Flow Battery Solution for Smart Grid Renewable Energy Applications

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Area of Interest

- Clean, renewable-energy-based National Smart Grid
- Energy storage
  - Safe, reliable, cost-effective
  - Utility-scale, national deployment
  - Scalable to specific power levels required by renewable energy technologies
  - Environmentally advantageous

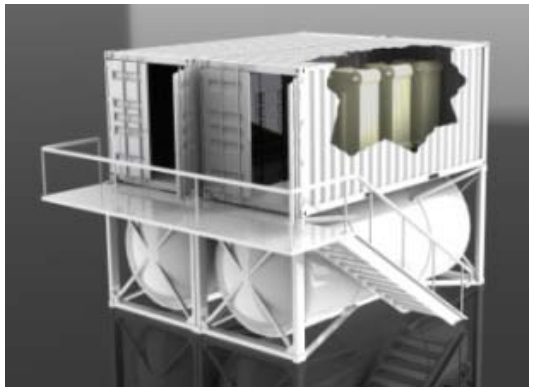
Problem

- Irrigation wants reliable, low cost power
  - Remote locations, critical demand concurrent with highest stress in grid

Approaches	Problems	Impact of Storage
Grid electric connection	Service (to remote loc.) Reliability, Cost	Shift demand off peak: cost down, reliability up
On-site diesel generation	Emissions, fuel cost, maintenance	None
Grid electric + PV	Low value of off-peak PV generation, utility demand charges	Energy costs reduced Reliability increased Grid emissions reduced
Diesel + PV	Emissions, fuel costs, PV offset limited by sun	Enabling Energy costs reduced Emissions reduced

Project Objectives

- Advance a technology that will become an essential building block of a renewable-energy-based Smart Grid
- Integrate an advanced, innovative Battery Energy Storage System with an intermittent renewable energy source

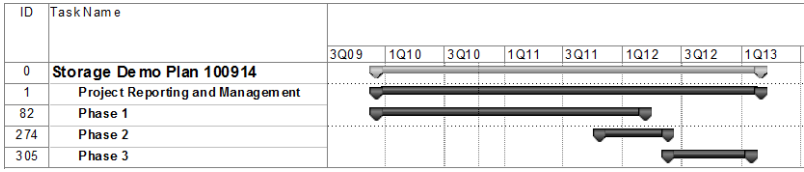


- Reduce electricity costs and environmental impacts for large energy users, such as agricultural irrigation

Project Description

- Scope: Demonstration of EnerVault's Vault-20 Battery Energy Storage System (250 kW, 1 MWh)
- Duration: Three years, through January 2013
- Result: Deployment of a Vault-20 beta system with a 180 kW dual tracking PV array in CA
- Team: Project team includes Montpelier Nut Company and JKB Energy

