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Low Cost Large Scale PEM Electrolysis for Renewable Energy Storage

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Organization: Proton OnSite

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Project ID: PD090

Overview

Timeline

- Project Start: 19 June 2010
- Project End: 18 Aug 2012
- Percent complete: 40%

Barriers

- Barriers addressed
  G: Capital Cost
  H: System Efficiency

Table 3.1.4. Technical Targets: Distributed Water Electrolysis Hydrogen Production [a, b, c]

Characteristics	Units	2003 Status	2006 Status [c]	2012 Target	2017 Target
Hydrogen Cost	$/gge	5.15	4.80	3.70	<3.00
Electrolyzer Capital Cost [d]	$/gge $/kW	N/A N/A	1.20 665	0.70 400	0.30 125
Electrolyzer Energy Efficiency [f]	% (LHV)	N/A	62	69	74

Budget

- Total project funding
  - DOE share: $1,000,000
- Planned Funding for FY12
  - DOE share: $500,000

Partners

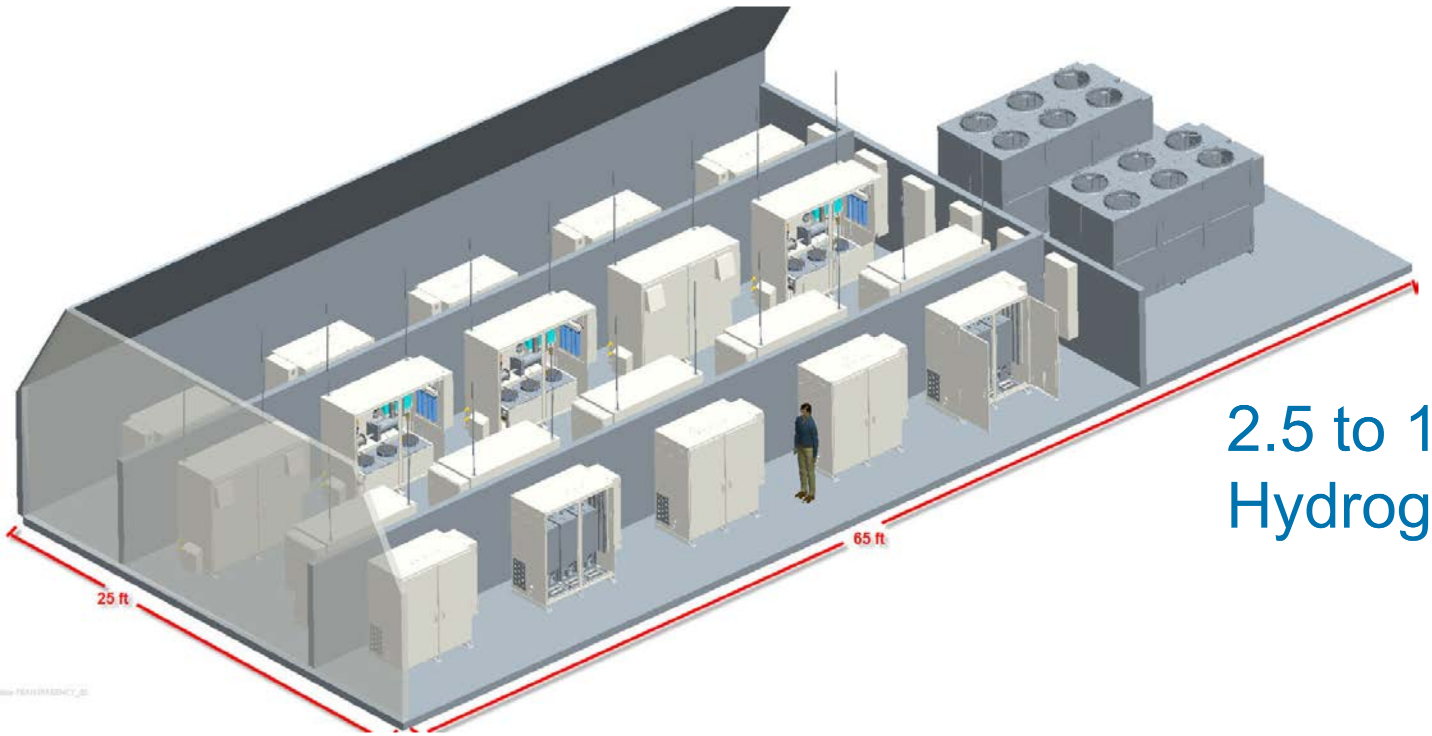
- 3M
- University of Wyoming

Relevance: Hydrogen Value Proposition

- Stored H_2 can drive multiple revenue streams
  - Transportation fuel
  - High value chemical streams
  - Green production of fertilizer
  - Regeneration of electricity through fuel cell use
  - Supplement to natural gas for higher efficiency
- Easily scalable; can independently scale charge, discharge, and storage capability
- Centralized and distributed options to capture energy currently not being utilized

Relevance: 50,000 kg/day concept

- Renewable energy growing rapidly world-wide in both wind and solar
- Need a continuum of options and hybrid solutions including grid-scale H_2 production



2.5 to 10 MW PEM Hydrogen Plant Concept

Relevance: Overall Cost of Electrolysis

- Precious metal costs at 50,000 kg/day are prohibitive at current loadings
  - Goal: Reduce by order of magnitude
- Operating costs driven by efficiency
  - Oxygen overpotential and membrane ionic resistance drive 90% of stack efficiency losses
  - Goal: Increase catalyst activity by 10x
  - Goal: Decrease membrane thickness by 50%
- Balance of plant not yet defined at centralized scale
  - Goal: Develop conceptual plant

