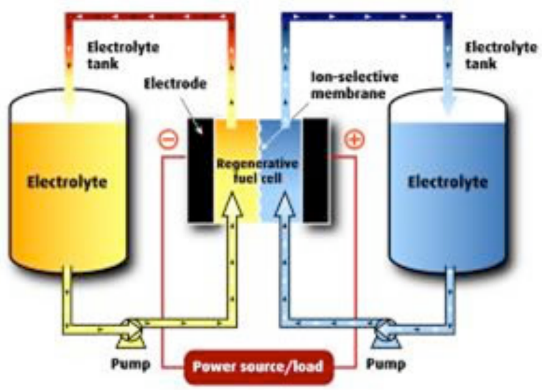
Redox Flow Batteries

Thomas Zawodzinski

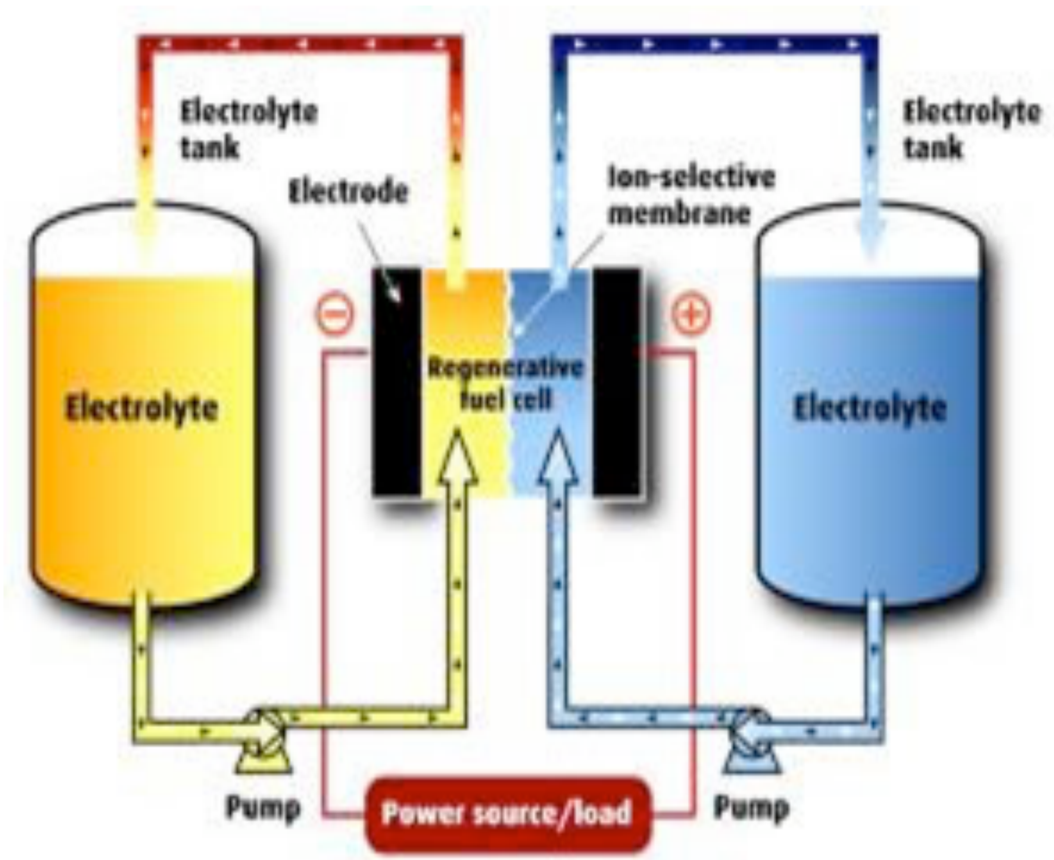


Power

Energy

Figures Courtesy of Electrosynthesis

Redox Flow Systems

