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Low Cost Large Scale PEM Electrolysis for Renewable Energy Storage

Presenter: Dr. Katherine Ayers

Organization: Proton OnSite

Date: May 15, 2013

Project ID: PD090

Overview

Timeline

- Project Start: 19 June 2010
- Project End: 18 Aug 2013
- Percent complete: 80%

Budget

- Total project funding
  - DOE share: $1,100,000
- Funding for FY13
  - DOE share: $500,000

Barriers

- Barriers addressed
  - G: Capital Cost
  - H: System Efficiency

Table 3.1.5 Technical Targets: Central Water Electrolysis Using Green Electricity [a,b]

Characteristics	Units	2011 Status [c]	2015 Target [d]	2020 Target [e]
Hydrogen Levelized Cost (Plant Gate) [f]	$/kg H_2	4.10	3.00	2.00
Total Capital Investment [b]	$M	68	51	40
System Energy Efficiency [g]	%	67	73	75
	kWh/kg H_2	50	46	44.7
Stack Energy Efficiency [h]	%	74	76	78
	kWh/kg H_2	45	44	43
Electricity Price [i]	$/kWh	From AEO '09	$0.049	$0.031

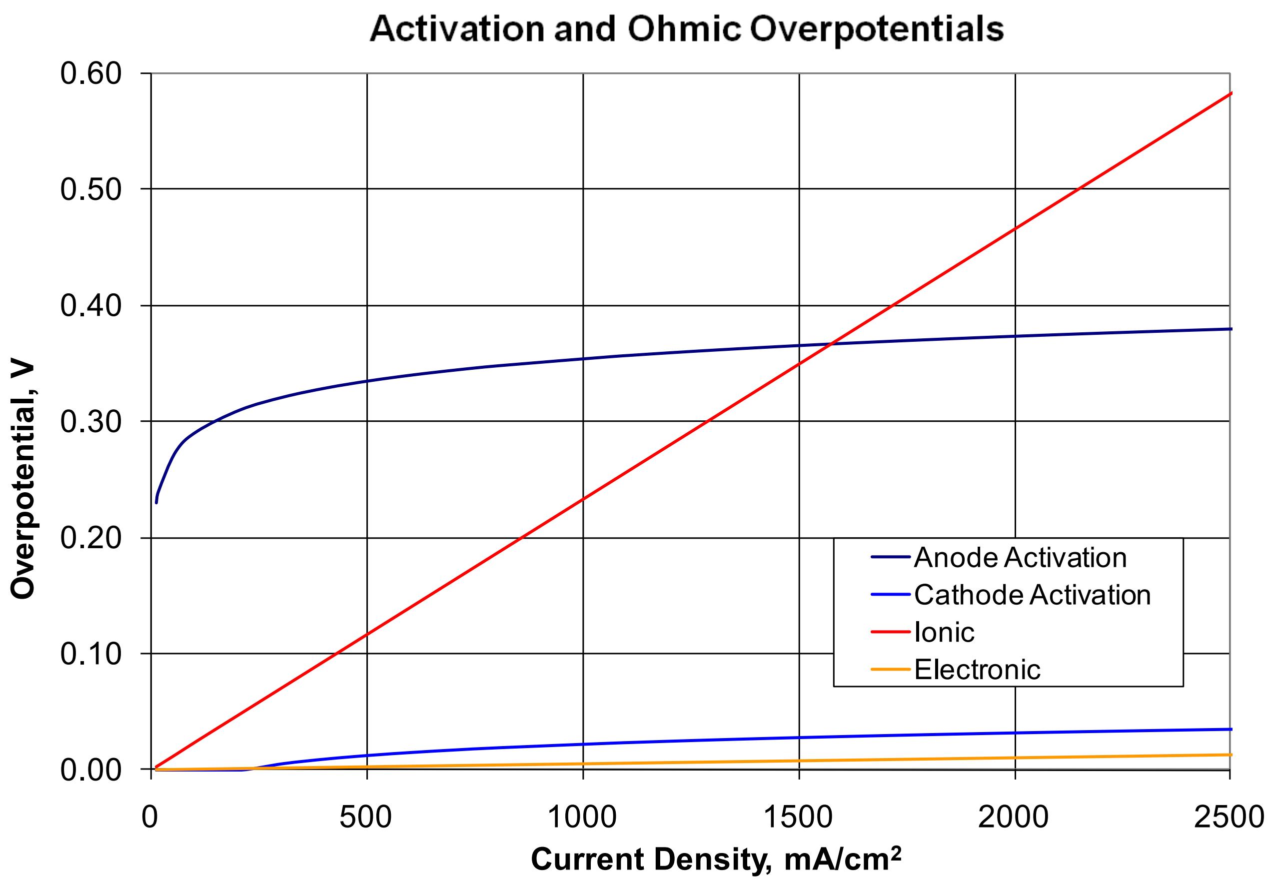
Partners

- 3M
- University of Wyoming

Relevance: Project Objectives

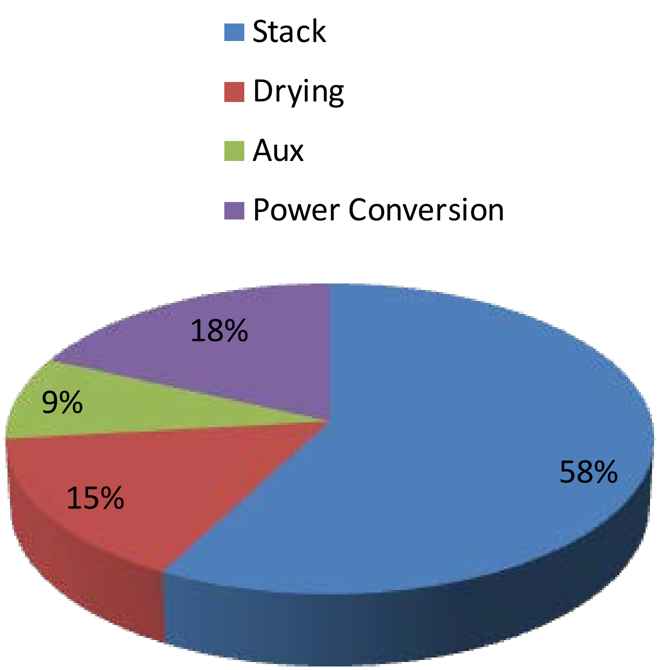
- Identify optimal anode catalyst composition through combinatorial exploration
- Reduce catalyst loading through improved processes and NSTF structures
- Demonstrate 1000 hours system operation at >69% efficiency
- Develop 50,000 kg/day concept design
- Perform cost and environmental analysis