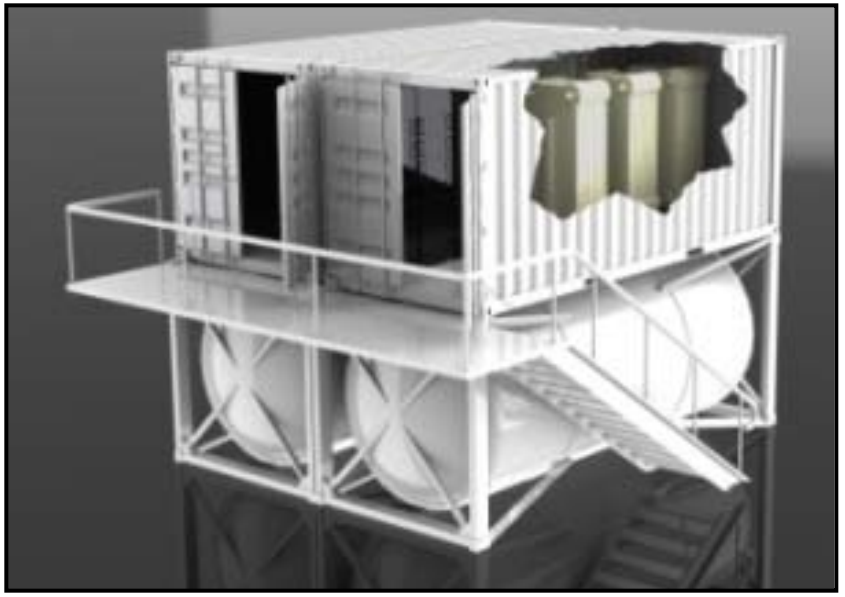
Project Phases

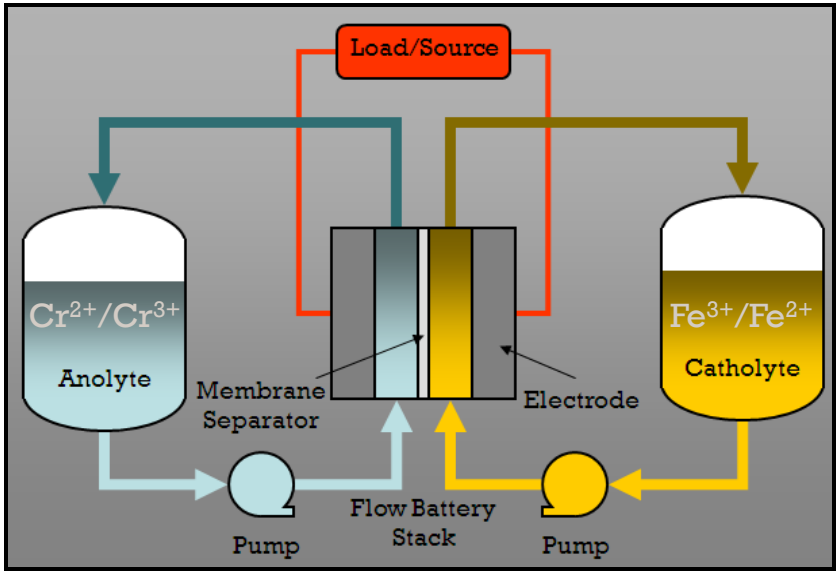


- Phase 1, Dec. 2009 – Oct. 2011
  - Develop EnerVault's energy storage technology into a 40 kW utility-scale system building block
  - Complete preliminary design of the Vault-20 system
- Phase 2, Oct. 2011 – May, 2012
  - Build 250 kW, 1 MWh Vault-20 beta system
    - Final design and full system integration
    - Power conditioning system, controls, and tanks
  - Complete off-site testing in Albuquerque, NM
- Phase 3, May 2012 – Jan. 2013
  - Commission and demonstrate Vault-20 system

Features & Benefits

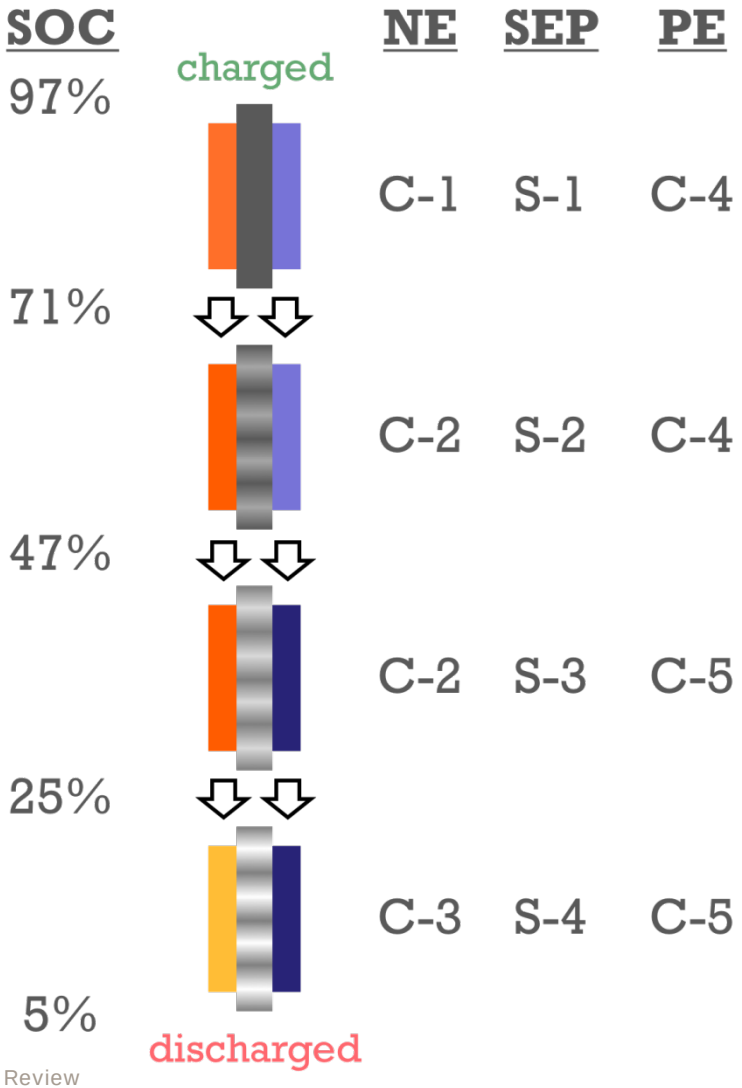
- Safety
  - Liquid reactants
  - Minimal vulnerability
  - No thermal runaway
- Reliability
  - Dissolved reactants
  - Less complex design
  - Simpler controls
- Cost Effectiveness
  - Low-cost design
  - Low-cost materials
  - Low-cost reactants