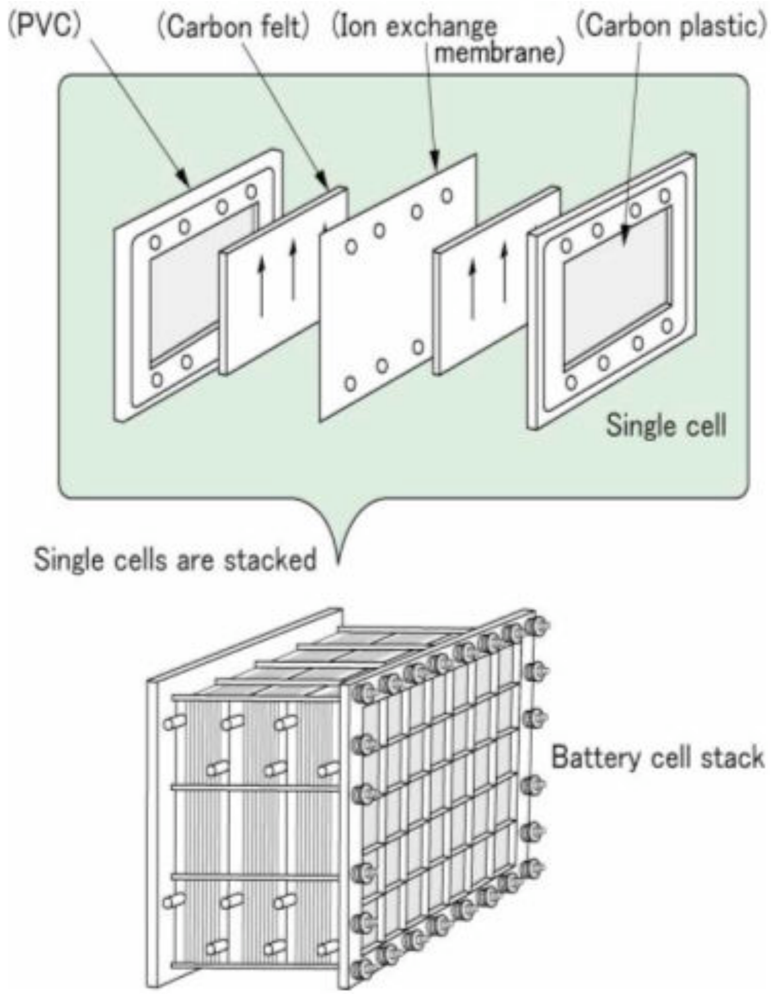


Favorable Attributes

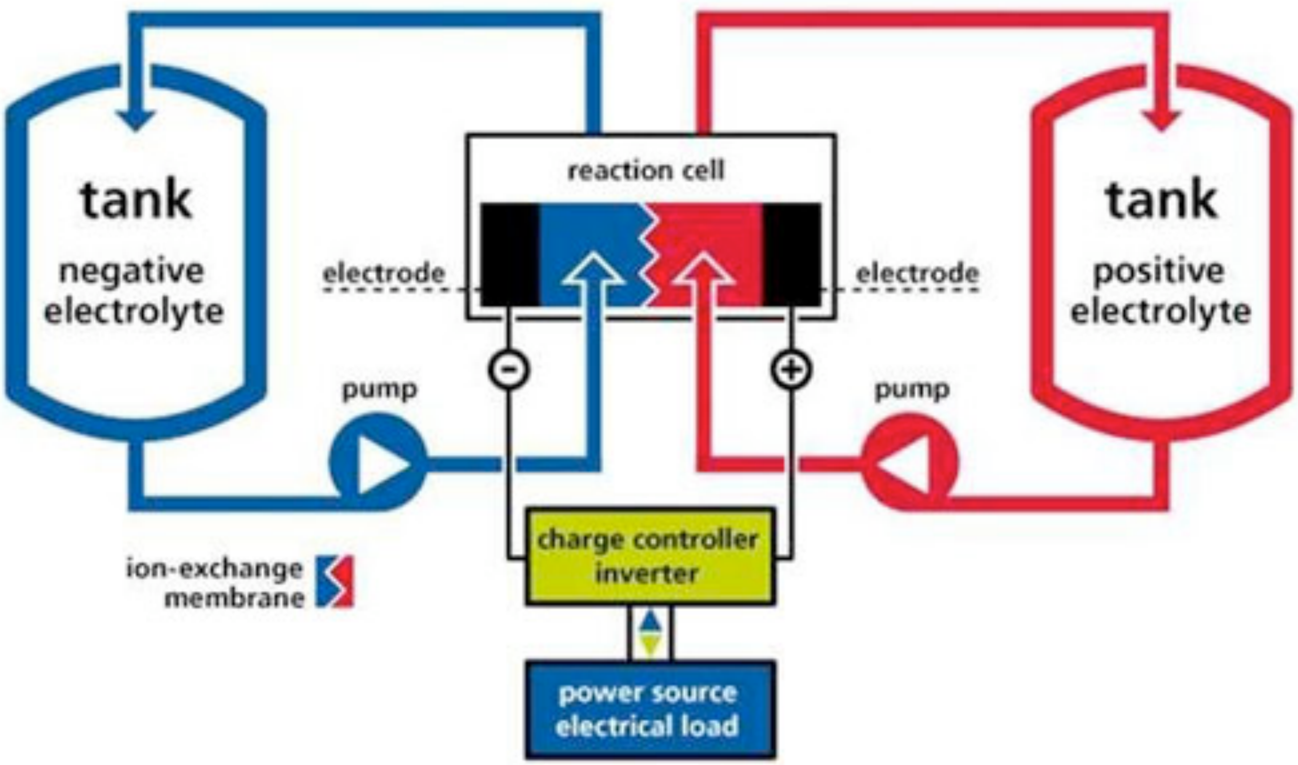
- ***Cost***
- ***Scalability***
- ***Efficiency***
- ***Longevity***
- ***Safety***