Relevance: Efficiency Breakdown



Stack

System



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: Hydrogen Value Proposition

- High interest in Europe for MW scale hydrogen production via electrolysis
  - Recovery of stranded wind capacity
  - Higher conversion efficiency for bio-derived methane
- Flexibility of product stream
  - Transportation fuel/backup power
  - High value chemical processes
  - Natural gas pipeline injection
- Maintains U.S. competitiveness in the international market

Top Level Approach

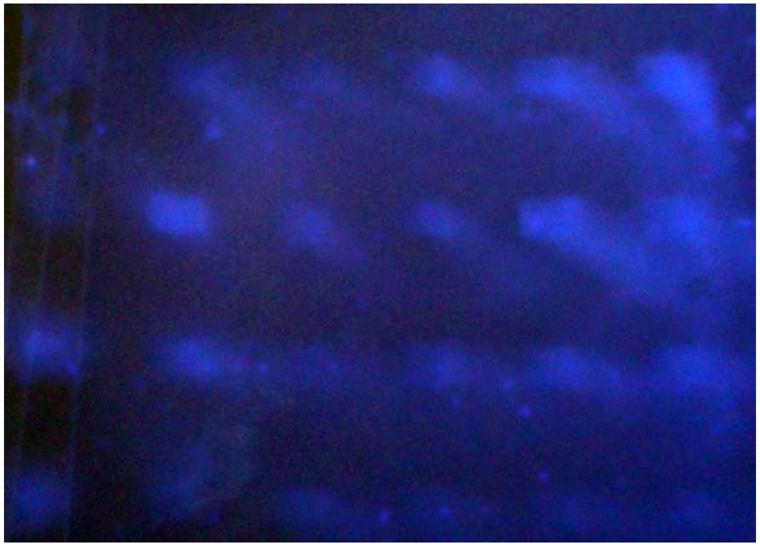
- Task 1.0 Project Kickoff
- Task 2.0 MEA Optimization
  - 2.1 – Catalyst Composition Optimization
  - 2.2 – MEA Performance Evaluation
  - 2.3 – Electrode structure and catalyst utilization
  - 2.4 – Estimation of Efficiency
- Task 3.0 Scale-up of MEA Configuration
  - 3.1 – Process Development for 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	100%
3.0	MEA Configuration Scale Up	• Tooling procured	80%
4.0	50,000 kg/day Concept	• System components identified • Preliminary costs established • Component sizing completed	95%
5.0	Cost Analysis/ Environmental Analysis	• Pending completion of Task 4.1	

Technical Accomplishments: AMR 2012 Review

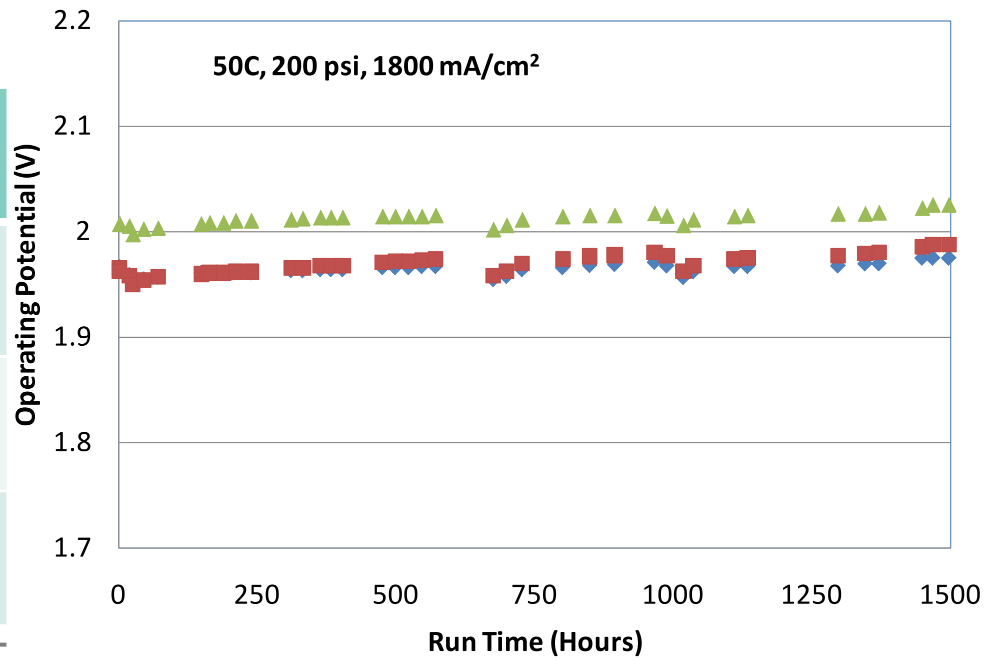
- Demonstrated combinatorial screening technique
- Demonstrated 50% reduction in loading with no performance impact
- Initial plant concept completed



