Sustainable Technologies of Renewable Energy Storage

Commercializing the CWRU Iron Flow Battery

A Technology with Promise for Commercial Utility Energy

Energy Storage and Integration Workshop – Emerging Technologies from the Region

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Case Western Reserve University
Great Lakes Energy Institute

Sustainable Technologies of Renewable Energy Storage

A strong and experienced technical team in place with commercialization support

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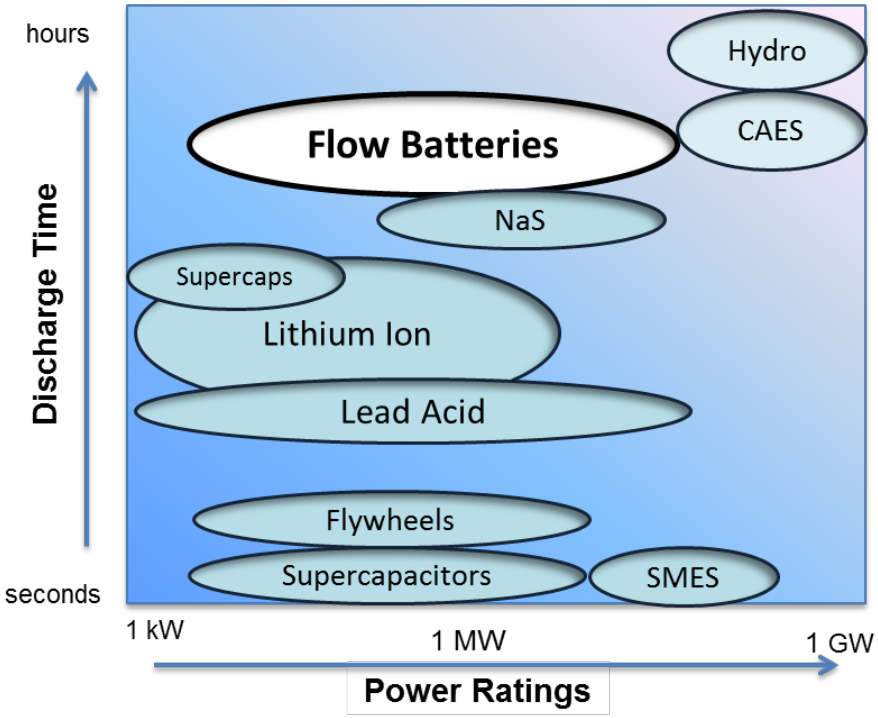
Tech Leadership	Prof. Robert F. Savinell and Prof. Jesse S. Wainright	Combined 60 years of electrochemistry, engineering, and materials experience
Technical Team	Stephen Selveston, Elizabeth Freund PhD students	Fundamental electrochemical measurements and design
	Andrea Burke and Enoch Nagelli, Postdocs	CFD modeling of electrode and stack design, cell design, testing and performance diagnoses
	Nick Sinclair, Research Engineer	Experimental measurements and testing, cost-performance modeling
T2M	Mike Allan	Technology transfer, IP protection, licensing manager

Large-Scale Energy Storage - a wide range of power and energy storage opportunities

	Benefit Type	Capacity (hrs)	Power (MW)
Electric Grid Scale	Load Following	1 – 4	1 – 500
	Reserve Capacity	1 – 2	1 – 500
	Supply Capacity	4 – 6	1 – 500
	Time Shift	2 – 8	1 – 500
Transmission & Distribution	Congestion Relief	3 – 6	1 – 100
	Upgrade Deferral	3 – 6	0.25 – 5
	On-Site Power	8 – 16	< 5 kW
	Time-of-use $ Mgt.	4 – 6	10^{-3} – 1
	Demand Charge Mgt.	5 – 11	0.05 – 10
Renewable	Time-Shift	3 – 5	10^{-3} – 500
	Capacity Firming	2 – 4	10^{-3} – 500
	Grid Integration	1 – 6	10^{-4} – 500