Known Chemistry, Radical Design

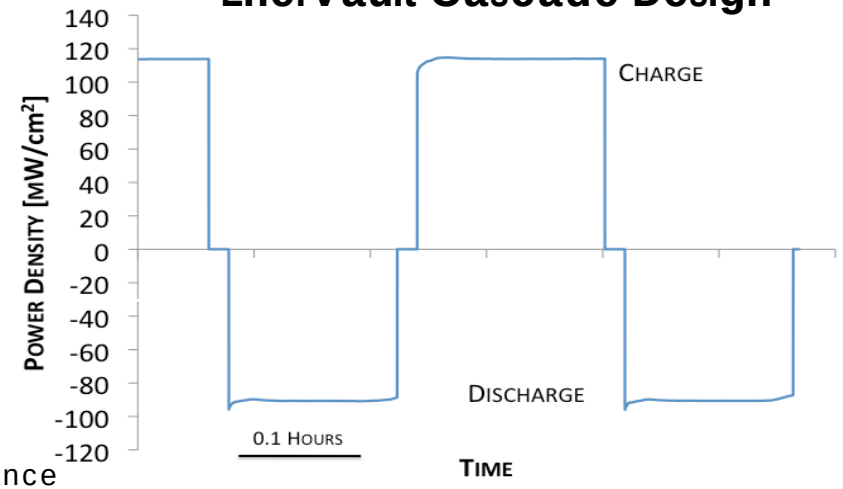
- Engineered Cascade
  - Developed by EnerVault
- US Patent # 7,820,321
  - USPTO Greentech program
- Distinctive features
  - Balances coulombic and voltaic efficiencies
  - Simplified controls
  - Steady DC voltage
  - Macroscopic state-of-charge indicator



Design Validation

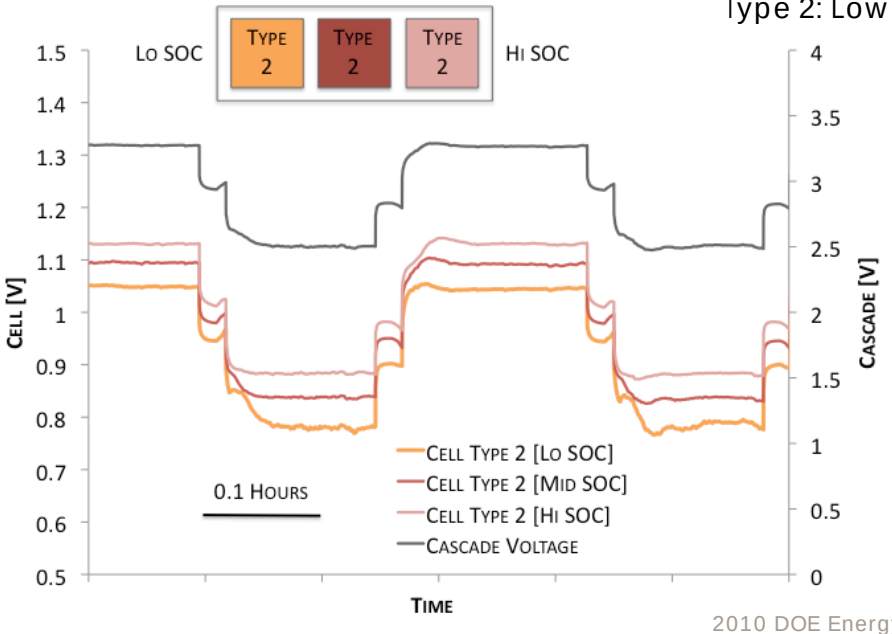
	Legacy Cell	Standard Cascade	EnerVault Cascade
Voltage Efficiency [%]	76	76	80
Energy Efficiency [%]	67	67	70