Technical Accomplishments: Catalyst Composition

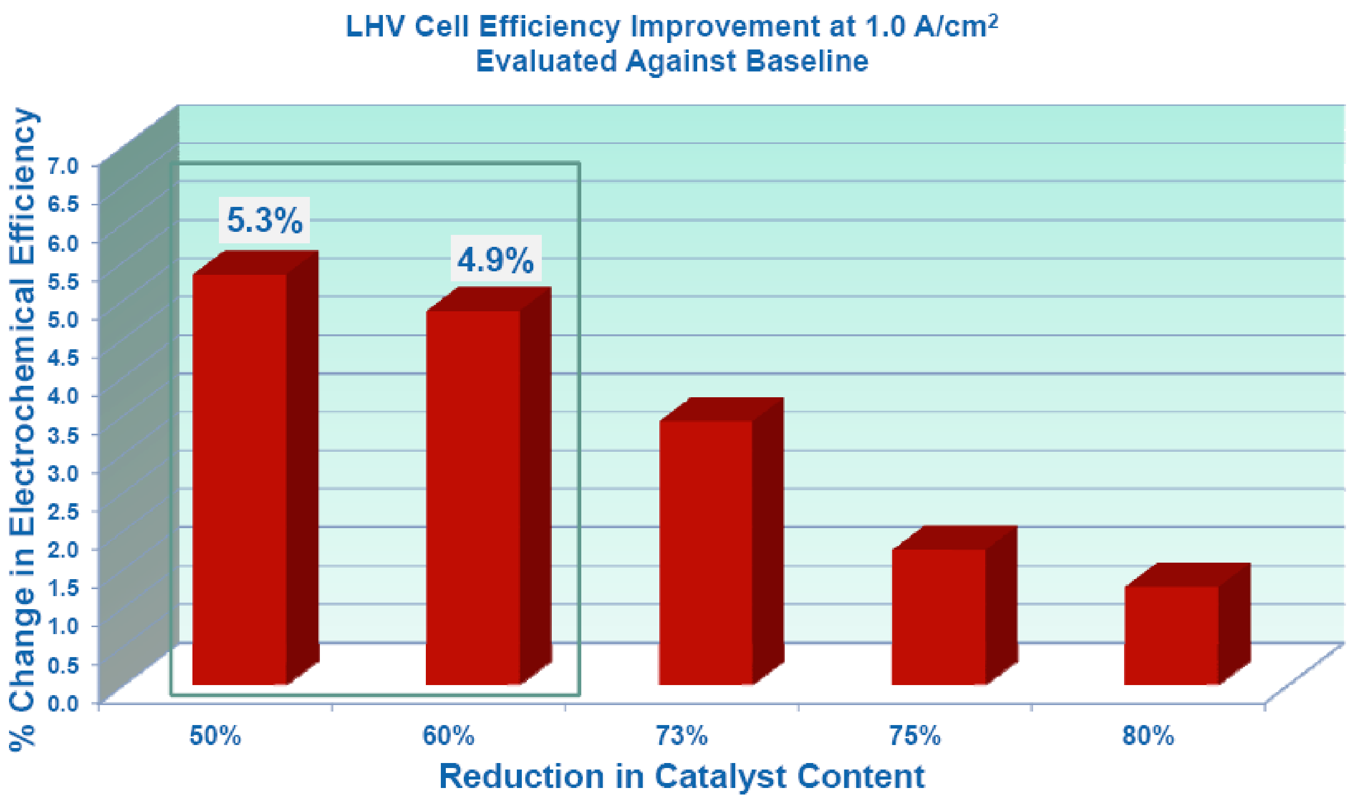
- Examined combinations of metals such as Ir, Al, Pt, Ru, Sn, Rh, and Pd
  - Combinatorial experiments suggested optimized formulations
- Cell testing validated predictions and tested durability
- SEM after operation still shows all elements present

	Metal 1 (at%)	Metal 2 (at%)	Metal 3 (at%)
Theoretical/ Design Point	51	23	26
Operated MEA, Point 1	56.25	20.00	23.75
Operated MEA, Point 2	47.58	21.61	30.86