Relevance: Project Objectives

- Identify optimal anode catalyst composition through combinatorial exploration
- Reduce catalyst loading through improved processes and NSTF structures
- Demonstrate 1000 hours system operation at >69% efficiency
- Develop 50,000 kg/day concept design
- Perform cost and environmental analysis

Approach
Task Breakdown

- Task 1.0 Project Kickoff
- Task 2.0 MEA Optimization
  - 2.1 – Catalyst Composition Optimization
  - 2.2 – MEA Performance Evaluation
  - 2.3 – Electrode structure and catalyst utilization
  - 2.4 – Estimation of Efficiency
- Task 3.0 Scale-up of MEA Configuration
  - 3.1 – Process Development for Wider MEA Format
  - 3.2 – Fabrication and Test of Larger MEA Format
- Task 4.0 50,000 kg/day Conceptual Design
- Task 5.0 Cost Analysis and Environmental Impact

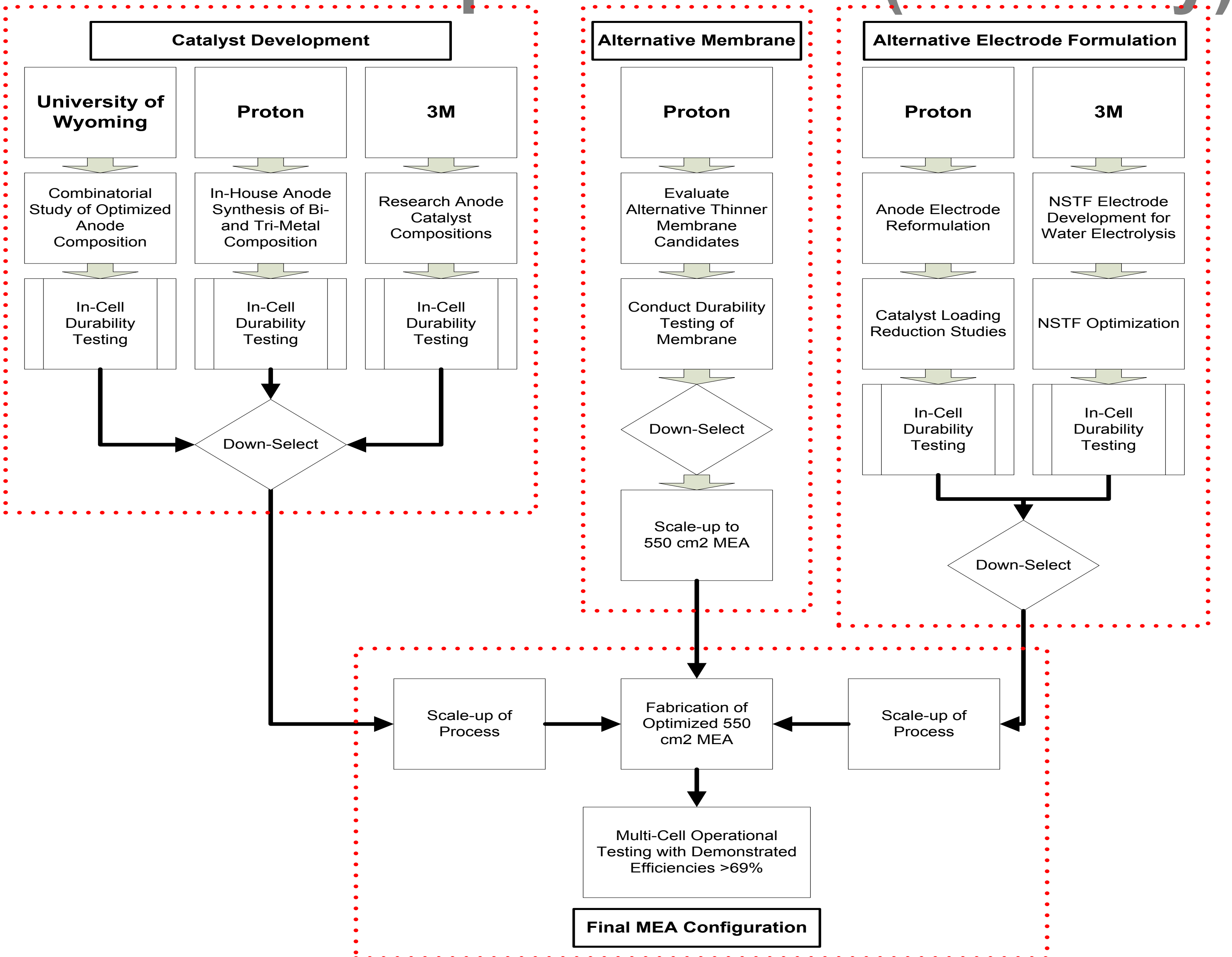
Technical Accomplishments

Task	Task Description	Progress Notes	Completion
1.0	Project Kickoff		100%
2.0	MEA Optimization	• Developed ink formulation for 50% catalyst loading reduction • Combinatorial synthesis set up	30%
3.0	MEA Configuration Scale Up	• Tooling procured	15%
4.0	50,000 kg/day Concept	• System components identified • Preliminary costs established • Component sizing completed	80%
5.0	Cost Analysis/ Environmental Analysis	• Pending completion of Task 4.1	

