Proton ENERGY SYSTEMS | The Leader in On-site Hydrogen Generation

High Performance, Low Cost Hydrogen Generation from Renewable Energy

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Organization: Proton Energy Systems

Date: May 11, 2011

Project ID #PD071

Overview

Timeline

- Project Start: Sept. 2009
- Project End: December 2013
- Percent complete: 25%

Budget

- Total project funding
  - DOE share: $3,186,826
  - Contractor share: $849,206
- Funding for FY11
  - DOE share: $762,610

Partners

- Entegris, Inc. (Industry)
- Penn State (Academic)
- Oak Ridge (National Lab)

Barriers

- Barriers addressed

  G: Capital Cost

  H: System Efficiency

  J: Renewable Electricity Generation Integration

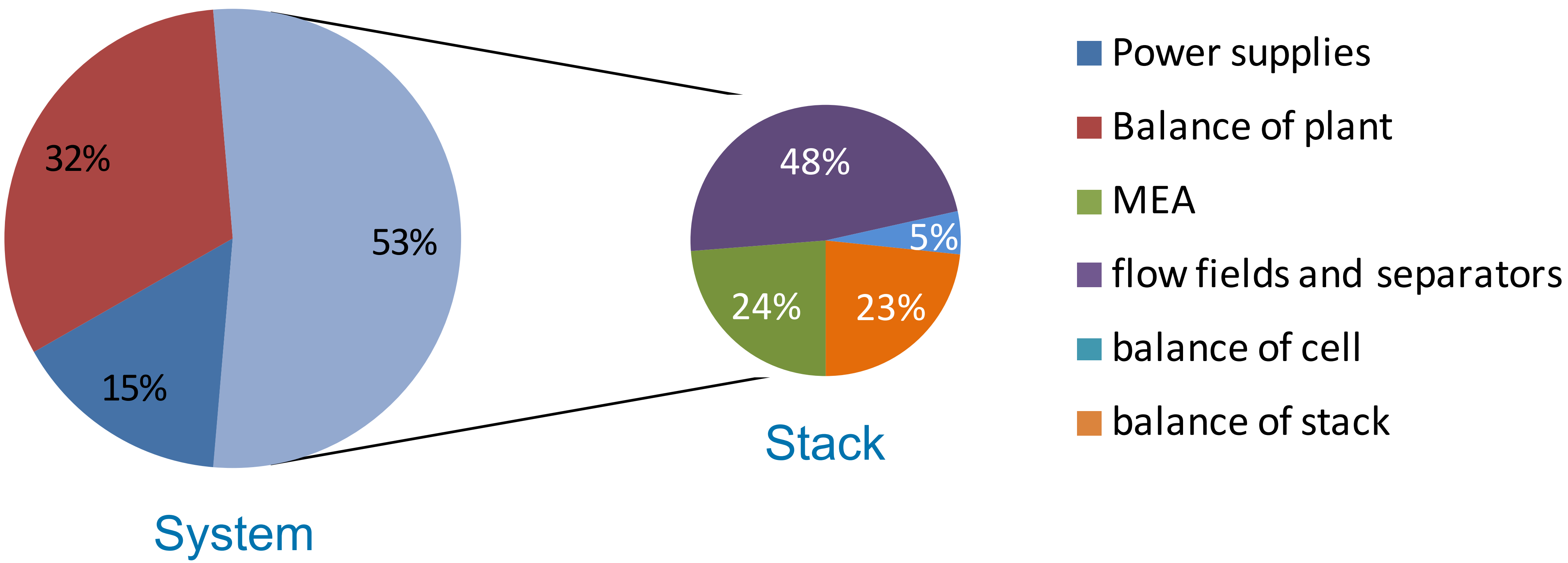
Table 3.1.4. Technical Targets: Distributed Water Electrolysis Hydrogen Production [a, b, c]

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

Table 3.1.4 Source:
DOE Hydrogen, Fuel Cells & Infrastructure Technologies Program Multi-Year Research, Development, and Demonstration Plan, Updated April 2009

Relevance
Overall Cost of Hydrogen

- Cell stack largest contributor to system cost
  - Flowfields, separators and MEAs drive stack cost



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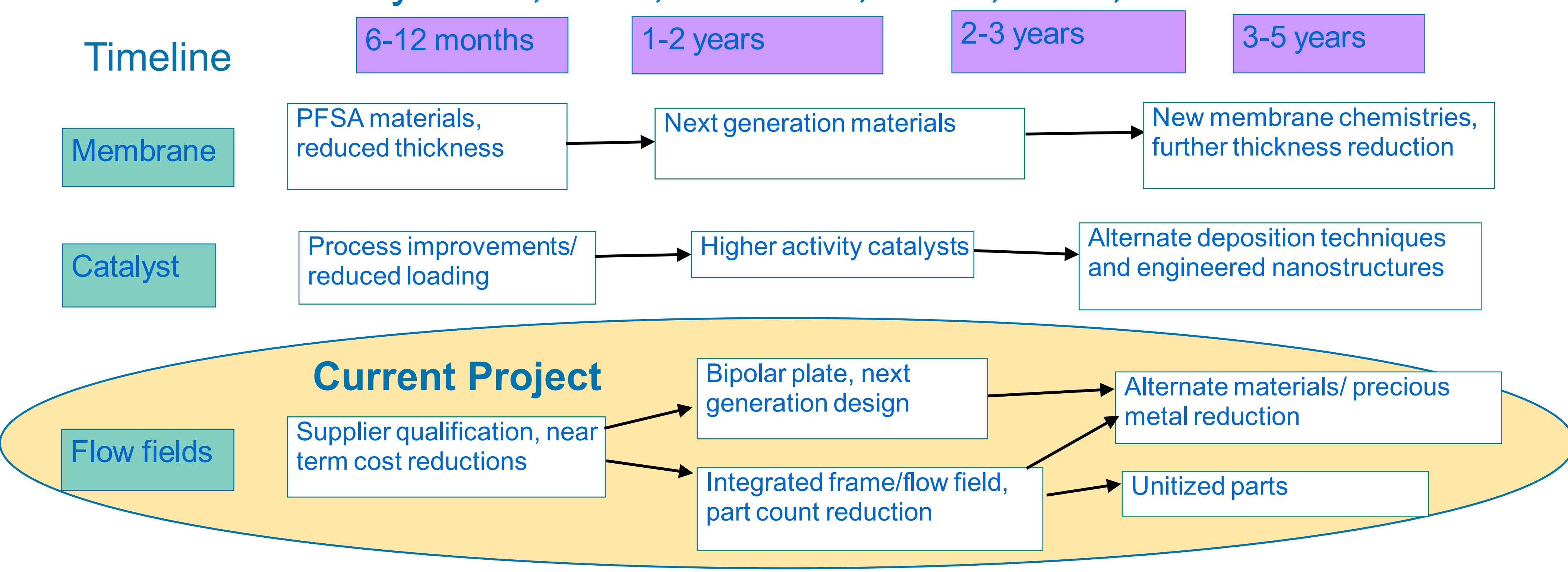
Relevance
Proton Roadmap

