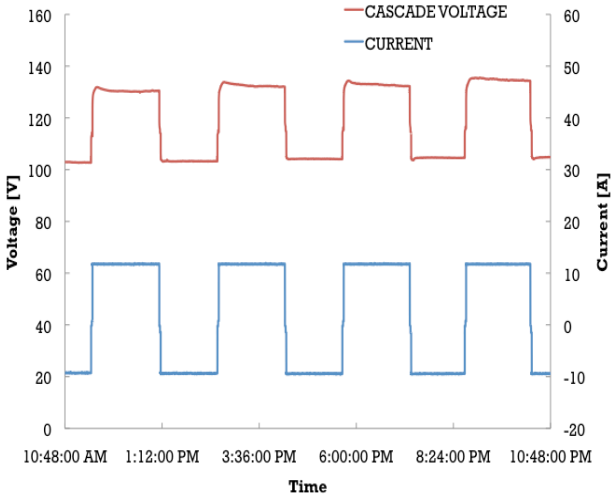
# Program Progress

- 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

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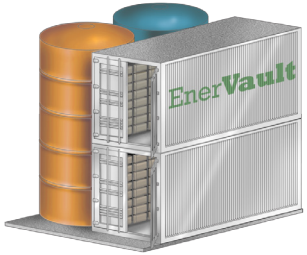
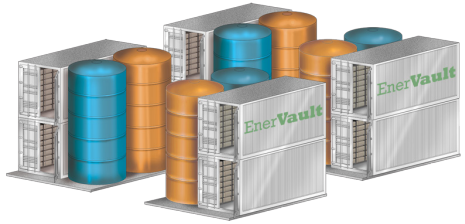
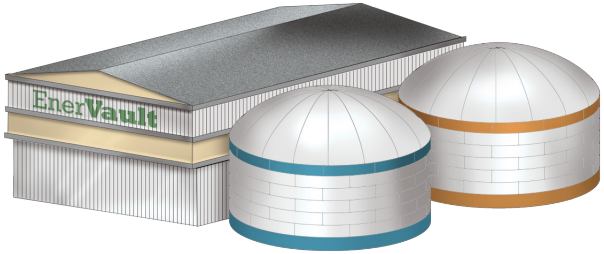
# Future Applications and Impact

- Modular, tailored solutions for multiple applications




| Market | Distributed Renewable Energy | Commercial & Industrial | Utilities and Grid |
|---|---|---|---|
| App's | Time Shifting | Demand Management<br>Extended Emergency Backup | Renewable Integration<br>Demand Management<br>T & D Deferral<br>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 |

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# 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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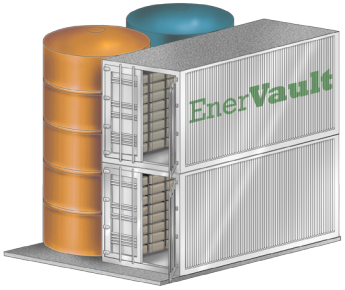


**Test System Development**

Able 2 kW

Bravo 5 kW

Charlie

Delta 7 kW

Echo 21 kW

**Project Support**

NYSERDA

California Energy Commission

U.S. Department of Energy – ARRA Storage Demo

EnerVault Corporation

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U.S. DEPARTMENT OF ENERGY

STATE OF CALIFORNIA ENERGY COMMISSION

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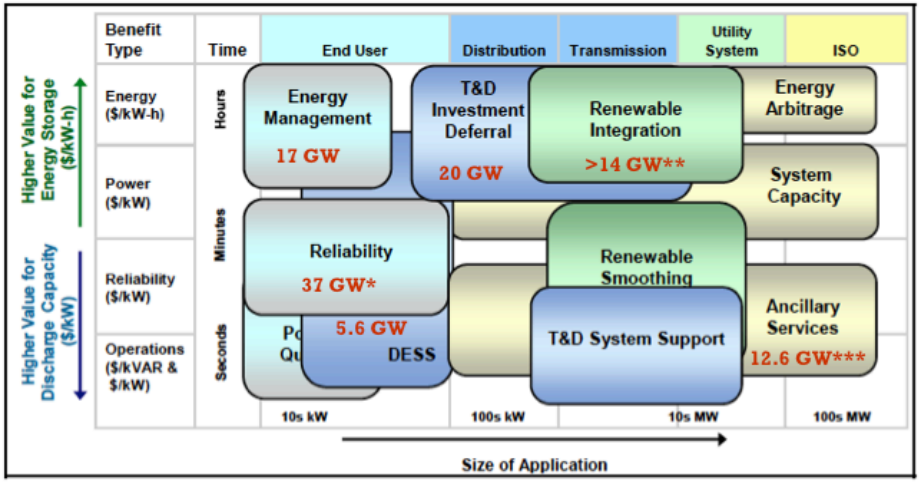
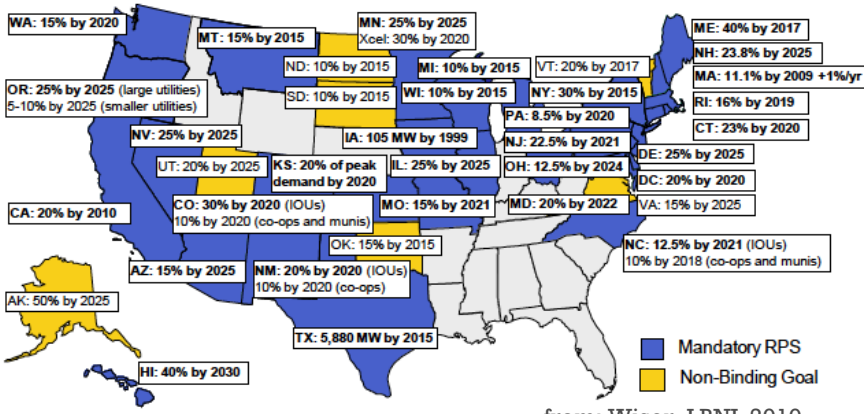
# Program Impact

- **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

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# 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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