High Energy Storage Capacity Low Cost Iron Flow Battery

Developing a Slurry Electrode

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ARPA-E — Changing What's Possible

E3L @ CWRU

All-Iron Flow Batteries:

- Single, low-cost active element - Iron
- Mild pH, non-toxic electrolyte
- Able to operate with inexpensive microporous separators
- **Iron is readily available domestically**
- Positive: $2Fe^{2+} \xrightarrow{charge} 2Fe^{3+} + 2e^- \quad E^o = +0.77V \ vs \ NHE$
- Negative: $Fe^{2+} + 2e^- \xrightarrow{charge} Fe^0 \quad E^o = -0.44V \ vs \ NHE$

Slurry Electrodes:

- Slurries are made by mixing conductive particles into the electrolyte.
- While charging, iron is plated onto the particles
- The particles carry the plated iron out of the active cell and are stored externally
- **Decouples power and energy capacity**

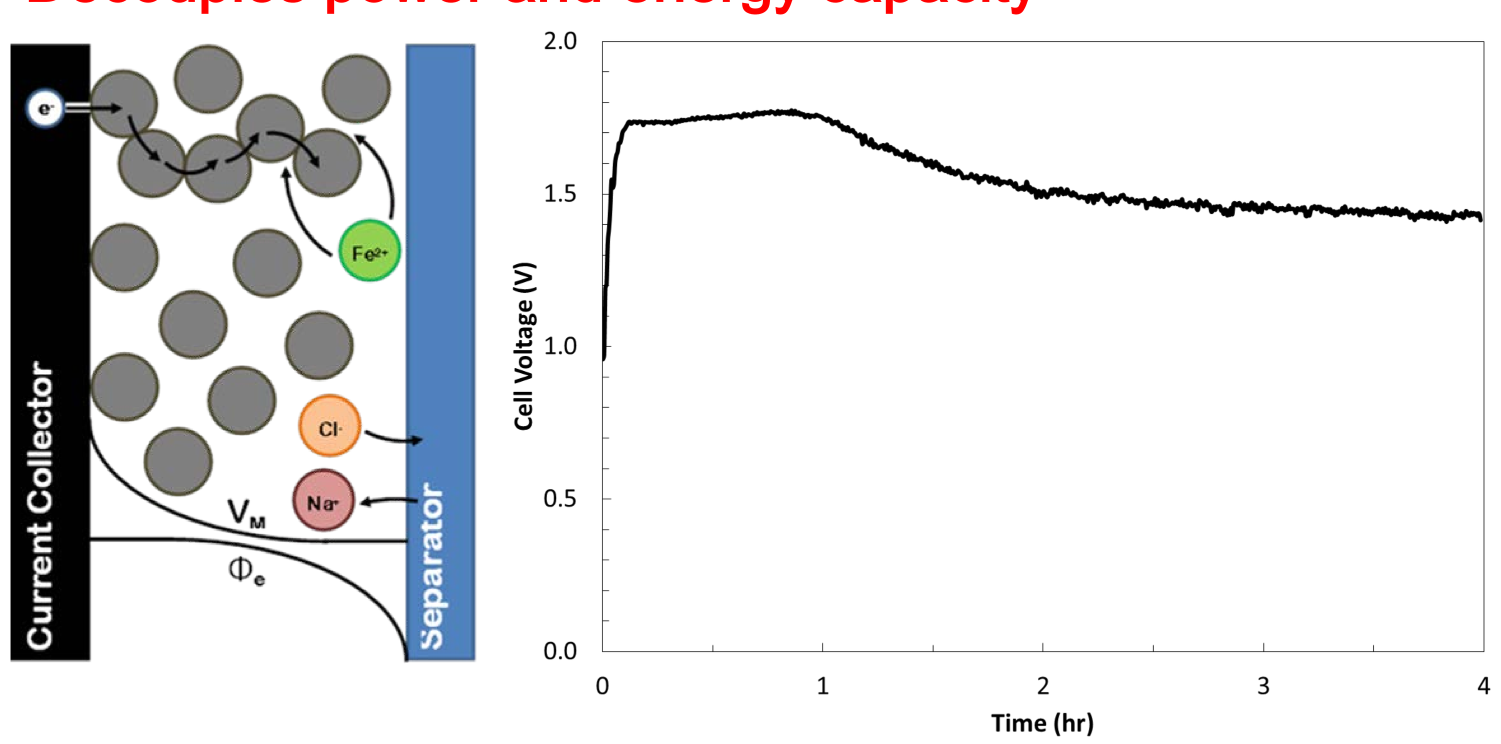


Figure 1: Cell voltage during initial charge at 200 mA/cm^2
Metalizing the carbon reduces the overpotential.