- Detailed Technology Roadmap developed internally
  - High level outline shown below
- Over 15 projects completed or active to date
  - Funded by DOE, NSF, ARPA-E, ONR, DoD, and internal funds



Relevance
Project Objectives

- Improve electrolyzer cell stack manufacturability
  - Consolidation of components
  - Incorporation of alternative materials
  - Improved electrical efficiency
- Reduce cost in electrode fabrication
  - Reduction in precious metal content
  - Alternative catalyst application methods

Top Level Approach

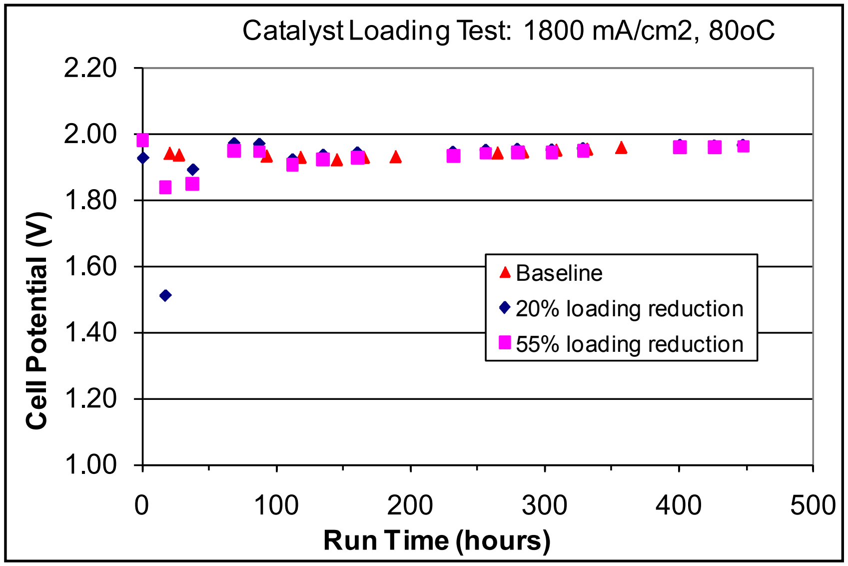
- Task 1.0: Catalyst Optimization
  - Control catalyst loading
  - Improve application
- Task 2.1: Computational Cell Model
  - Develop full model
  - Flex parameters, observe impact on performance
- Task 2.2: Implement New, Lower Cost Cell Design
  - Design and verify parts
  - Production release
- Task 2.3: Prototype Concepts
  - Test material compatibility
  - Fabricate test parts
- Task 2.4: Composite Bipolar Plates
  - Demonstrate functionality
- Task 3.0: Low Cost Manufacturing
  - Laminate concepts
  - Alternate processes
- Task 4.0: Operational Testing and Stack Scale Up
- Task 5.0: Manufacturing Development
- Task 6.0: Manufacturing Qualification
- Task 7.0: H2A Model Cost Analysis
  - Input design parameters
  - Assess impact of changes