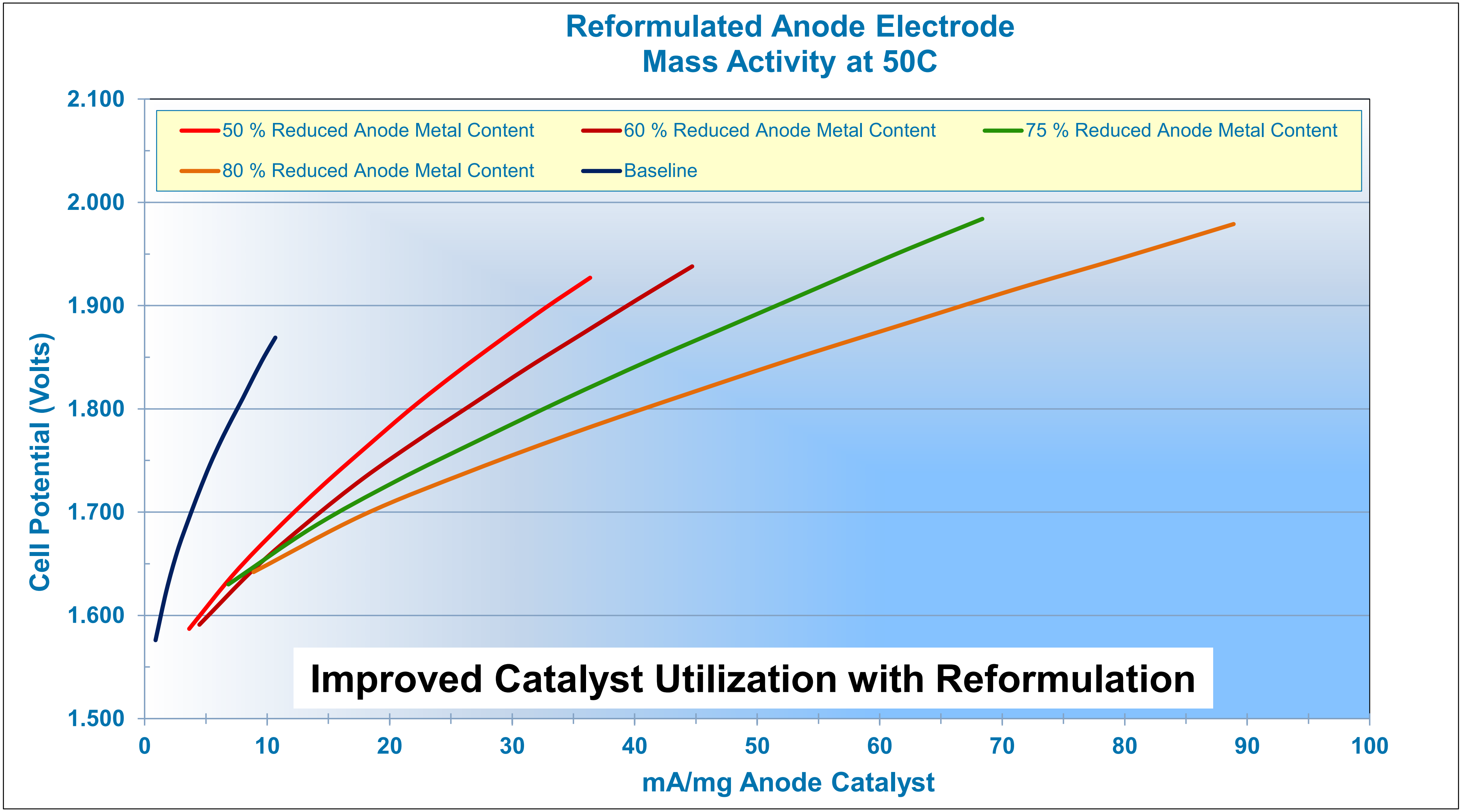
Technical Accomplishments
Task 2.0: MEA Optimization

- Increased electrochemical efficiency and cost-reductions through multiple approaches
  - **Proton:** Reformulation of electrode ink, enabling reduced catalyst loadings through better utilization
  - **University of Wyoming:** Combinatorial study of oxygen evolution catalyst for efficiency optimization.
  - **3M:** Development of NSTF (Nanostructured Thin Film) electrode for further loading reductions on optimized composition.
- All efforts will be combined with thinner alternative membrane.

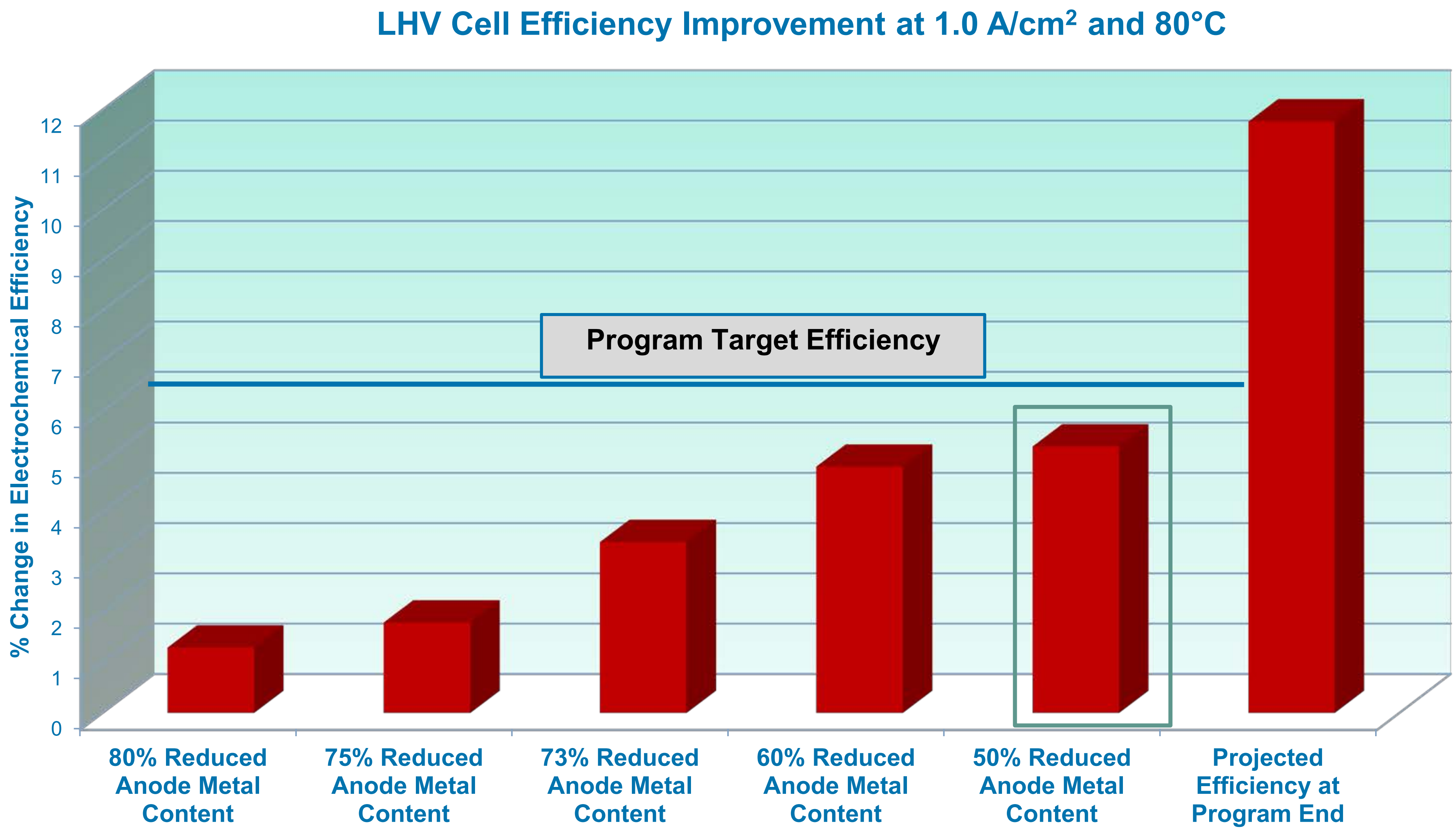
Technical Accomplishments
Task 2.0: MEA Optimization (Pathway)