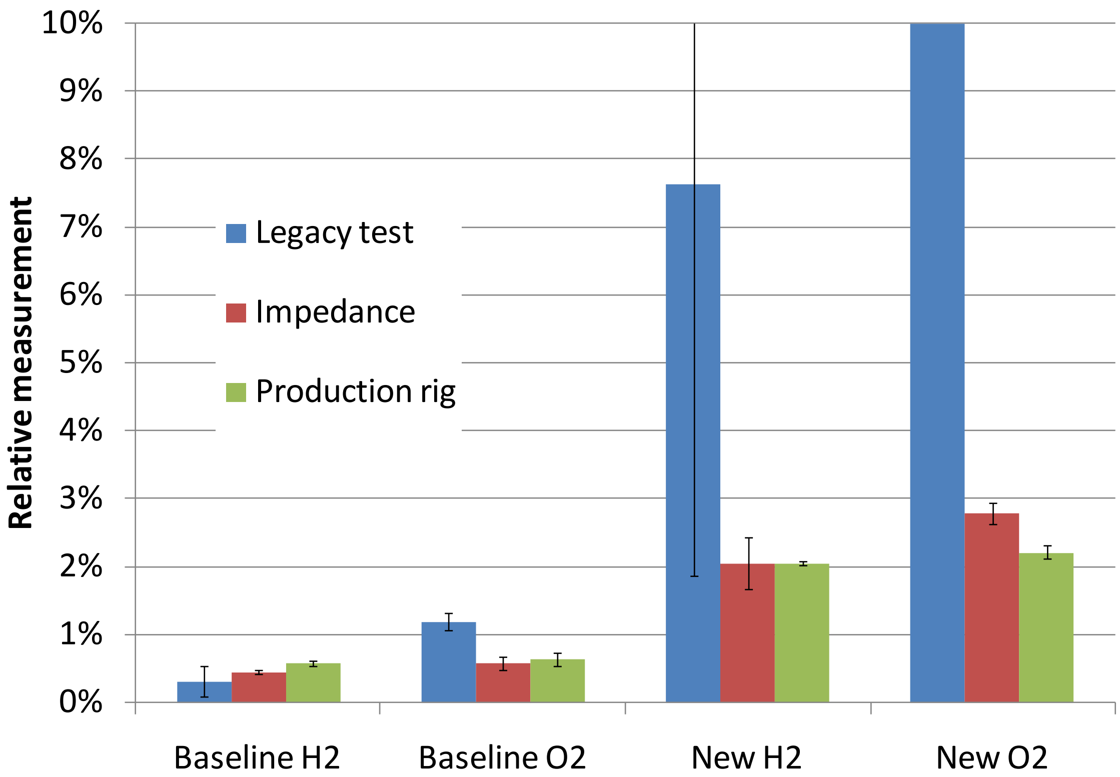


Technical Accomplishments: Catalyst Loading

- Completed formulation and process optimization for 50% reduction in loading vs. baseline
- Improvements also provided efficiency benefit; possibly due to through plane resistance changes.