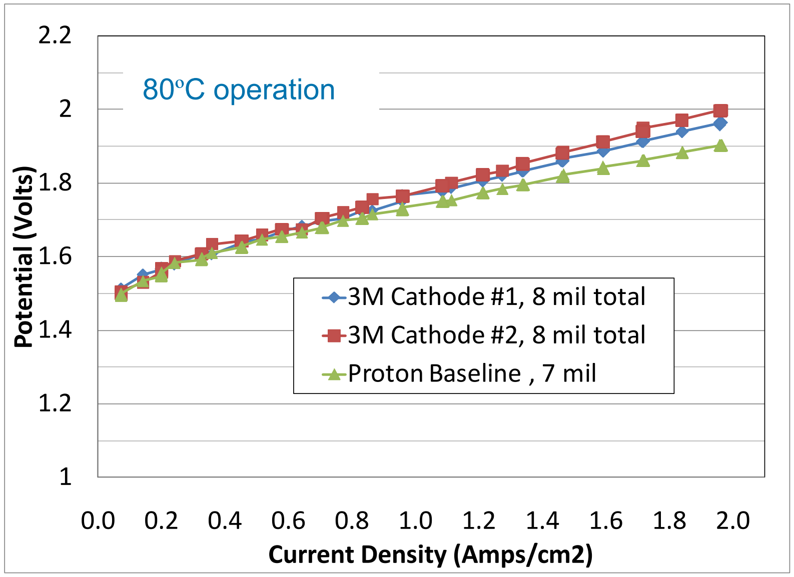
Progress on Milestones

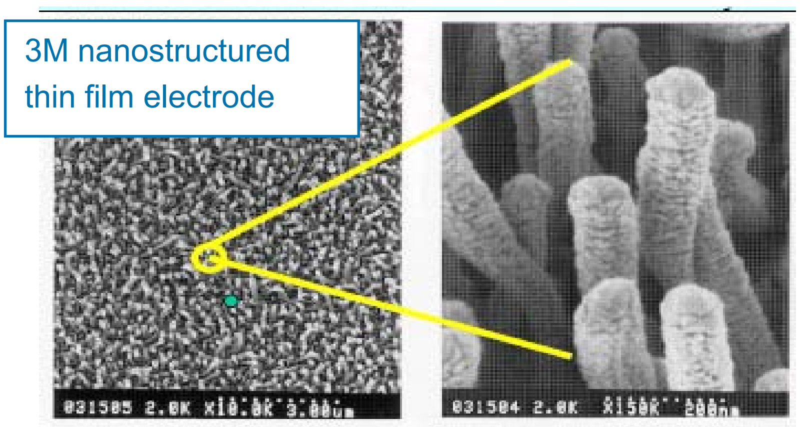
Task Number	Project Milestones	Task Completion Date	
		Original Planned	Percent Complete
1	Catalyst Optimization	03/31/10	100%
2.2	Improved Flowfield Implementation	05/30/10	100%
2.1	Electrolyzer Cell Model	01/30/11	100%
2.3	Next Generation Flowfield Prototypes	05/30/10	100%
2.4	Metal-Composite Laminate Plate Fabrication	12/31/10	100%
3.1	Metal-Composite Plate Development	12/30/11	15%
3.2	All-Metal Laminate Plate Development	12/30/11	15%
3.3	Hydrogen Resistant Coating Development	12/30/11	10%
4.1	Sample Operational Tests	12/31/11	15%