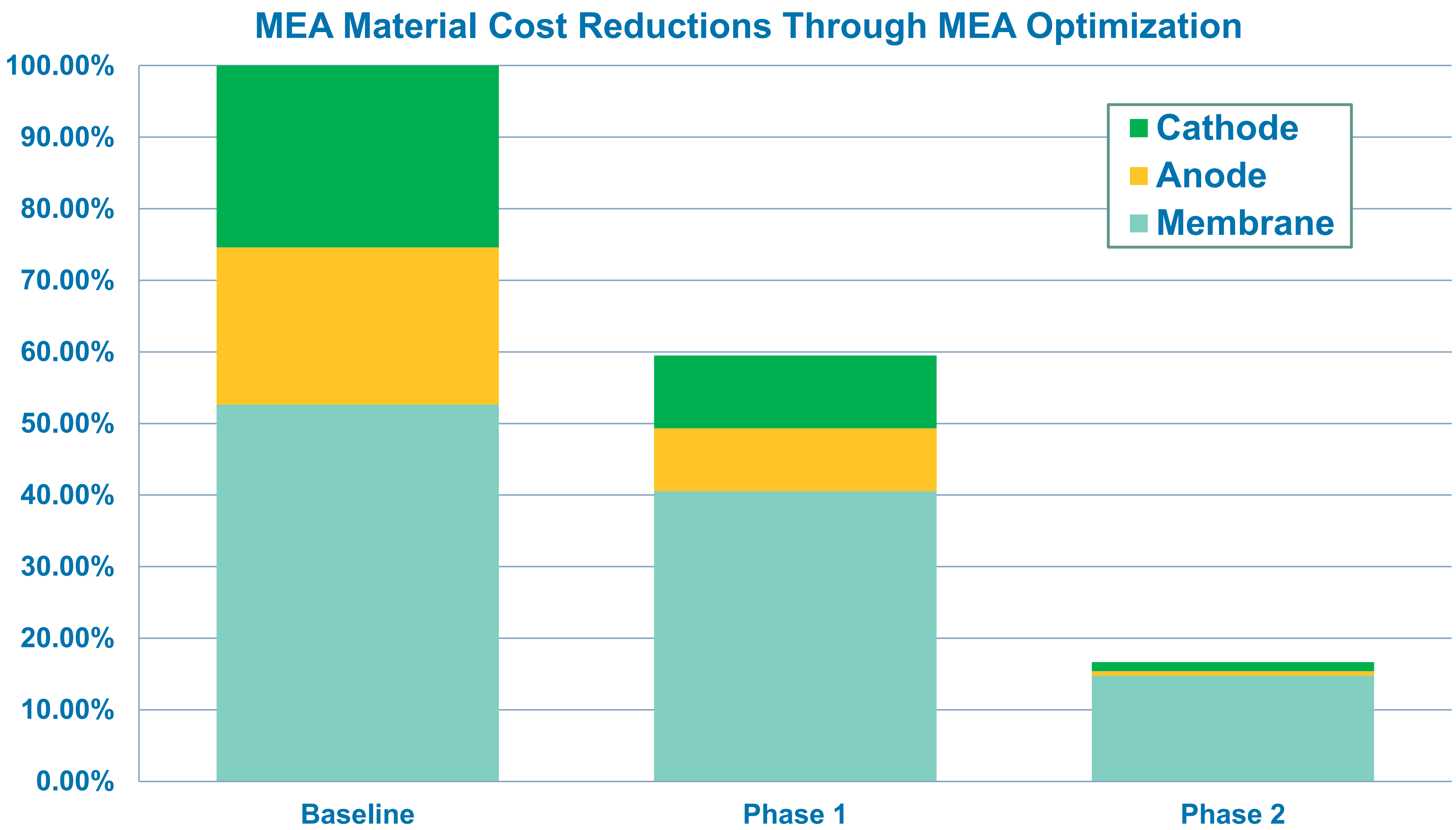
Technical Accomplishments
Task 2.0: MEA Optimization