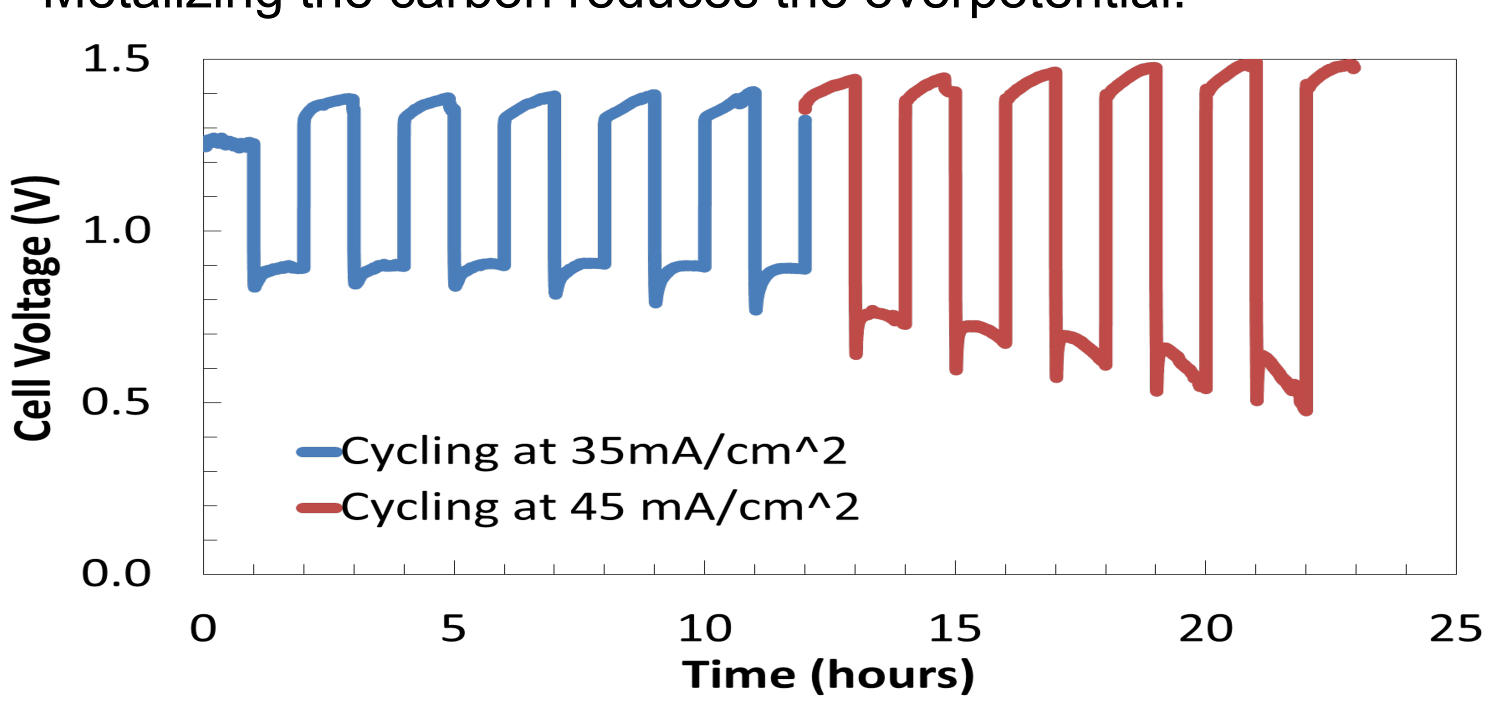


Figure 2: Cell voltage while cycling

Goals of the ARPA-E Program:

- Optimize slurry electrode
  - Slurry stability, viscosity, conductivity
- Demonstrate operating prototype slurry electrode
  - Voltaic and coulombic efficiencies
- Model full scale stacks to estimate system performance
- **Develop strategic partnerships with expertise for scale-up, manufacturing, supply chain development, system integration, and testing**