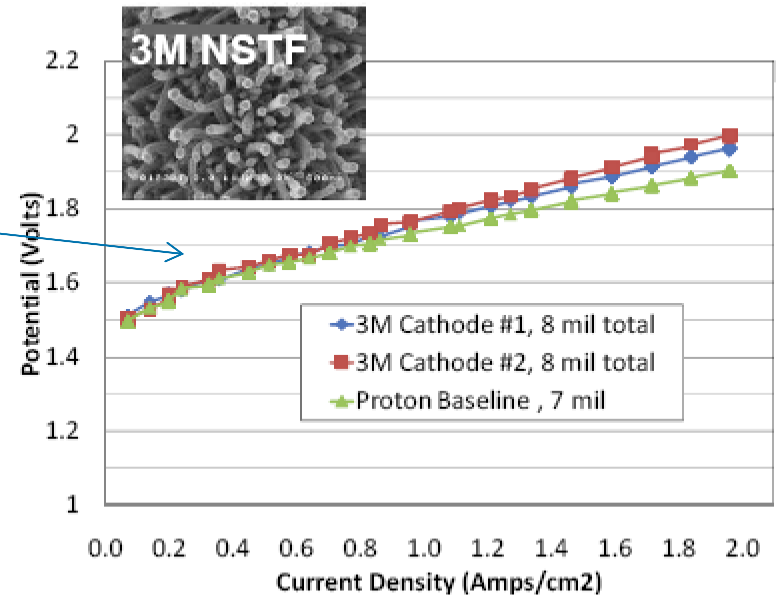
Technical Accomplishments: QC

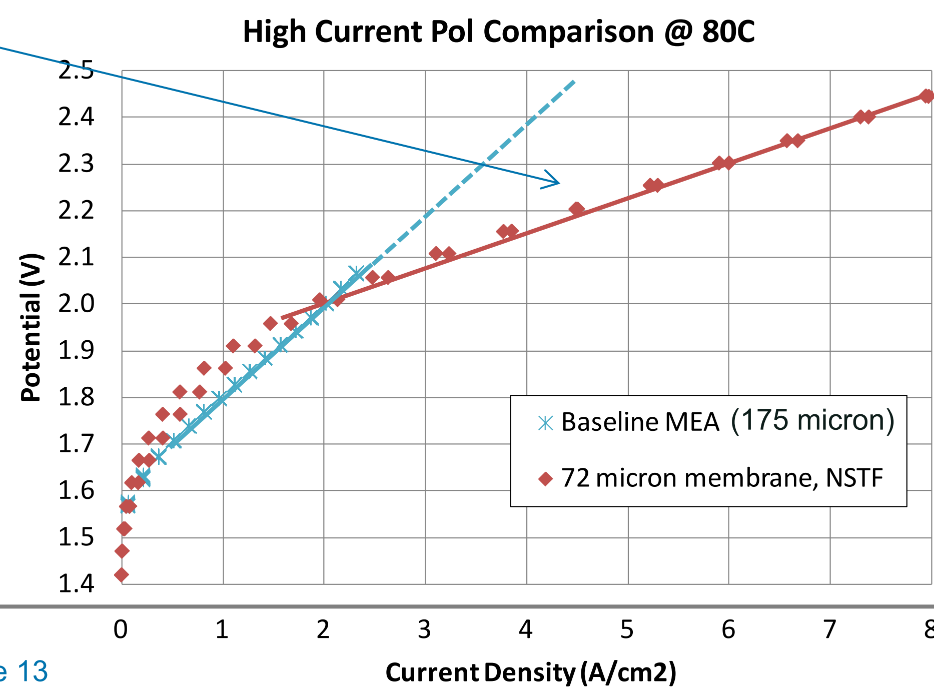


- Legacy QC electrical test gives non-meaningful data with new process
- Full impedance scan yields acceptable correlation with legacy test on baseline, much better repeatability but too cumbersome
- Production high frequency test provides consistency and speed

Technical Accomplishments: Catalyst Structure

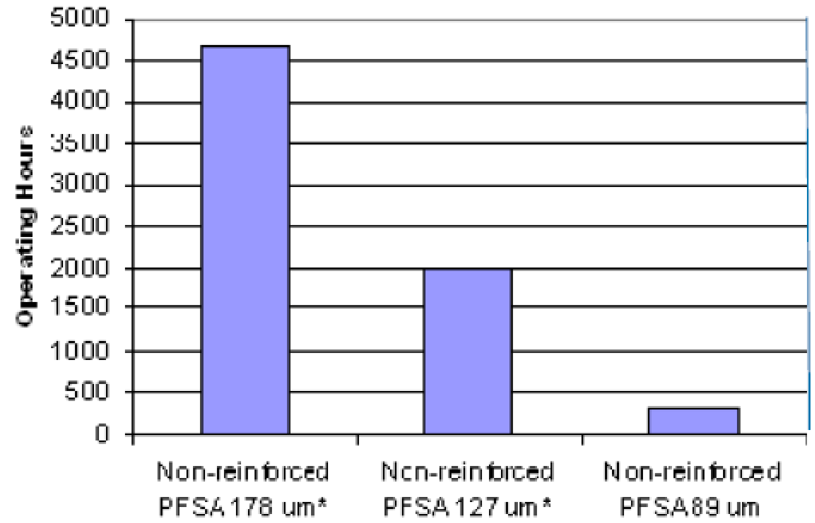
- Have shown equivalent performance at cathode
- Anode still showing higher activation energy
- Lack of mass transfer limitations implies loading is sufficient; optimizing structure and composition for activity