Technical Accomplishments
Task 2.0: MEA Optimization

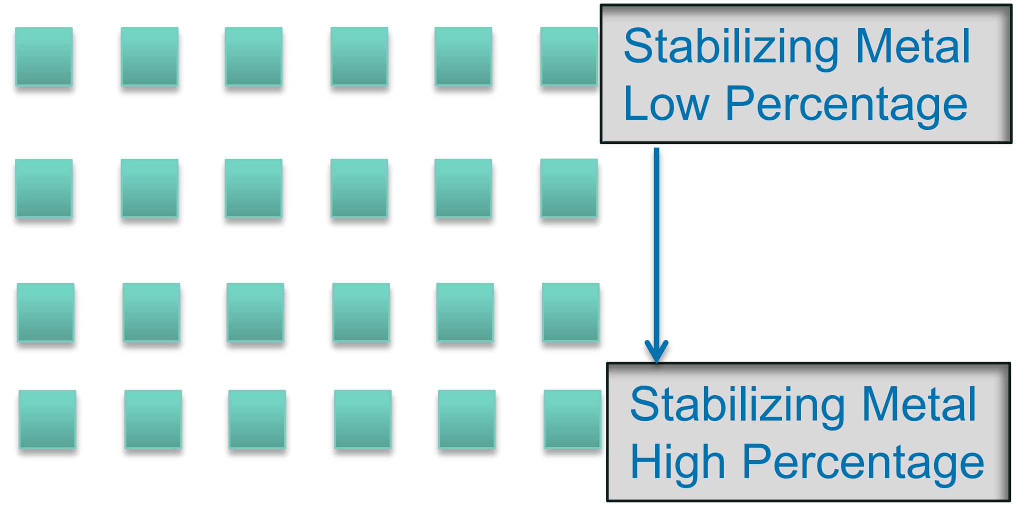


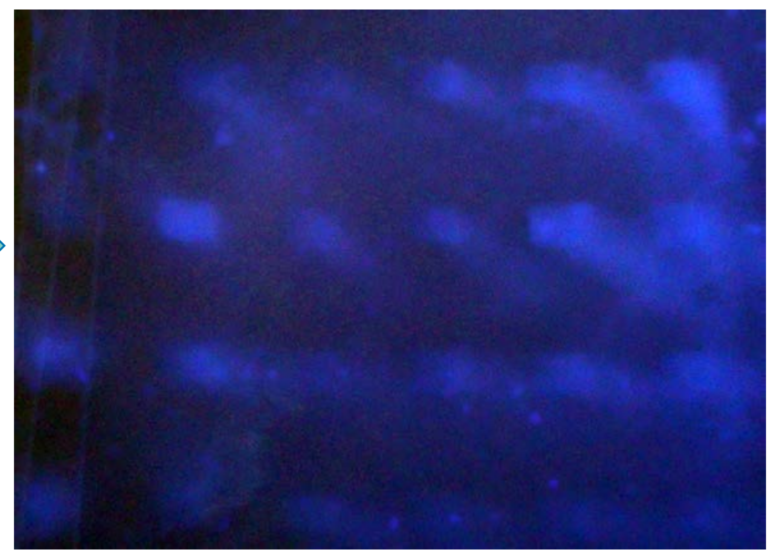
Technical Accomplishments
Task 2.0: MEA Optimization



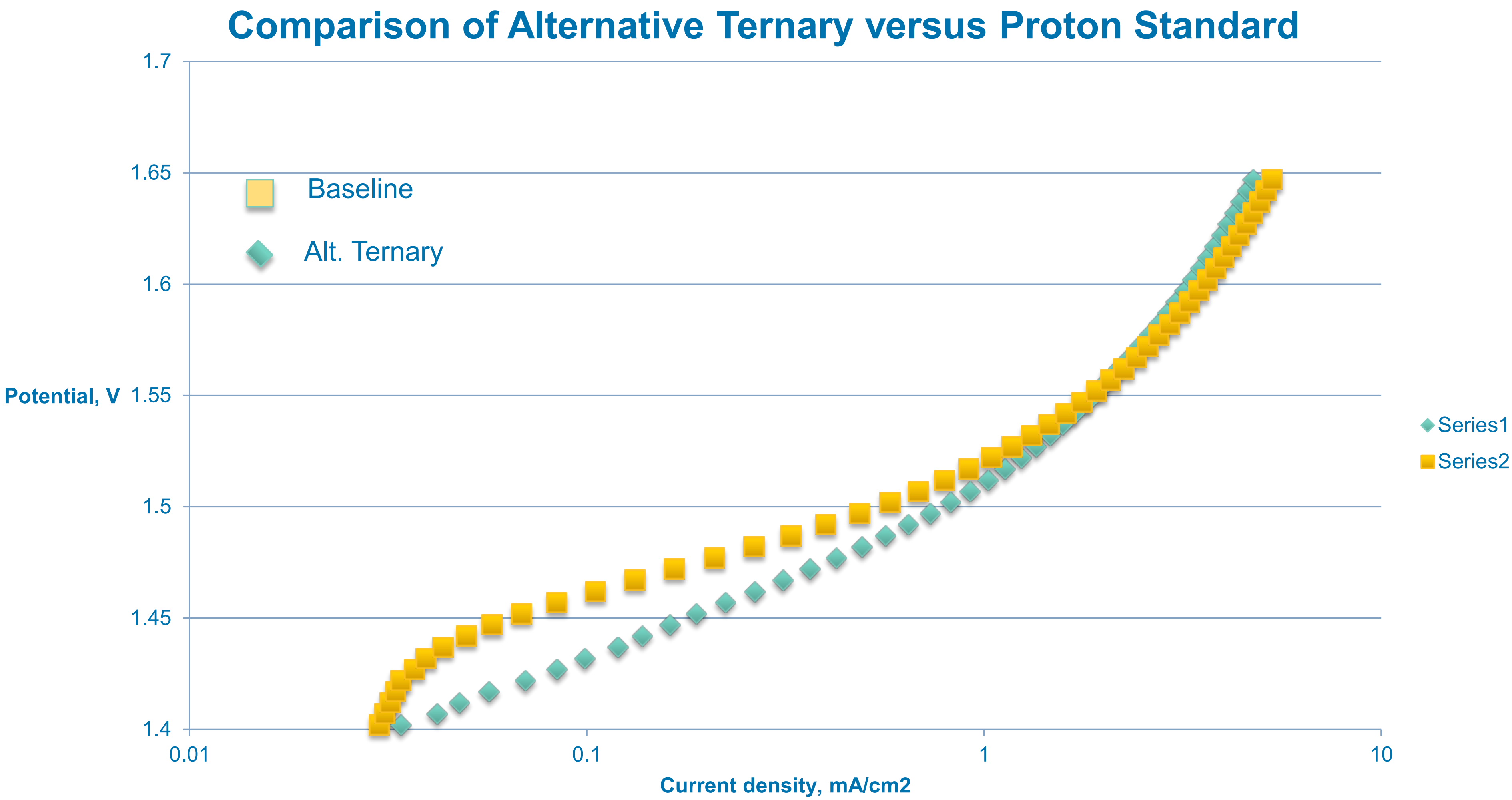
Technical Accomplishments
Optimization Discrete Compositions