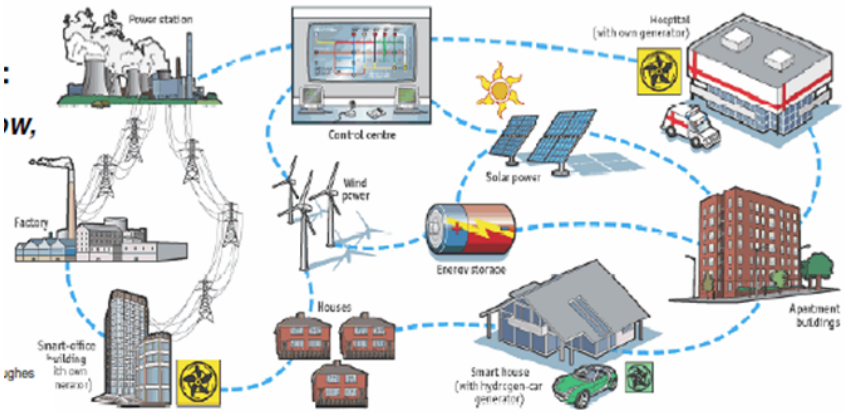
J. Eyer, G. Corey, Sandia Report, SAND2010-0815 (2010).
D. Rastler, EPRI Report 1020676 (2010).
P. Denholm, J. Jorgenson, et. al, NREL Report NREL/TP-6A20-5865 (2013).

Utility Energy Storage- a growing market with large value chain impact

Market Projections

> 350 GW projected market
> 4 hours of storage
< $250/kW; <$100/kWh

Global market $182M in 2014
Global market $6B by 2020**
Global market $9B by 2023



** GE report to Routers, June 26, 2015

VALUE CHAIN FOR ENERGY STORAGE

Materials /Minerals → **Design & Fab** → **Integrators** → **Utilities & Apps**

3M, DuPont Graftech, SGL

ITN, TDM, UTC, Tesla, Johnson Control

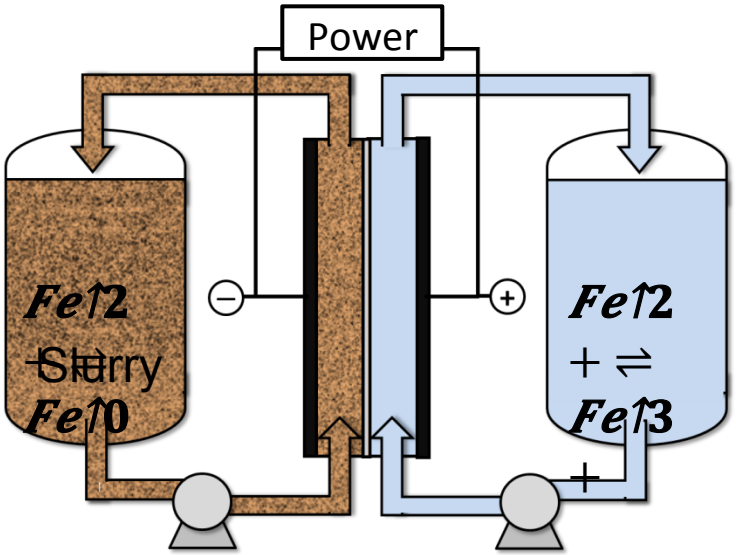
P-H, Rockwell, GE, Eaton, ABB, Siemans

FirstEnergy, FirstSolar, PJM, EPRI, AES

CWRU Iron Flow Battery

A promising, cost-effective, environmentally safe technology

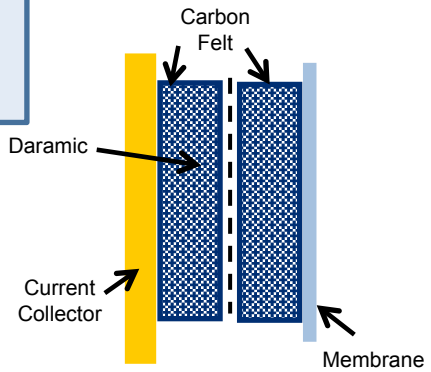
- ***Expected cost effective operation***
  - Low CAPEX
  - High round-trip efficiency
- ***Cost effective, sustainable materials***
- ***PH neutral chemistry***
  - safe to manufacture
  - safe to install & maintain
- ***System simplicity***
- ***Early Proof-of-Concept and fundamental research funded by DOE and ARPA-E***