Conversion technology similar to PEM fuel cells

Basic Structure of RFB



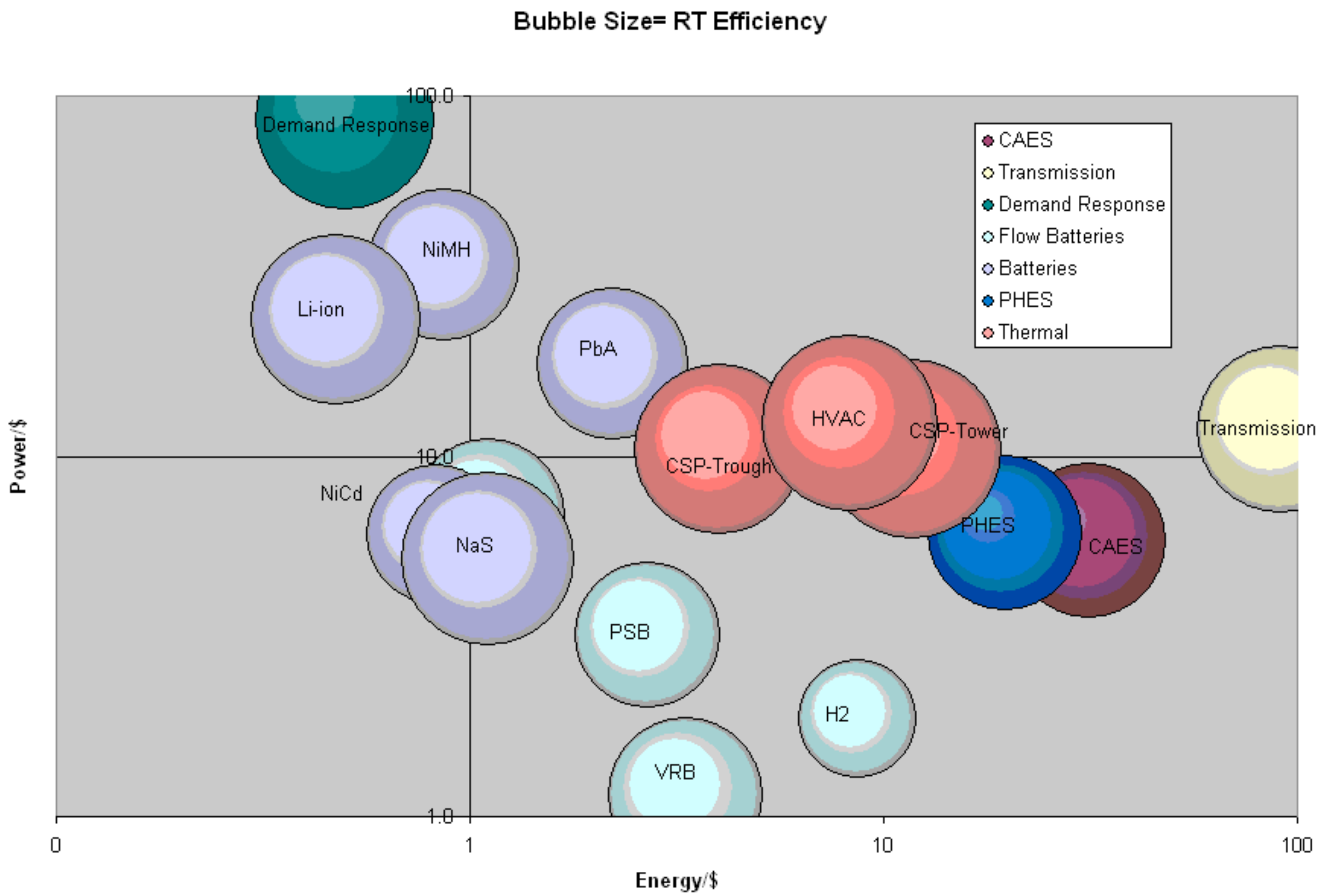
Keep in mind that this is a system!