The research grade materials ink jet printer uses water soluble precursors of the metal oxides of interest to print discrete compositions of materials as well as gradients of materials.



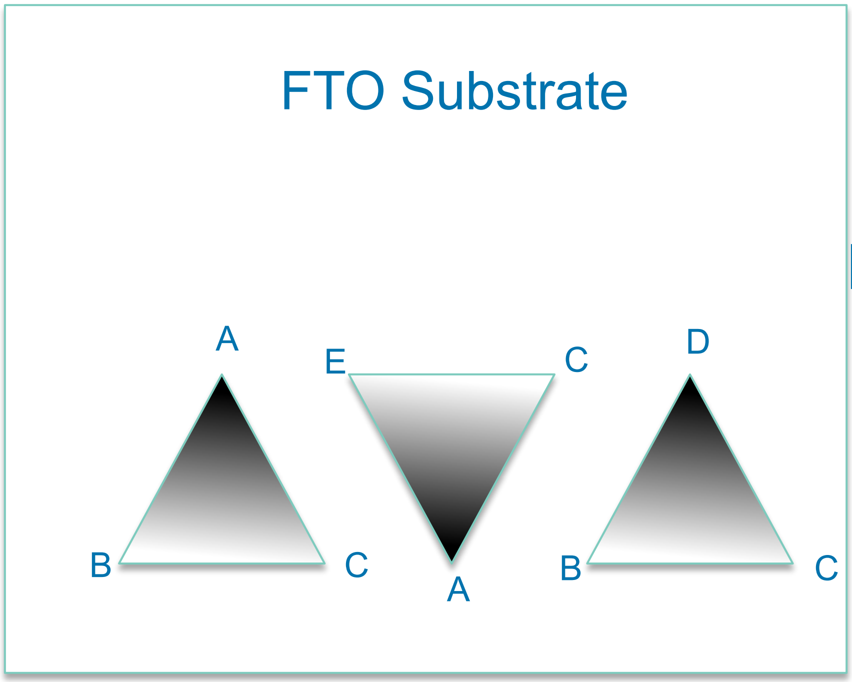


Technical Accomplishments
Current Voltage Analysis



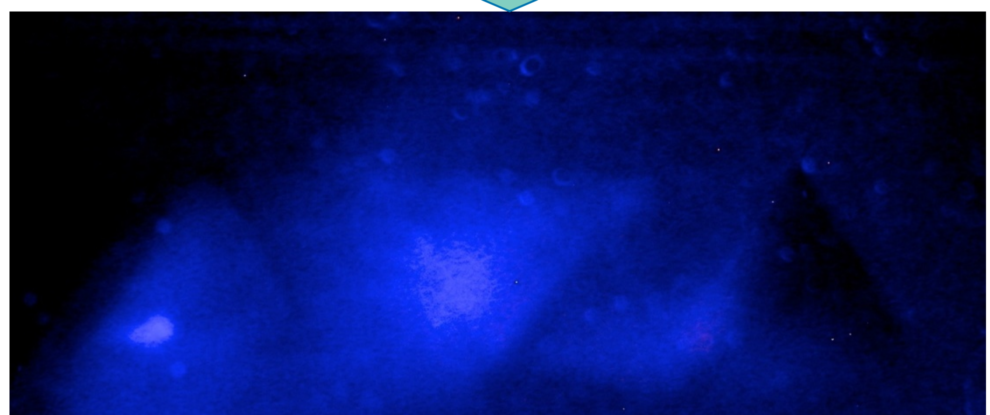
Current voltage analysis of initial promising mixture discovered.
The mixture was found using the discrete composition procedure previously described.

Technical Accomplishments
Ternary Gradient Mixtures



- Gradients of different metals printed in triangular shapes
- Each vertex represents 100% pure material
- Edge opposite a vertex represents 0% of that material

Three ternary mixtures immersed in electrolyte indicator solution.



Three mixtures during the fluorescent screening process as potential is applied. Fluorescence indicates a localized increase in the proton concentration preceding oxygen evolution.