$$2Fe\uparrow 2+ \rightleftharpoons 2Fe\uparrow 3+ +2e\uparrow -$$

$$Fe\uparrow 2+ +2e\uparrow - \rightleftharpoons Fe\uparrow 0$$

$$E\uparrow 0 = 1.21\ V$$



U.S. DEPARTMENT OF ENERGY

arpa·e

CWRU HYBRID IRON FLOW BATTERY LABORATORY DEMONSTRATION ACCOMPLISHMENTS

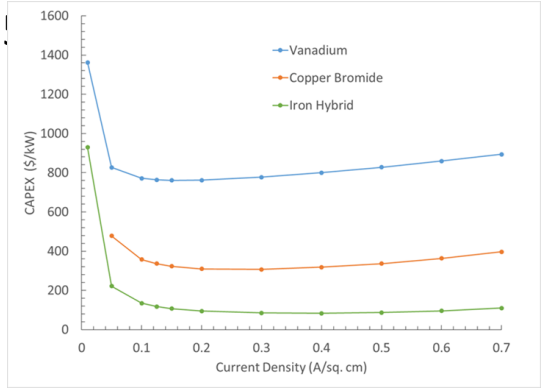
DOE/OE PROGRAM TARGETS

- VE of 80% and CE of 95% at 100 mA/cm^2
- Capacity 200 mAh/cm^2
- <$250/kW and <$125/ kW-h
- Long lifetime-10 to 20 years

IP: Patent application pending in US and Internationally
Disclosures filed on high performance membrane, electrolyte re-balancing, and alternative chemistries

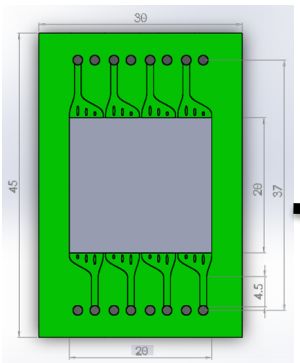
LAB DEMONSTRATED WITH PROTOTYPE CELLS 1/10 OF COMMERCIAL SIZE

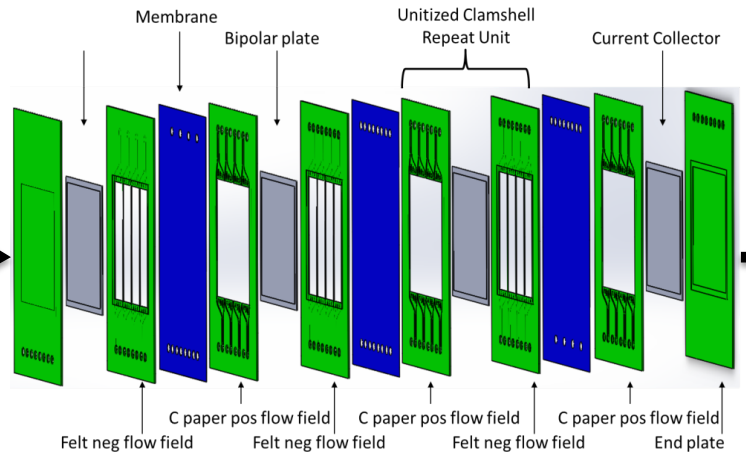
- VE of 75% and CE of 95% at 100 mA/cm^2
- Capacity 400 mAh/cm^2
- ~$105/kW and $26/Kw-h for four hours battery (PNNL Capex model)
-



CWRU Flow Battery Prototype Development Plan

GAP: Demonstrate target performance in full size single cell and then in stack, identify first markets, firm commercialization plan, raise capital





Module Prototype

500 kW DC system @ 80% efficiency

Single Cell Clamshell, 40 watt

25 Cell Stack, 1 kW DC

<u>Integration</u>
500 kW DC system

FIRST GENERATION 4-HOUR HYBRID

ARPA-E Slurry Electrode Development

SECOND GENERATION DE-COUPLED

CWRU Flow Battery Prototype Development

Next step opportunities under discussion

- ✓ NEWCO with venture funding
- ✓ Partnerships
- ✓ Leverage funding through ARPA-E and Ohio Third Frontier
- ✓ Start-up with SBIR grants

Regional Partnerships

Product designers, manufacturers, membrane and carbon material providers, renewable energy suppliers, integrators, users and customers

Summary

STORES

Sustainable Technologies of Renewable Energy Storage

- A large and growing stationary energy storage market
- The CWRU Iron Flow Battery Technology-Low cost and efficient energy storage, scale-able, safe, and environmentally benign
- Next steps plan for scale-up, testing, and commercialization
- Questions?

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