4.2	Post Operational Testing Analysis	03/30/12	0%
4.3	Stack Scale Up	09/30/12	0%
5	Bipolar Plate Manufacturing Development	06/30/13	0%
6	Bipolar Plate Manufacturing Qualification	09/30/13	0%
7	H2A Cost Model Analysis	09/30/13	50%
8	Project Management	09/30/13	30%

Technical Accomplishments
Task 1.0: Catalyst Optimization

- Demonstrated new alternative application techniques
- Step 1: 55% reduction on anode
- Step 2: >90% reduction on cathode







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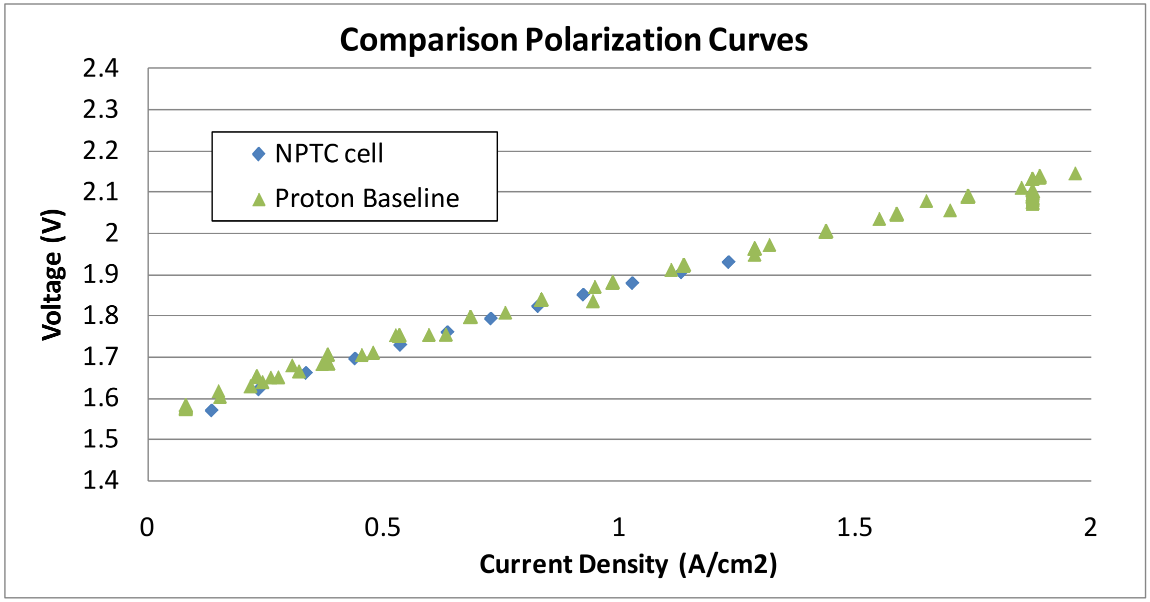
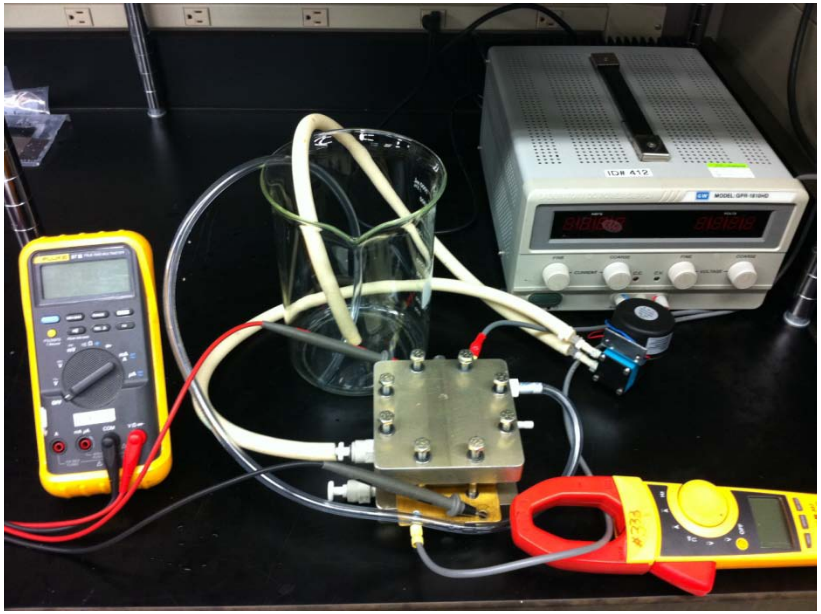
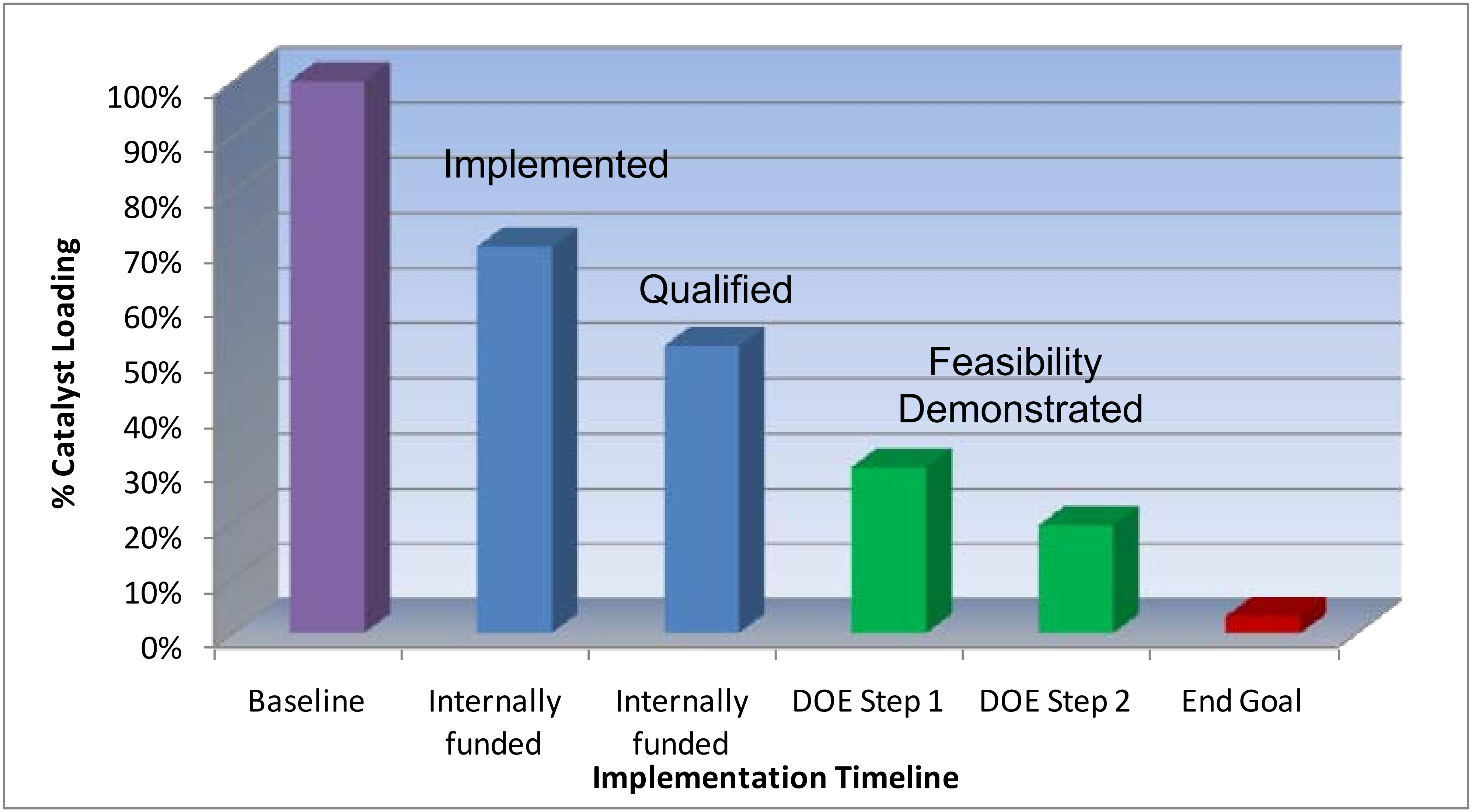
Technical Accomplishments
Task 1.0: Catalyst Optimization