Technical Accomplishments MEA Optimization: 3M

Membrane Development:

- Current process capabilities evaluated for Proton cell widths. Process validation experiment on schedule.
- Successful lamination of multi-layer membrane construction has yielded thicker membrane required for electrolysis testing.

Catalyst Development

- First set of CCM's supplied to Proton Onsite, on test to investigate:
  - NSTF electrode formation being assessed with alternative membrane
  - Applicable noble metal loading range with NSTF technology platform base-lined and established based on diminishing returns on performance and manufacturability.

Technical Accomplishments
Task 4.0: System Design

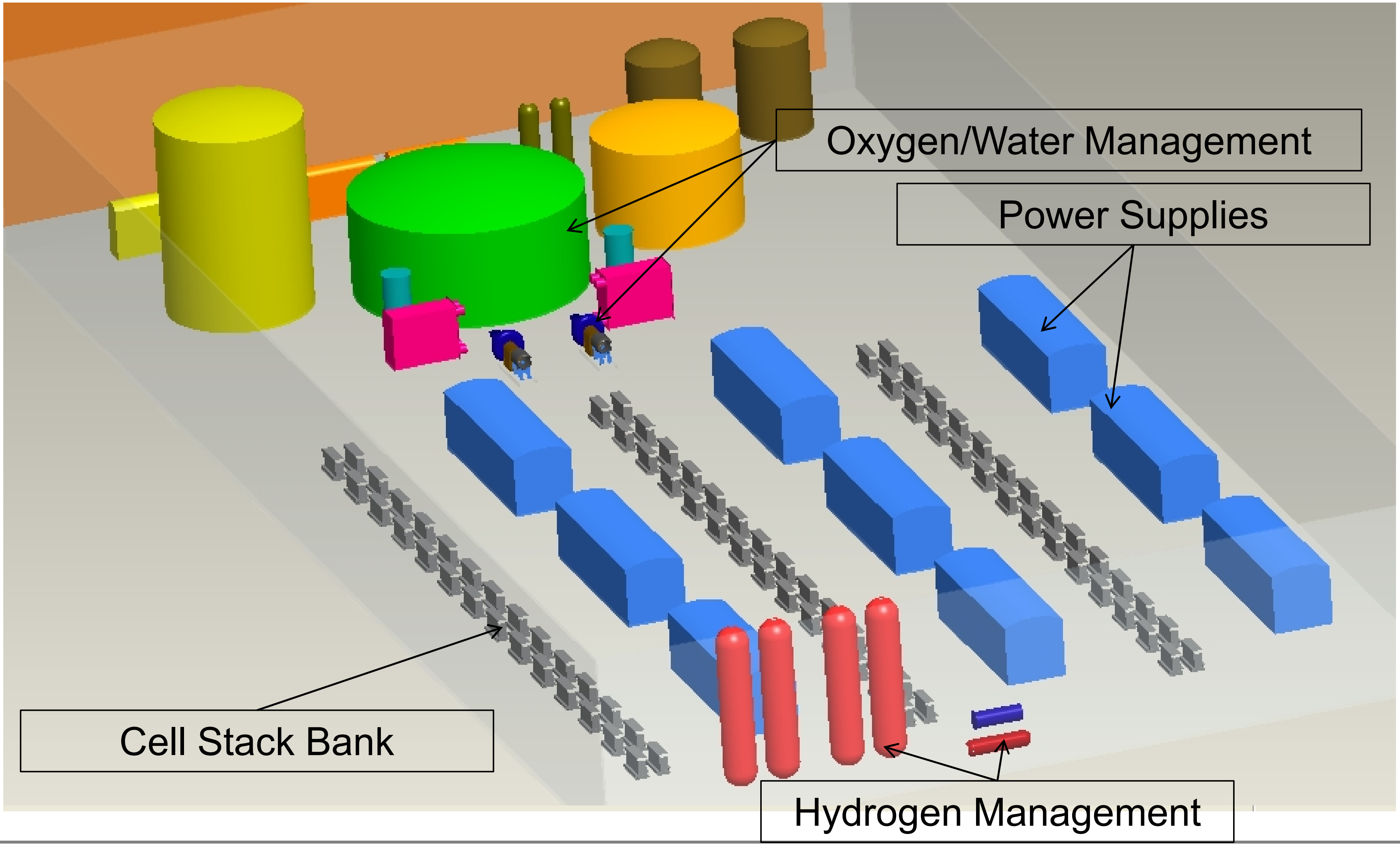
Major System Components Evaluated and Sized

- Stacks
- Power Supplies and Power Electronics
- Water and Oxygen Management
- Hydrogen Gas Management
- Water Deionization Treatment Plant

Component Sizing:

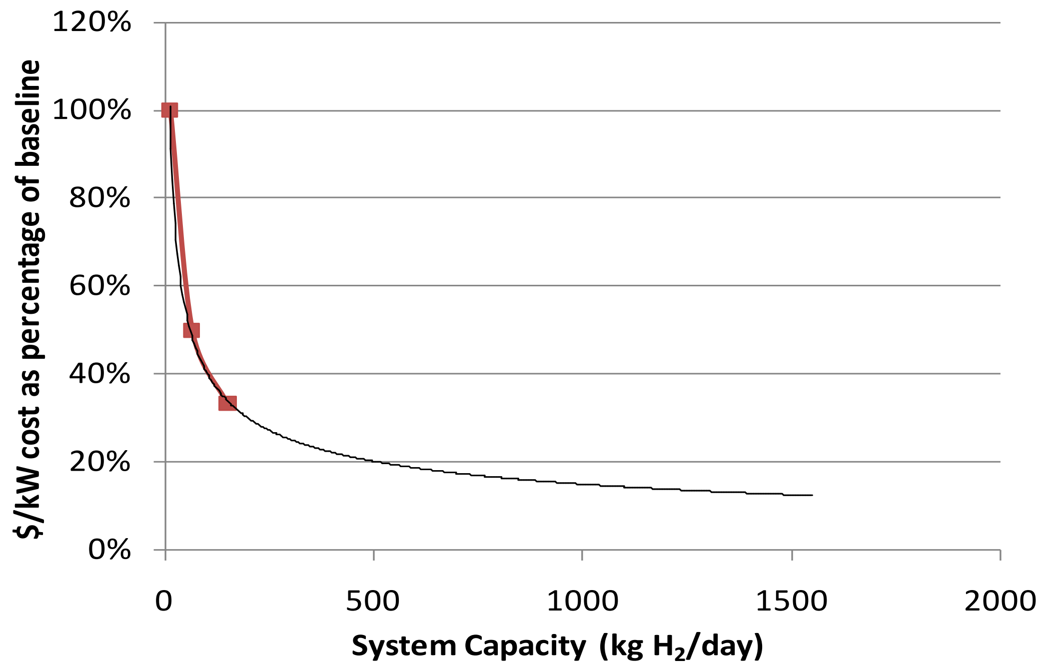
- Economies of Scale:
  - Fewer no. of large components is less expensive than more components of smaller size (in general)
- Large Component Availability:
  - Can get most components in sizes where just 1 or 1 “set” (redundant items) is needed (i.e. least capital expense)
  - Largest Component: a cooling tower, may be greatly reduced or eliminated if local natural sink can be used
- Detailed Studies Needed:
  - Component reliability vs. impact to capital cost when determining component redundancy.

Technical Accomplishments
Task 4.0: System Design



Technical Accomplishments
Task 5.0: Cost Analysis

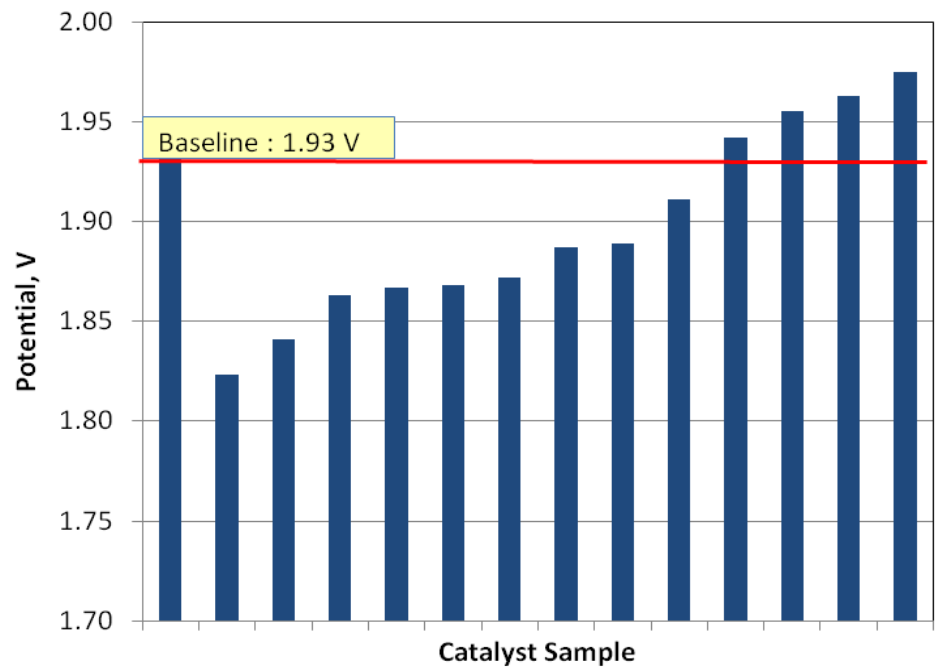
- Phase 1 Approach:
  - Extrapolated cost from existing systems
  - 1500 kg/day module
  - Projected result: $0.56/kg production capital cost



- Phase 2 Approach:
  - Quoted major subcomponents based on system design
  - Same stack module as above
  - Result: $0.49/kg production capital cost

Future Work: Proton

- **Continue Phase I work on alternative catalyst blends for cost-reduction and efficiency improvements**
  - Refine compositional matrix and evaluate
  - Scale-up synthesis for larger cell stack platform



- **50,000 kg/day Concept**
  - Add stack Balance of Materials (BOM) as inputs
  - Conduct environmental impact assessment
  - Update with MEA electrical efficiencies and operational data as testing progresses

Future Work: 3M

Membrane Development

- Work will continue to fabricate 3M 800 EW membranes for scale-up to 550 cm^2 MEA configuration through:
  - Direct casting
  - Multi-layer lamination (successfully done for 50 cm^2)
  - CCM fabrication on roll-to-roll equipment

Catalyst Development

- Establish preferred target catalyst loading levels for both cathode and anode electrodes
- Verify NSTF-$Pt_{50}Ir_{50}$ alloy baseline with down-selected PEM
- Optimize catalyst performance and durability:
  - 3M's binary composition refinement; limited ternary alloys
  - Application of post-deposition surface energy treatments (3M –SET process)
- Duplicate optimized catalyst composition in NSTF format

Summary

- **Relevance:** Demonstrates technology pathway to centralized PEM electrolysis at acceptable cost and efficiency
- **Approach:** Optimize catalyst utilization and activity for 10X loading reduction; minimize BoP cost through scale up
- **Technical Accomplishments:**
  - Concept review complete for 50% reduction in PGM content
  - New blends synthesized for activity optimization
  - 50,000 kg/day concept developed and quoted
- **Collaborations:**
  - U. Wyoming: Combinatorial catalyst screening
  - 3M: NSTF anode development
- **Proposed Future Work:**
  - Manufacturing transition for initial reduction in catalyst loading
  - Catalyst activity and durability screening
  - Electrode and stack scale up
  - System environmental assessment