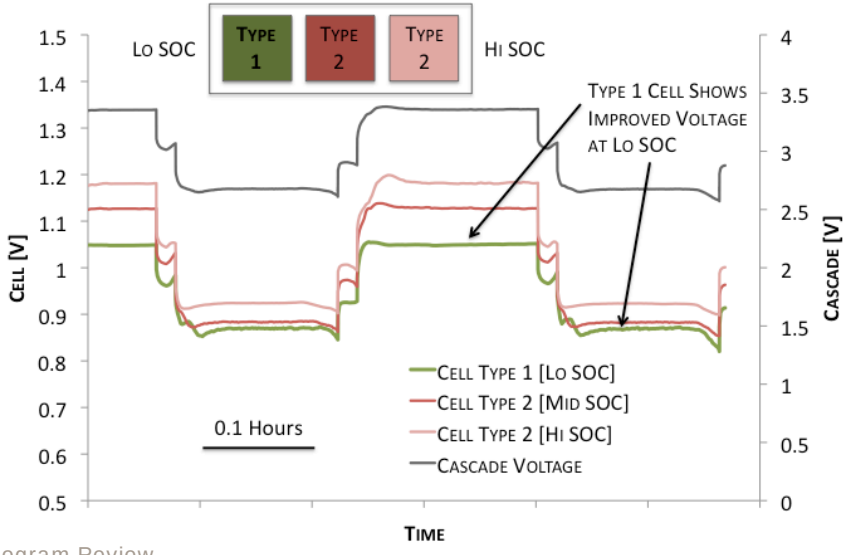
EnerVault Cascade Design



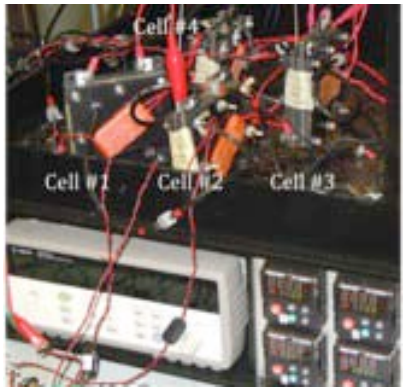
Legacy Design

Type 1: Low Resistance
Type 2: Low Crossover



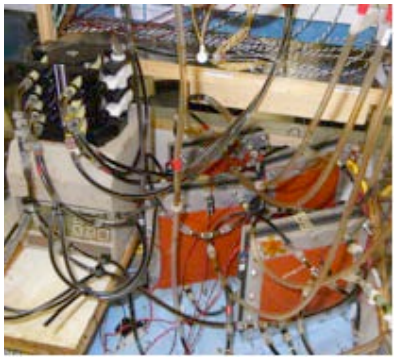


Progress



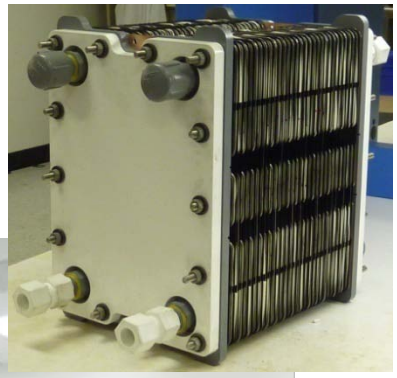
lab scale

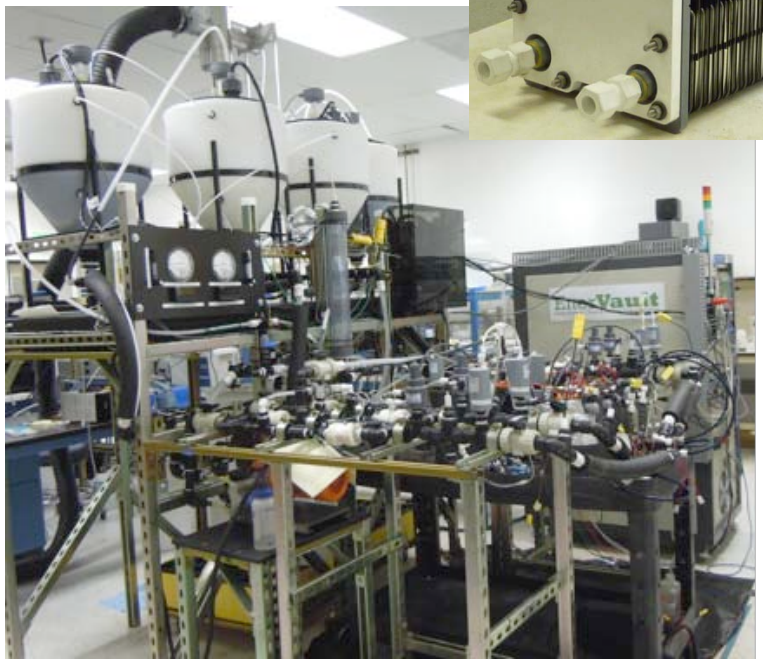
10x cell footprint



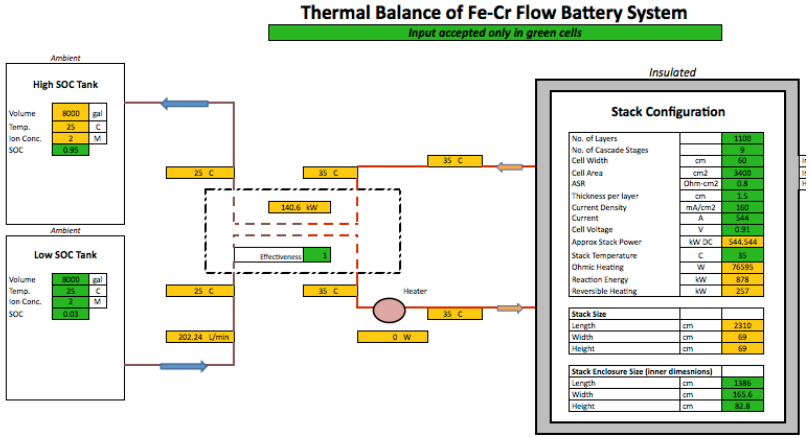
prototype scale

20x power





system simulator



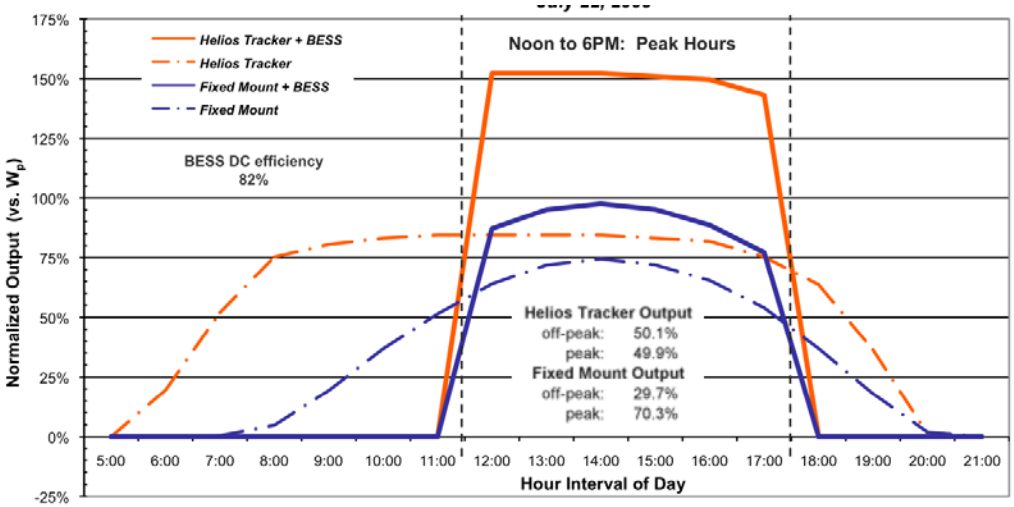
Benefits of Vault-20

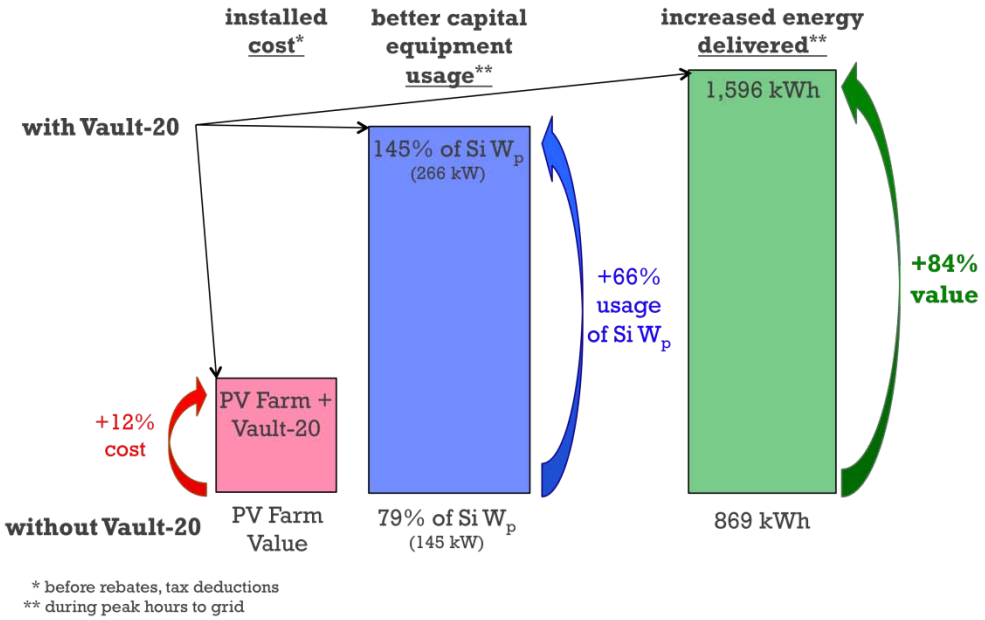
- Match for application
  - Thermally robust
  - Improved efficiency curve