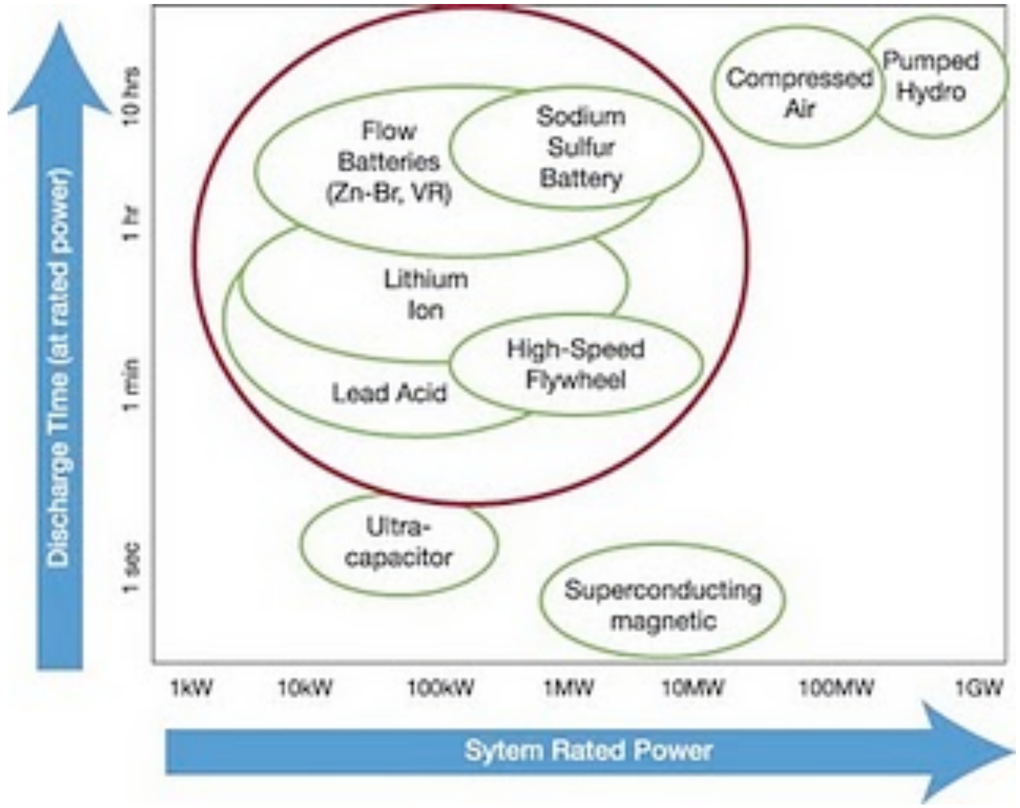
RFB chemistry

- *There are many types of RFB*
  - *Vanadium, Fe/Cr, Fe/Ce, Zn/Br_2, H_2/Br_2*
  - *New players, esp. using air electrodes*
  - *Note that they have several characteristics*
    - *Simple, inorganic redox couples*
    - *Simple, usually aqueous electrolytes*
- *VRBs*
  - *Positive electrode (VO_2^+/VO^+)*
  - *Negative electrode (V^{2+}/V^{3+})*
  - *Electrolyte: Sulfuric acid (~5M)*