- Qualified non-proprietary test cell for collaborator use
- Enables rapid sample turnover and comparison between sites





Relevance
Task 1.0: Reduction of noble metals



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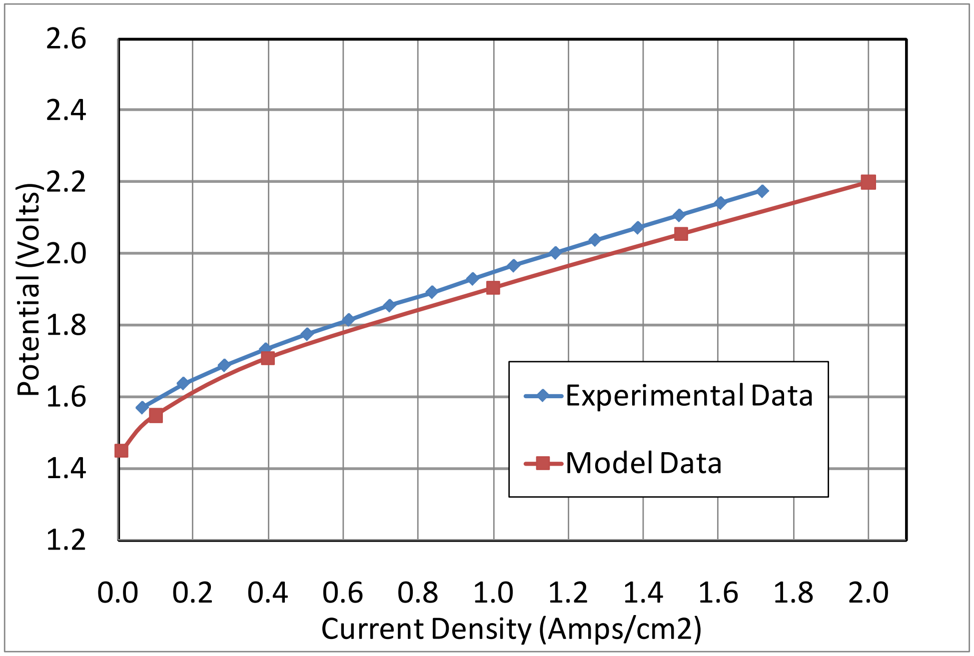
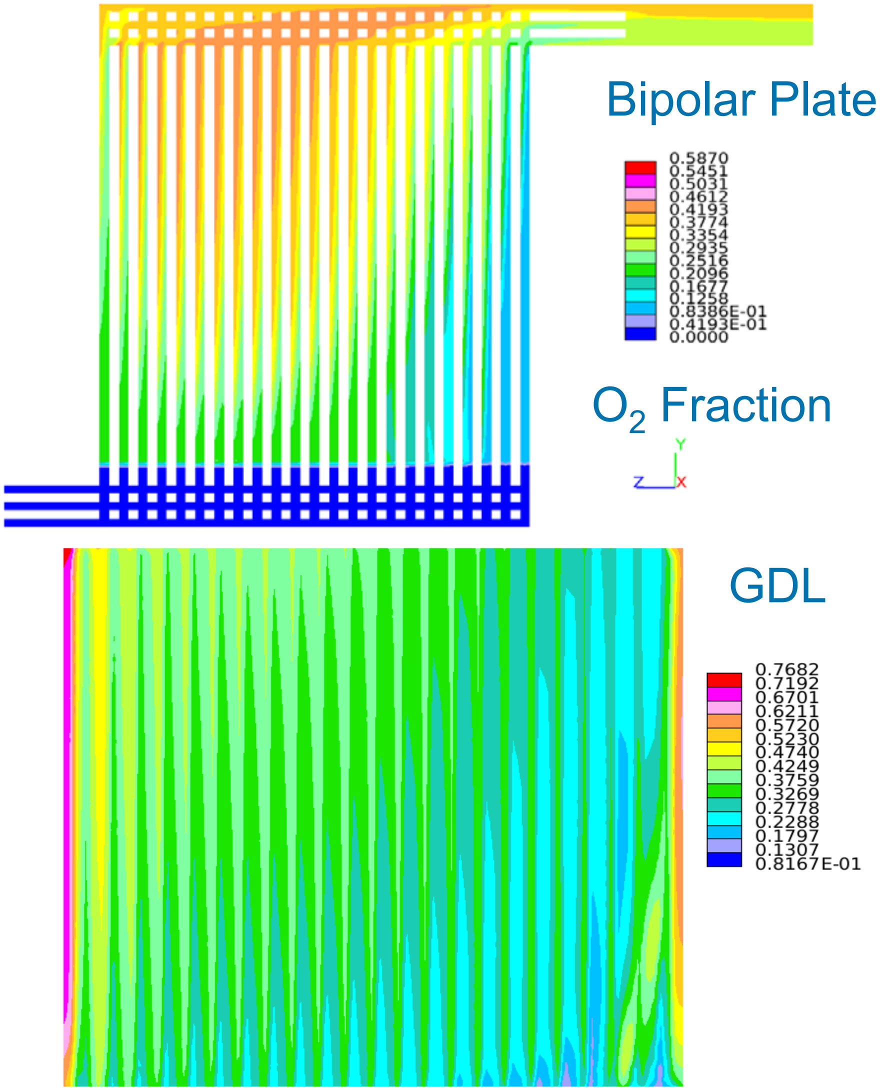
Technical Accomplishments
Subtask 2.1: Computational Model

- Modeling goals:
  - Current density distribution
  - Electrical potential distributions
  - Volume fraction of water and gases
  - Heat distribution





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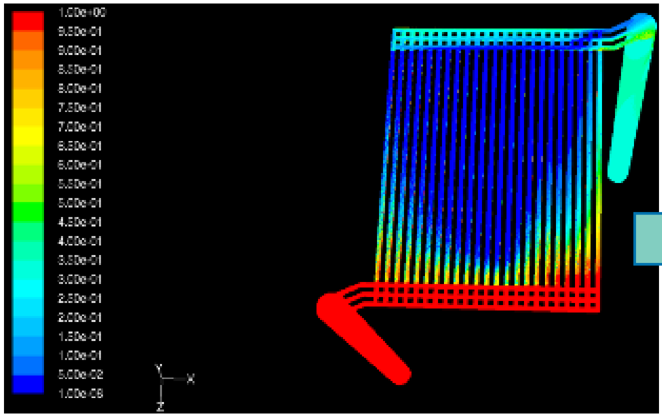
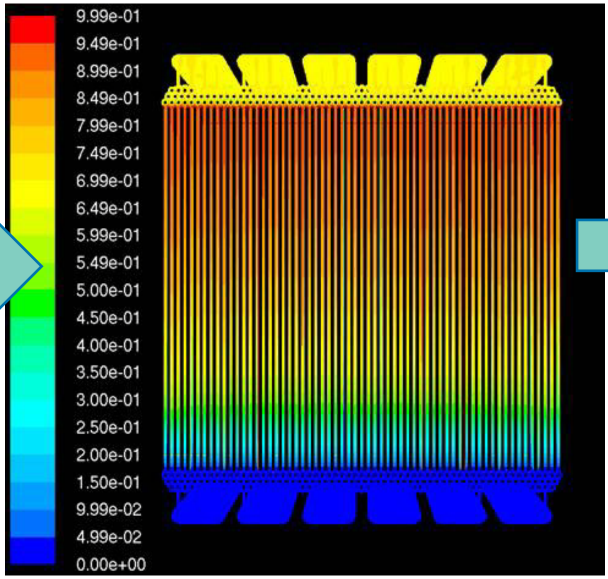
Relevance
Task 2.1: Performance Prediction