  - Electrolyte is permanent asset
  - Low incremental cost of added kWh
- Potential annual benefits

  > $100,000 savings

  > 100 tonnes $(CO_2)_e$

  > 60,000 gallons H_2O

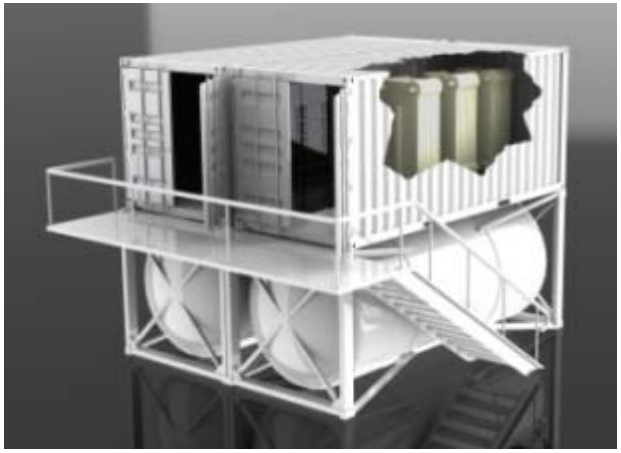




* before rebates, tax deductions
** during peak hours to grid

Summary

- Our project demonstrates the use of a radically-different flow battery technology in a large-scale renewable energy application
- EnerVault engineered cascade design validated
- Scale-up progressing according to plan
- Detailed project plan baselined; actual costs and progress are being captured
- Successful demonstration of the Vault-20 system in this application provides pathway to broad deployment for smart grid and renewable generation



Future Tasks

- Phase 1 Milestones

Milestone	Description	Date	Targets
✔ 4.4	Achieve Initial Performance Targets	5/30/2010	Achieve 0.8 kW/m^2
5.2	2-5 kW Prototype System Demo	2/1/2011	Achieve 2 kW at 70% Roundtrip Efficiency for 20 cycles
6.3	Demonstrate Full Scale Stack Design	5/31/2011	Achieve 1.0 kW/m^2
6.7	Operation of 40 kW Alpha stack for 1 month	10/20/2011	Achieve 85% DC Roundtrip Efficiency for 30 cycles

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Q & A