Where RFBs stand today…

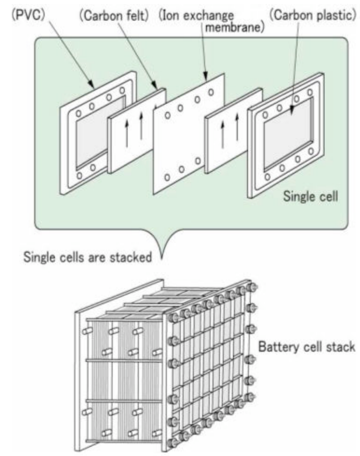


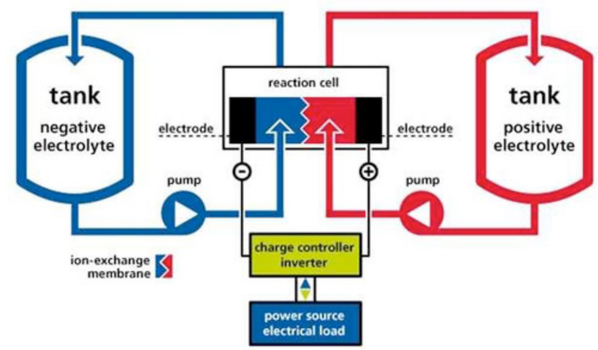
Where RFBs stand today…



RFB State of the Art: What needs work?

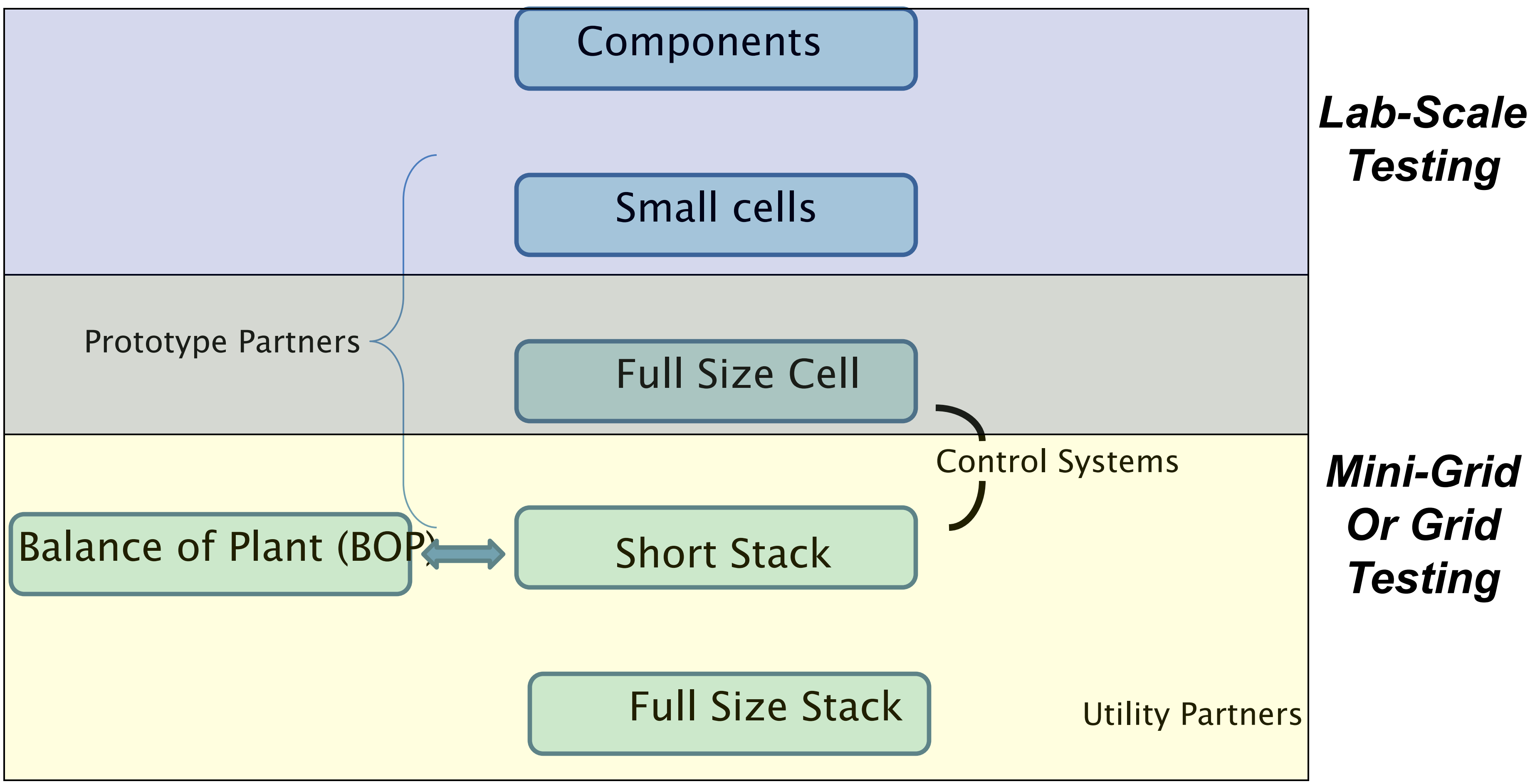
- ***Cell resistance:*** ***electrolyte, cell design issues***
- ***Redox couples:*** ***high voltage, solubility, reversibility, 'cross-over'***
- ***Stacks:*** ***seals, shunt currents, manifolds***
- ***Power electronics:*** ***control strategies, devices***
- ***Tanks:*** ***increased energy density***