Results of the ARPA-E one year seed program:

- Cost: \$105/kW and \$26/kWh
  - Achievable at 0.2 A/cm^2 and \$700/st Carbon
- Demonstrated stable, conductive, shear thinning slurries
- Parasitic losses due to pumping losses and shunt currents are < 2% for a 7 kW – 30 cell stack
- Negative Electrode Overpotential <100mV at 200 mA/cm^2 on charge
- Plating Capacity of >350 mAh Fe / g carbon feasible without loss of slurry stability

Future work:

- Increase the electronic conductivity to promote more favorable current distribution and lower ohmic overpotentials
- Utilize more cost effective particles
- Scale and test 400 cm^2 prototype cell

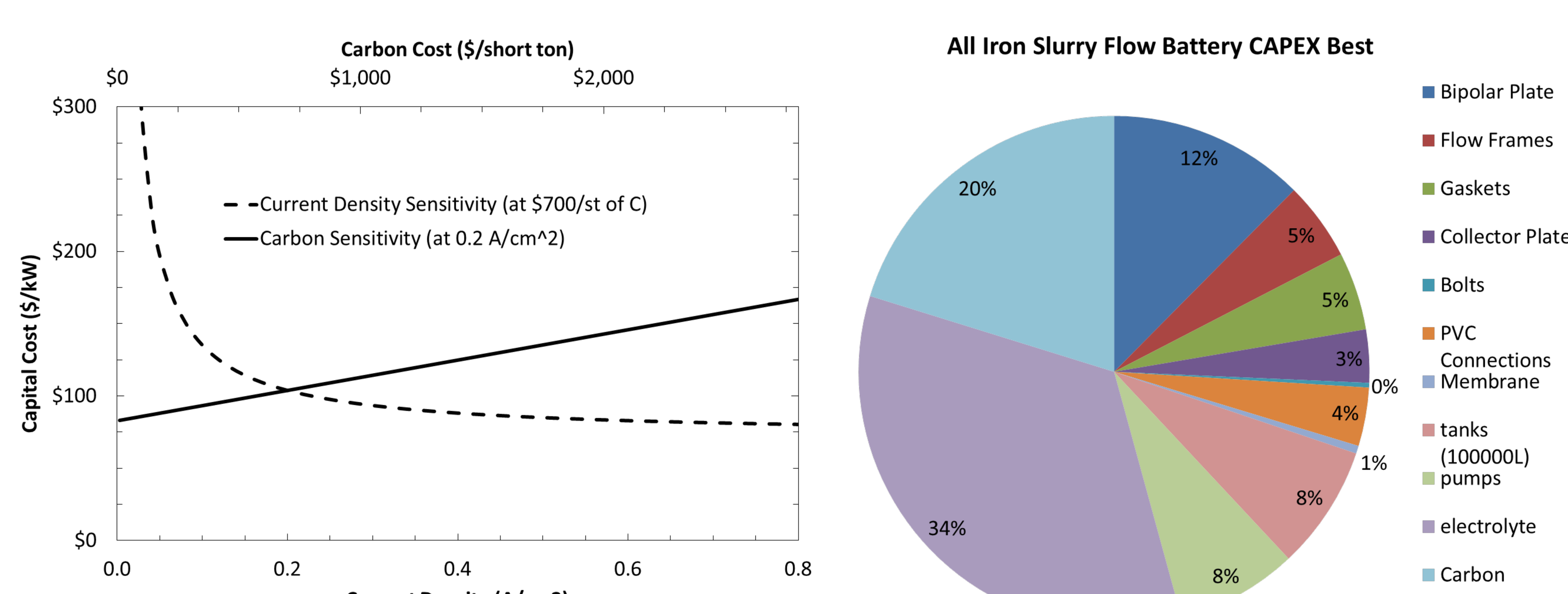
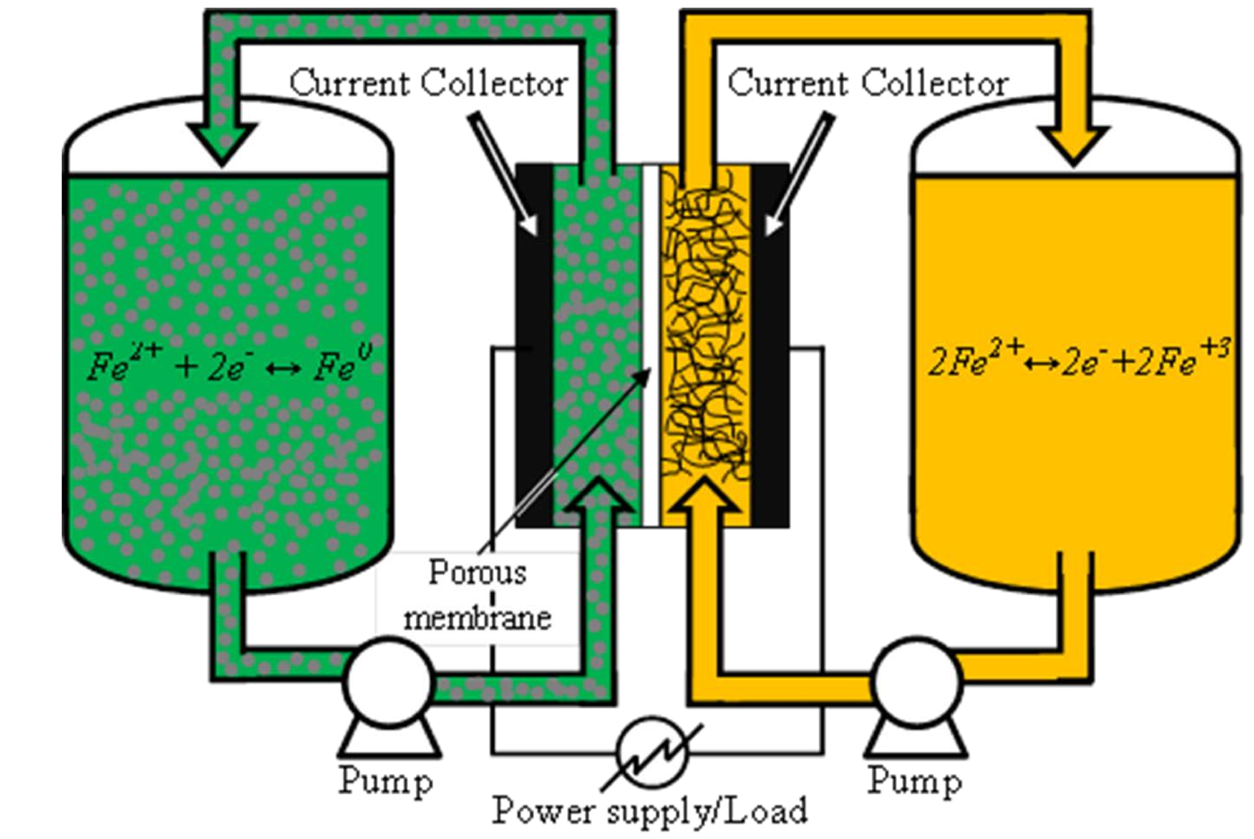