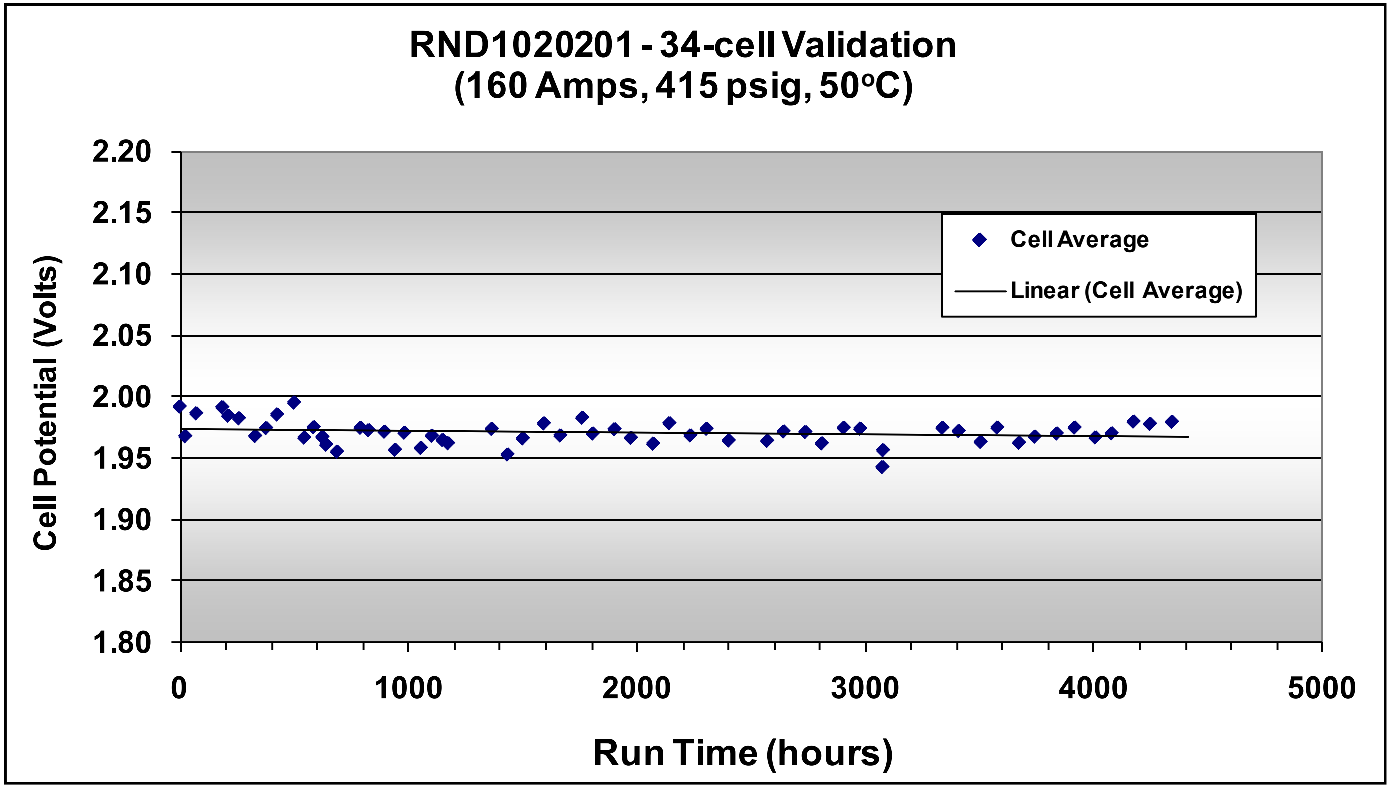
- Cell component architecture can be refined in light of model predictions
- Use conclusions for iterations of next generation designs





Technical Accomplishments
Subtask 2.2: Cell Improvements

- Implemented first design step Oct. 2010
- Over 1200 cells manufactured to date
- 12% stack cost savings demonstrated