ORNL taking holistic approach

Critical needs for RD &D at several levels
Build from experience with PEM FCs



Core elements: What we are working on…

- *Improved Cell Design to minimize electrolyte resistance*
- *Cell testing to reveal critical technology limitations*
- *Materials and Chemistry development*
  - *Membranes, electrolyte solutions, electrodes, redox couples*
- *Accelerated durability testing*
- *Extensive use of modeling at all stages*
- *Short stack development for 'small-grid' setting*
- *Power electronics to increase energy conversion efficiency*
- *Advanced storage methods - higher energy density*

Membranes/Electrolytes

Many Membranes Developed for FCs

- *Conductivity: controlled by water, ion content*
- *Cross-over: typically controlled by partitioning*
- *Durability: Both oxidizing and reducing conditions*

Will a non-aqueous system ever make sense?

- *Positive: increased voltage possible; multivalent ions*
- *Negative: even lower conductivity, COST, poor process fluids/safety*

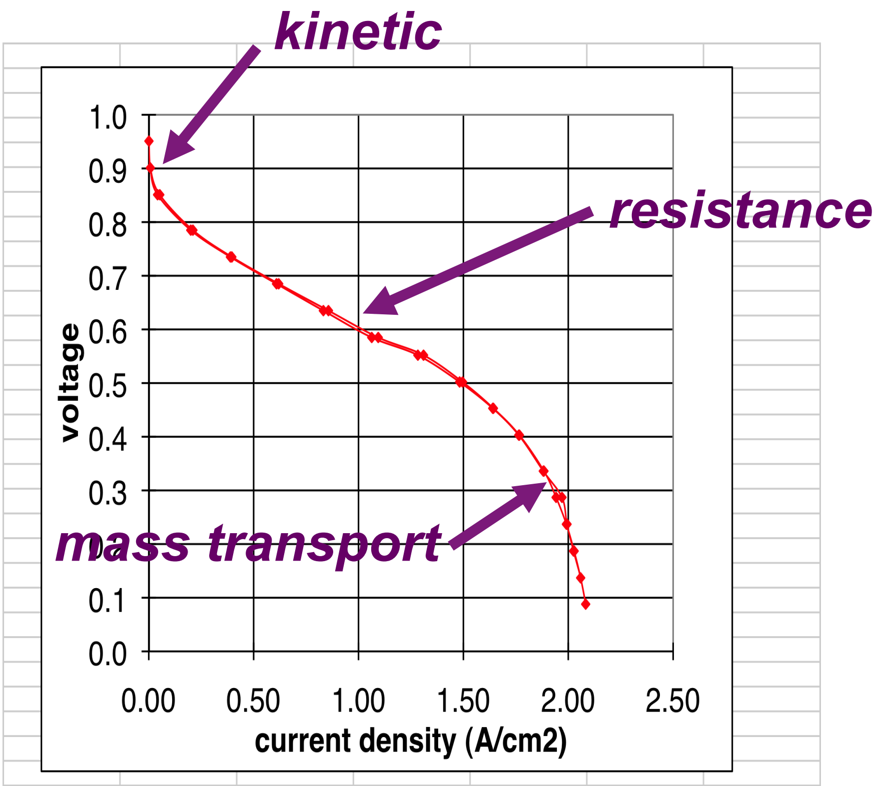
Melanie Moses-DeBusk

Testing for Insight
Workhorse Approach

Testing drives innovation in components and systems

- *New materials and processes inside cell/stack*
  - *Understand rates, mechanisms, interrelationship with storage*
  - *Systematic unraveling of key limiting issues*
- *Improvements in balance of plant and electrical elements*
  - *Understand cell 'transfer function'*
- *Full understanding of performance characteristics under realistic operating scenarios*
  - *Scaling up*

