Electrical Energy Storage
R&D at PNNL

Vincent Sprenkle
2012 DOE-Energy Storage System Program Review
September 26, 2012
PNNL Electrical Energy Storage (EES)

R&D strategy

Technology Transfer

Grid Analytics
- Roles of storage in US grids
- Value, locations, targets

EES Technologies
- Novel redox flow batteries
- Next gen Na-batteries
- Low cost, long life Li-ion
- New concepts, emerging technologies

Crosscutting science
- Computer Modeling
  - Mass/charge transport
  - Electrochemical
  - Flow, thermal, …
- Advanced diagnostic study, NMR, TEM, etc.
  - Basic chemistry
  - Materials structure
  - Physical properties
- Electrochemical study
  - Electrochemical activity
  - Reaction kinetics
  - Performance

Cost Analysis
- Cost and performance requirements

Academic/National Lab/Industrial Collaborations
Next Generation Redox Flow Batteries

Developed next generation redox flow battery (RFB) that can demonstrate substantial improvement in performance and economics, to accelerate its commercialization and market penetration, via collaborations with industries and universities.

**FY12 accomplishments**
- Licensed new V/V redox chemistry for commercial development.
- Developed Shunt Current Model and low pressure drop stack design.
- Demonstrated 1 kW/1kWh V/V Redox flow battery
  - 1.1kW / 1.4 kWh
  - 82% efficiency at 80mA/cm²
  - Projected cost < $560 kW at 1MW/4 MWh scale.
- Breakthrough in development of low-cost V/V membrane/separator

**Levelized cost ($/kWh)**

- New generation electrolytes of improved energy density and stability
- Low cost membrane/separators of improved selectivity and/or conductivity
- Optimized electrodes/current collectors of minimized polarization and resistance
- Novel cell and stack designs to reduce shunt current and double current density capability (>80 mA.cm⁻²)
- Optimized balance of plant and system to further improve round trip efficiency (>75%)
- Field demonstration and grid integration to further optimize RFBs and applications
- Mass-production and commercialization

**Via collaboration with industries and universities**

- **Short term**
  - Combined cycle gas turbine
- **Long term**
  - New generation electrolytes of improved energy density and stability
  - Low cost membrane/separators of improved selectivity and/or conductivity
  - Optimized electrodes/current collectors of minimized polarization and resistance
  - Novel cell and stack designs to reduce shunt current and double current density capability (>80 mA.cm⁻²)
  - Optimized balance of plant and system to further improve round trip efficiency (>75%)
  - Field demonstration and grid integration to further optimize RFBs and applications
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**Component**
- **Cell**
- **Stack**
- **System**

**S. Kim (Poster) - 9/26**
**V. Sprenkle – 9/28 – 11:10am**
**W. Wang – 9/28 – 11:25 am**
Sodium (Na) - Metal Halide Batteries

Develop novel Na-metal halide batteries that can meet cost and performance targets for renewable integration and grid applications, via introduction of planar designs and new minor chemistries and interfaces.

**FY12 accomplishments**

- Demonstrated stable battery performance at <200°C and c/3 in 3 cm² format. Lower operating temperature leads to lower capital and operating costs.
- Developed novel catholyte for < 200°C operation.
- Completed development of thin-electrode supported electrolyte with low resistance.
- Developed cost effective Zn based cathode chemistry to replace expensive Ni in 3 cm² format.
- Overcome Na wetting issues to enable < 200°C operation.
- 3 patent applications.

**Comparison of Na-metal halide battery microstructure after 280°C and 175°C operation resulting in enhanced durability at lower temperature.**
Unique Li-ion for community storage

Develop unique Li-ion batteries that are made from low cost (<$250/kWh), high cycle life (>5,000 deep cycles) electrode materials so that can meet, in particular, the cost and performance requirements for community storage.

**FY12 accomplishments**

- Second batch LiFePO$_4$/Li$_4$Ti$_5$O$_{12}$ based 18650 cells fabricated (K2 Energy).
- Initial rate and cycling performance collected.
- LiMn$_{0.9}$Fe$_{0.1}$PO$_4$, LiFeBO$_3$, and Li$_2$FeSiO$_4$ materials synthesized and electrochemically characterized.
- Zn$_2$GeO$_4$ anode with specific capacity of ~1,000mAh/g was developed with Penn State University.

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D. Choi – 9/27 – 10:55 am
Grid Storage and Cost Analysis Projects

Analysis of the current and future grid to determine impact of energy storage solutions and to determine where R&D dollars can be most effectively directed to advance state-of-the-art storage solutions to meet cost/performance targets.

FY12 accomplishments

- Completed National Assessment of Energy Storage: Phase 1: WECC
- Developed a candidate battery performance testing protocol for grid applications
- Developed components cost model for Redox Flow storage technology which:
  - Integrates shunt current and pumping losses
  - Optimizes operational parameters such as flow rate, SOC range, power density performed to yield lowest cost/kWh for 1 MW, 0.25 MWh, 1 MWh and 4 MWh systems

Detailed component cost breakdown V-V Gen 2 Redox Flow Battery, 1MW/4 MWh

M. Kintner-Meyer (Poster) – 9/26
V. Viswanathan – 9/28 – 9:45 am
M. Kintner-Meyer – 9/28 – 2:00pm
V. Viswanathan – 9/28 – 11:40 pm
**Na-ion battery**

Discover novel material structures that allow for facile Na$^+$ transport at RT and develop low cost Na-ion batteries that can demonstrate satisfactory performance.

**FY12 accomplishments**
- Demonstrated >80% capacity retention in 10000 cycles
- Investigated monolith carbon electrode materials as the cathode for Na-ion Batteries

>80% capacity retention in 10000 cycles
Acknowledgements

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Energy Storage Staff at PNNL:

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Cui Jun, Jin Yong Kim, Xiaochun Lu, Guosheng Li, Kerry Meinhardt, Dave Reed, Brent Kirby, …

Jun Liu, Yuyan Shao, Yuliang Chao, M. Vijayakumar, …

Michael Kintner-Meyer, Vish Viswanathan, …