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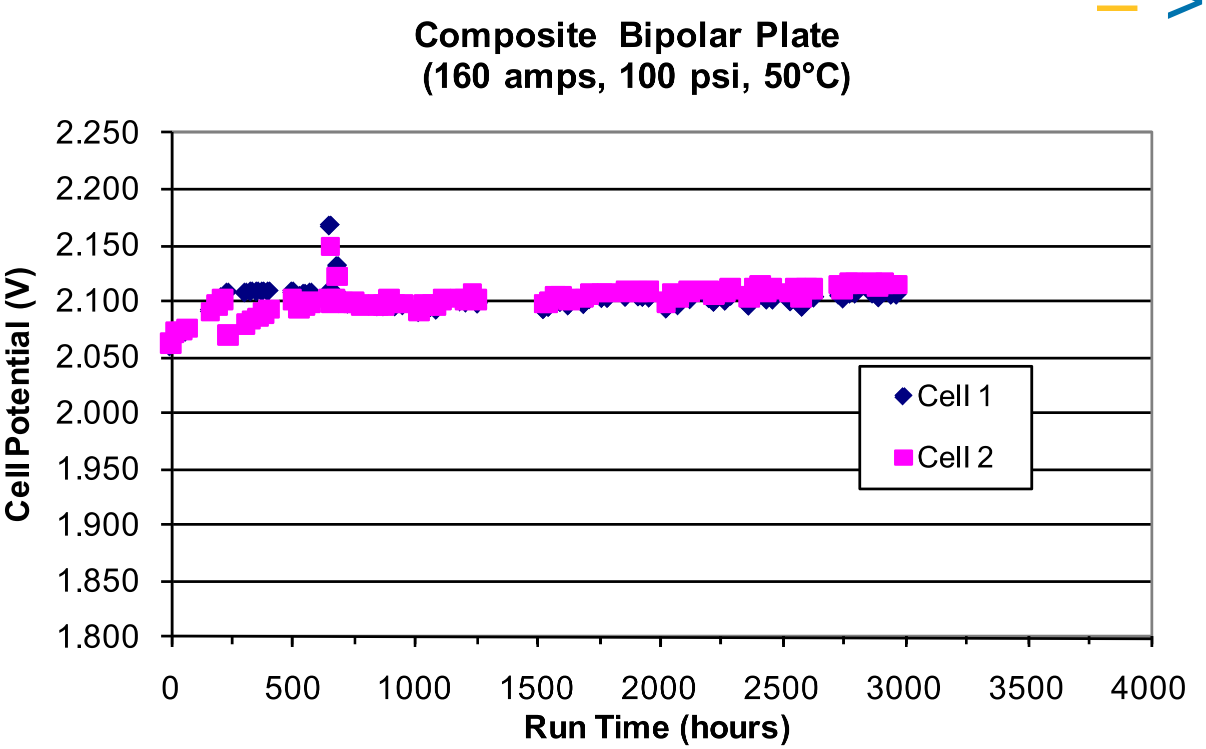
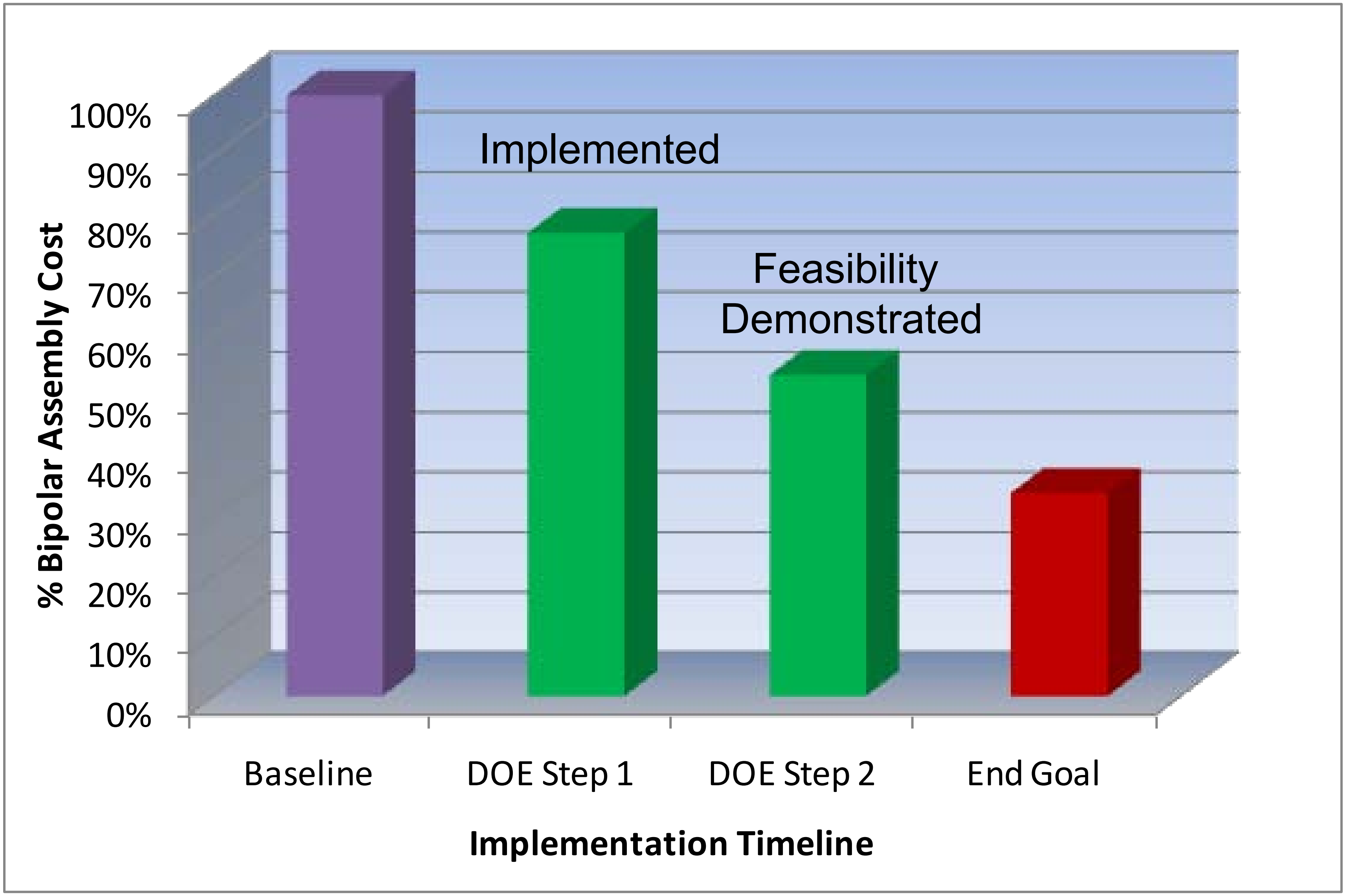
Technical Accomplishments
Subtask 2.3: Alternative Materials

- Built on previous work with test wafers
- Full bipolar plates show stable performance
  - >3000 hours demonstrated



Bipolar plate channels, nitrided plate

Relevance
Task 2: Flow Field Design



H2A Modeling Calculations – Year 1

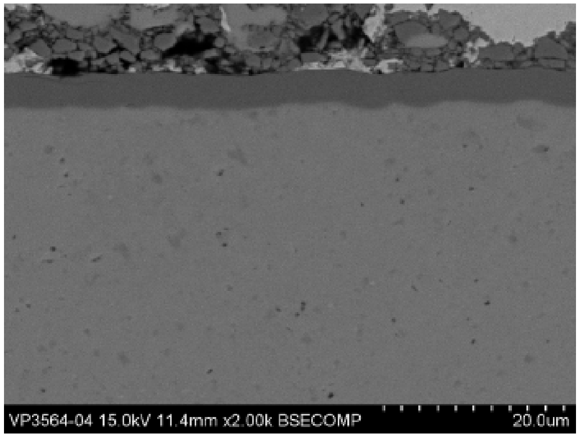
- Highlighted items implemented in production

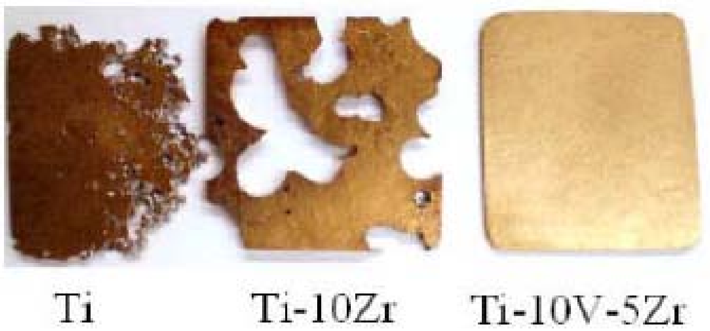
	Cost savings ($/kg)
Bipolar assembly	$ 0.24
Membrane	$ 0.30
Initial catalyst loading reduction	$ 0.06
Total	$ 0.60