Performance in Flow Systems:
Polarization Curves



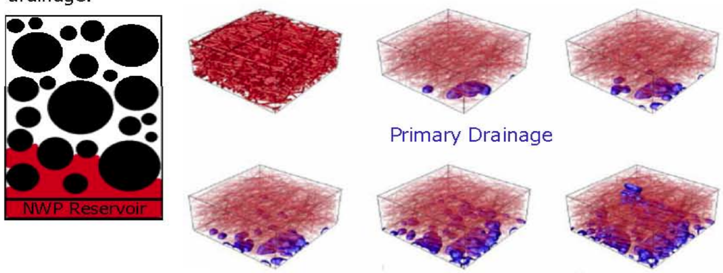
We separate and measure (both charge, discharge):

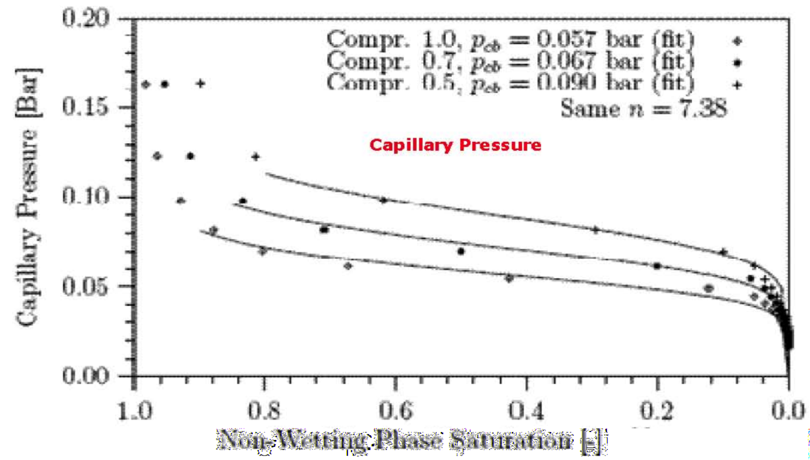
- *Electrode polarization for each electrode*
- *Membrane resistance*
- *Electrode ionic/reagent mass transport resistance*
- *GDL mass transport resistance*

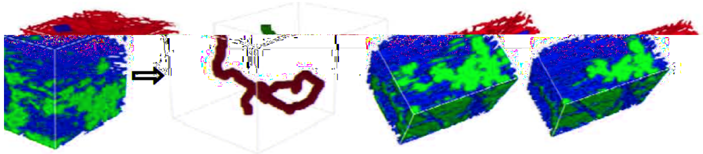
To be augmented by impedance tests as well as ex situ component tests

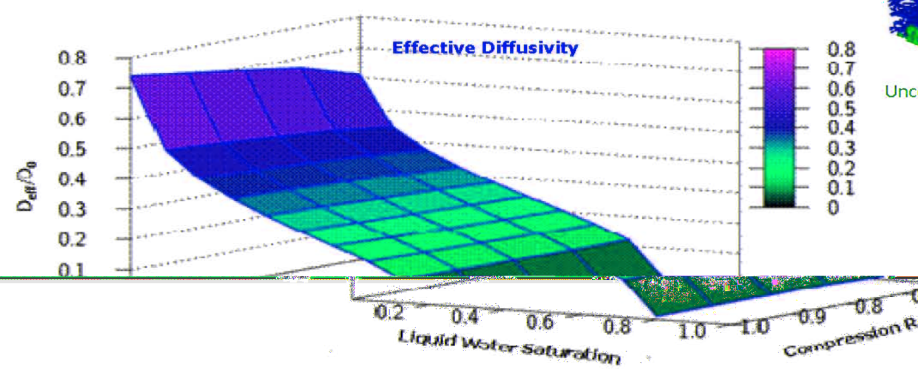
Modeling for Electrode Design

Pore Morphology Model (PMM):
- Relies on morphological decomposition of the 3-D digital image of the porous microstructure;
- Determines the pore space accessible to the invading phase using the pore radius as the ordering parameter corresponding to a specified pressure during drainage.









* P. P. Mukherjee *et al., under review.*

Partha Mukherjee

Thanks!

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