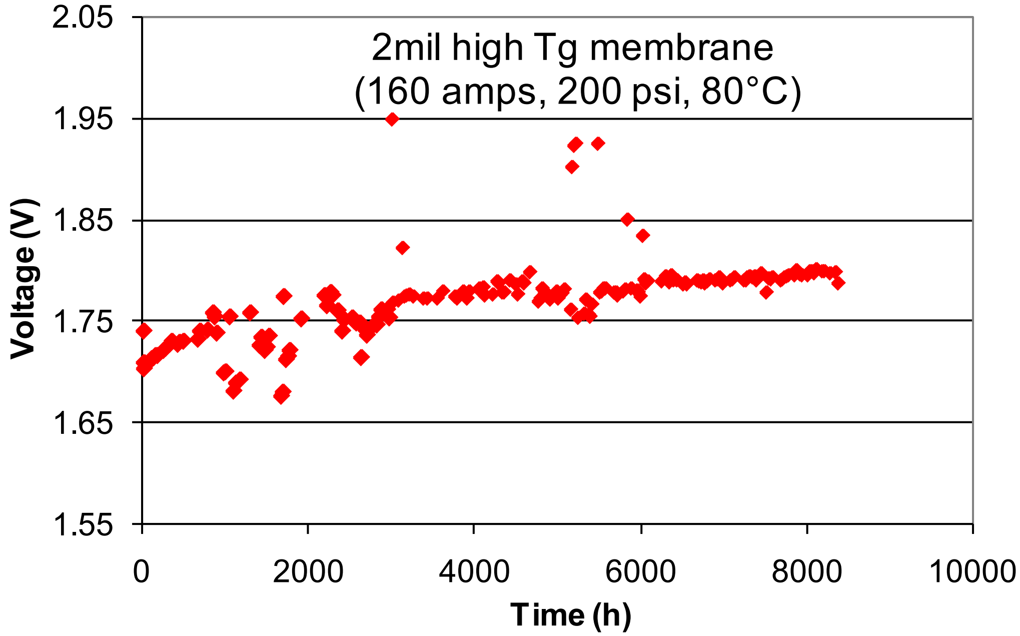


Technical Accomplishments: Membrane

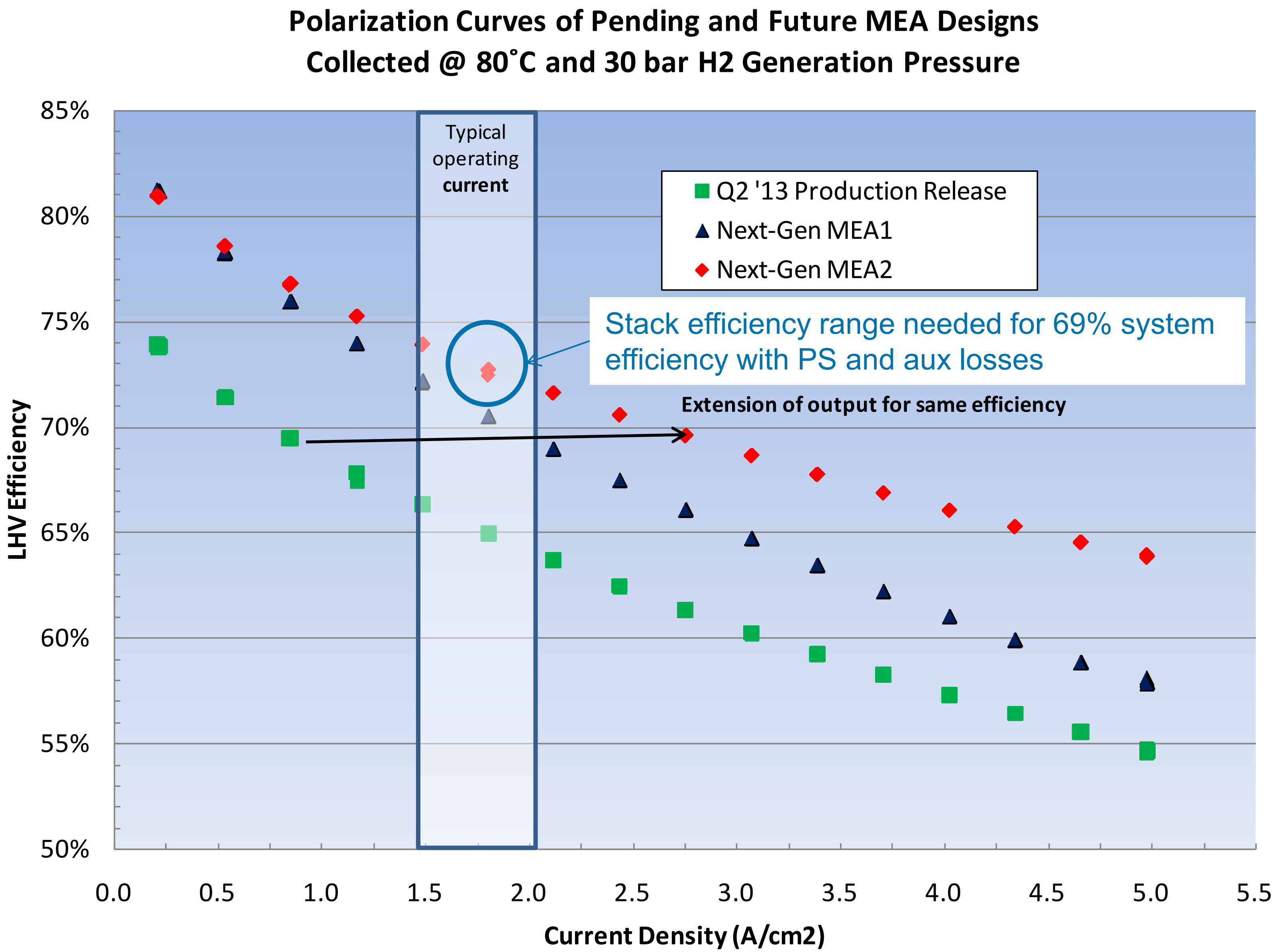
- Legacy membrane does not hold up at desired thicknesses and pressures