Figure 3: Estimated capital cost of a 1 MW / 4 MWh all-iron battery with slurry electrodes on both sides.



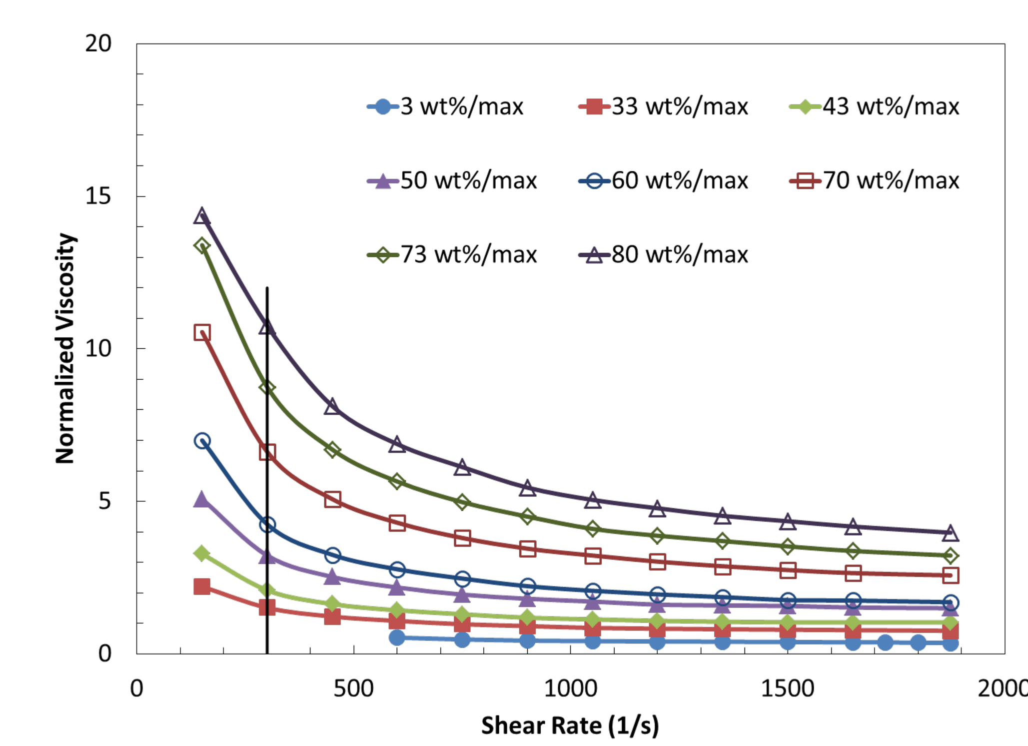


Figure 4: Slurry viscosity normalized to base electrolyte. The slurry shows shear thinning behavior. Typical shear is between 300-1200 s^{-1}.

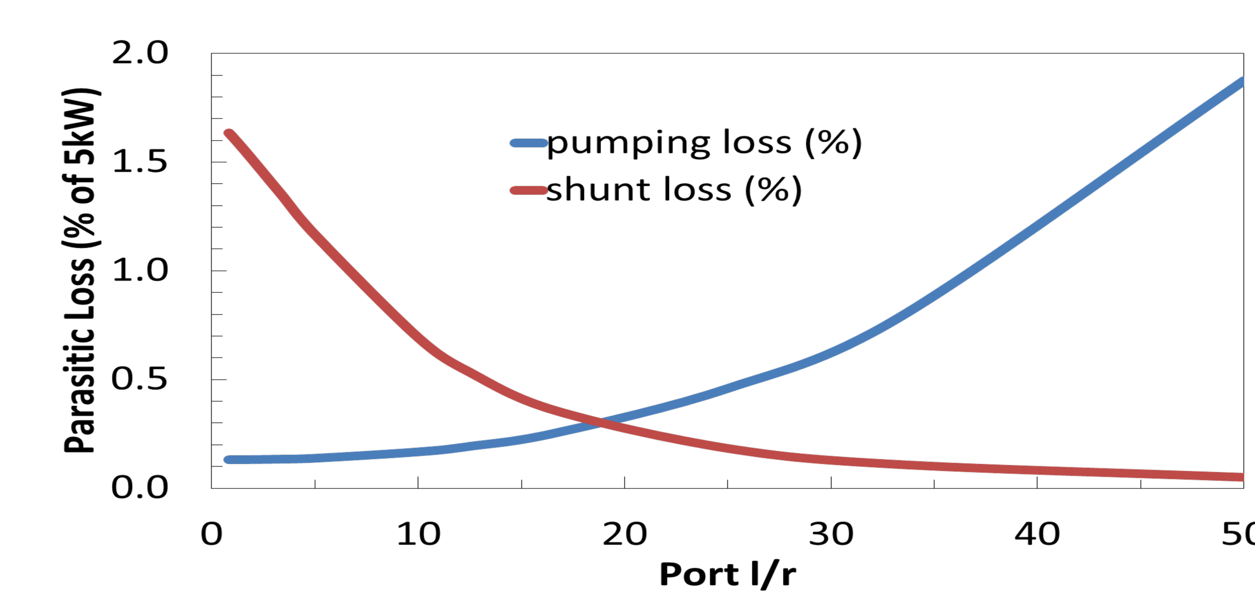


Figure 5: Shunt current and pumping losses. Model of a 30 cell stack, each 1000 cm^2. Stack power ≈ 5 kW at 140 mA/cm^2.

Acknowledgements

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