- Optimization of T_g, IEC, and reinforcement show good mechanical durability



Technical Accomplishments: Efficiency



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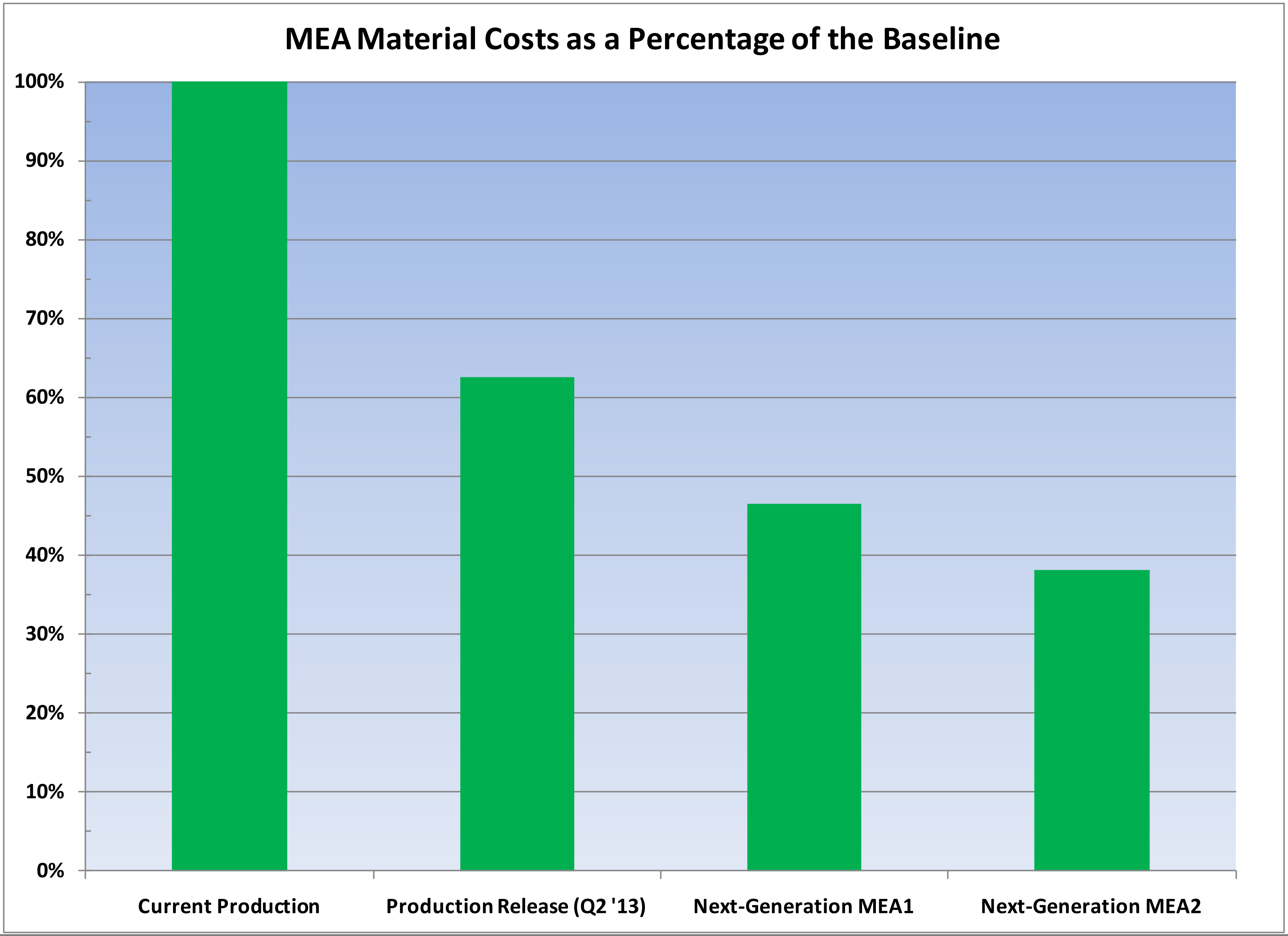
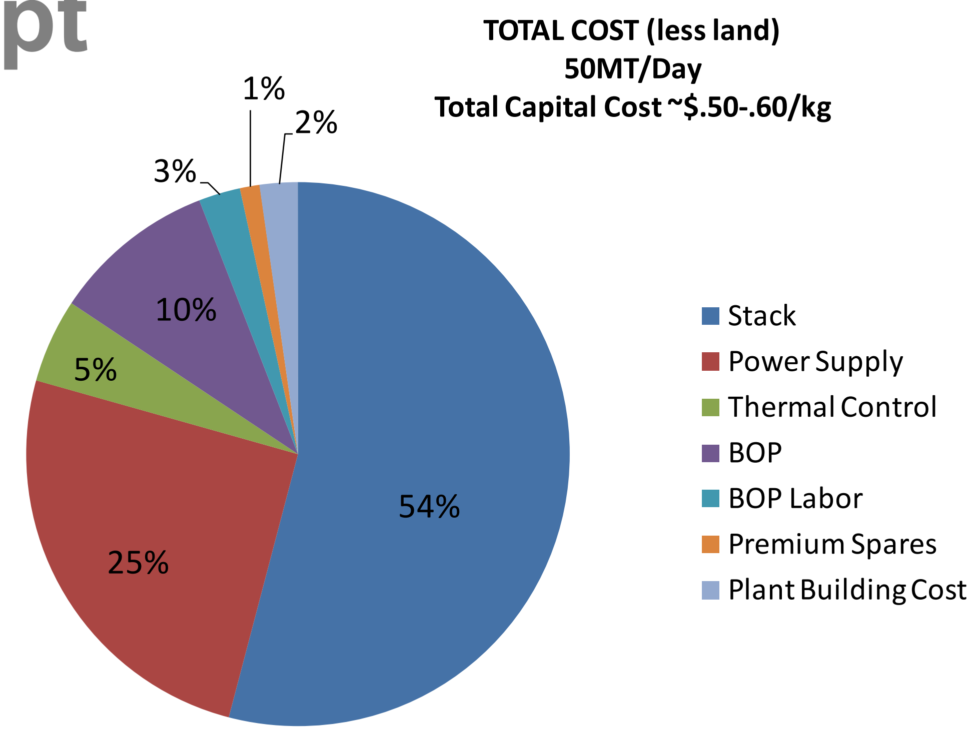
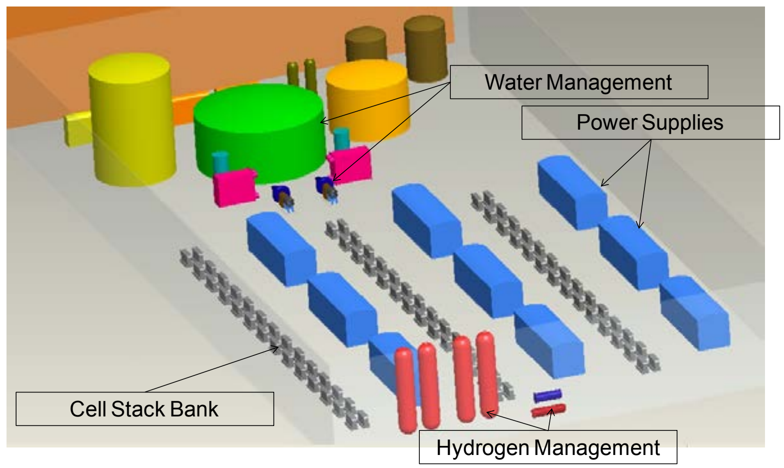
Technical Accomplishments: Part Cost



Technical Accomplishments: 50,000 kg/day Concept

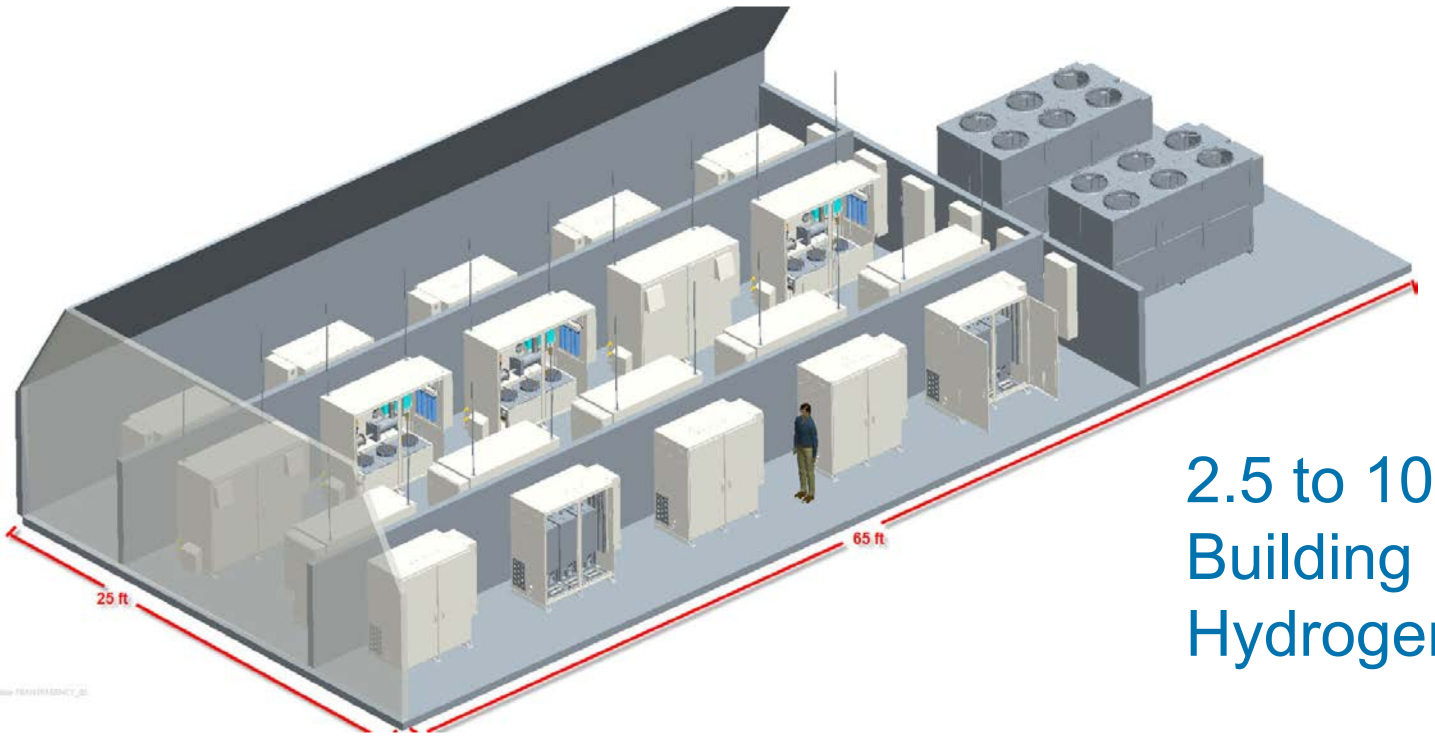
- Examined modular and plant design
- Quoted power supplies, cooling towers, pressure vessels, DI skids





Technical Accomplishments: 50,000 kg/day Concept

- Modular design being leveraged in Proton MW electrolyzer development



2.5 to 10 MW PEM
Building Block
Hydrogen Plant Concept

Collaboration

- Partners
  - 3M (Industry): Demonstrated feasibility of ultra-low loading on oxygen electrode
  - U. Wyoming (Academic): Developed combinatorial screen and ink deposition methods for compositions

Future Work: Proton

- Production implementation of 50% catalyst reduction
  - Cross-platform implementation
  - Documentation underway
  - New equipment purchased through alternate funds
- Continue investigation of ultra-low catalyst loading
  - Multiple possible pathways showing promise
- 50,000 kg/day plant concept
  - Conduct environmental impact assessment
  - Update H2A model with MEA electrical efficiencies and operational data as testing progresses
- Megawatt scale electrolysis balance of plant design: internally funded

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:**
  - Implementation of 50% reduction in PGM content in process
  - New blends synthesized for activity optimization
  - 50,000 kg/day concept leading into MW scale module
- **Collaborations:**
  - U. Wyoming: Combinatorial catalyst screening
  - 3M: NSTF anode development
- **Proposed Future Work:**
  - Continued optimization of ultra-low loading catalyst structures
  - System environmental assessment