Technical Accomplishments: Subtask 2.4 Alternative Coatings

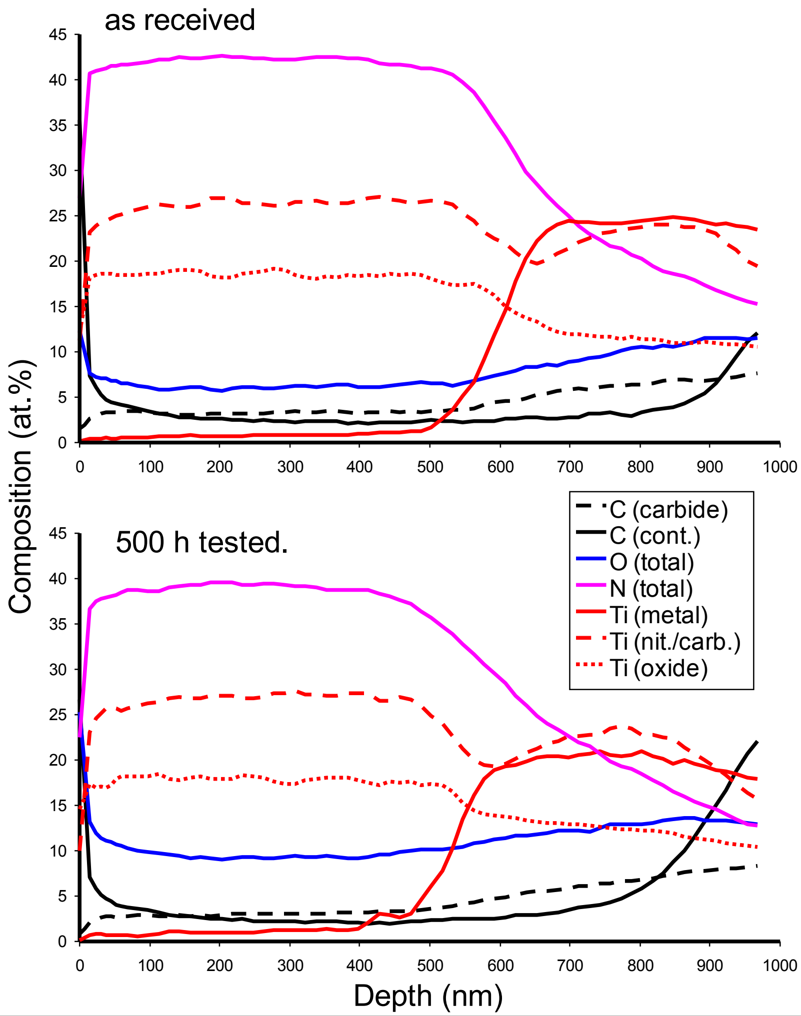
- Develop alternate protective coatings
  - Study with Oak Ridge on thermal nitriding and characterization

Nitride layer after 1300 hours operation





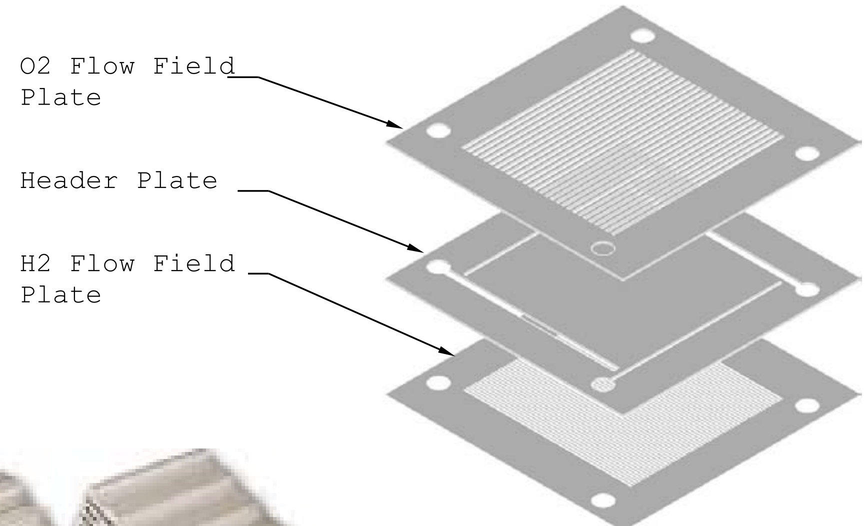
Oak Ridge alloy corrosion test

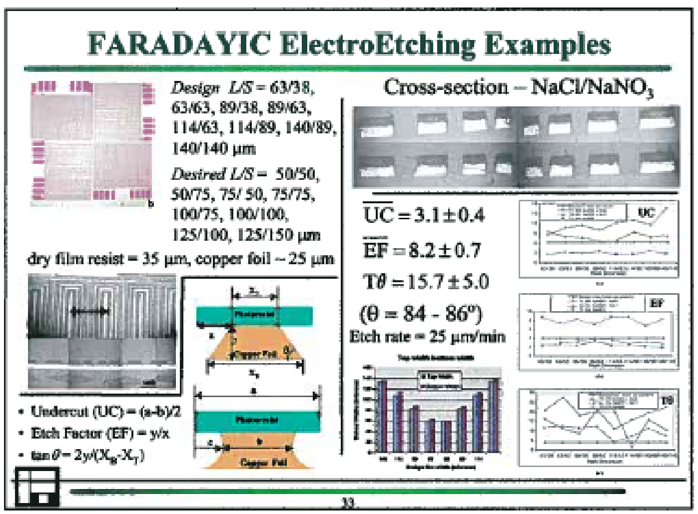


Technical Accomplishments
Task 3: Alternative Concepts

- Surveyed alternative manufacturing techniques in addition to Task 2 work

Diffusion bonding





Chemical/Electrochemical Etching

Stamping

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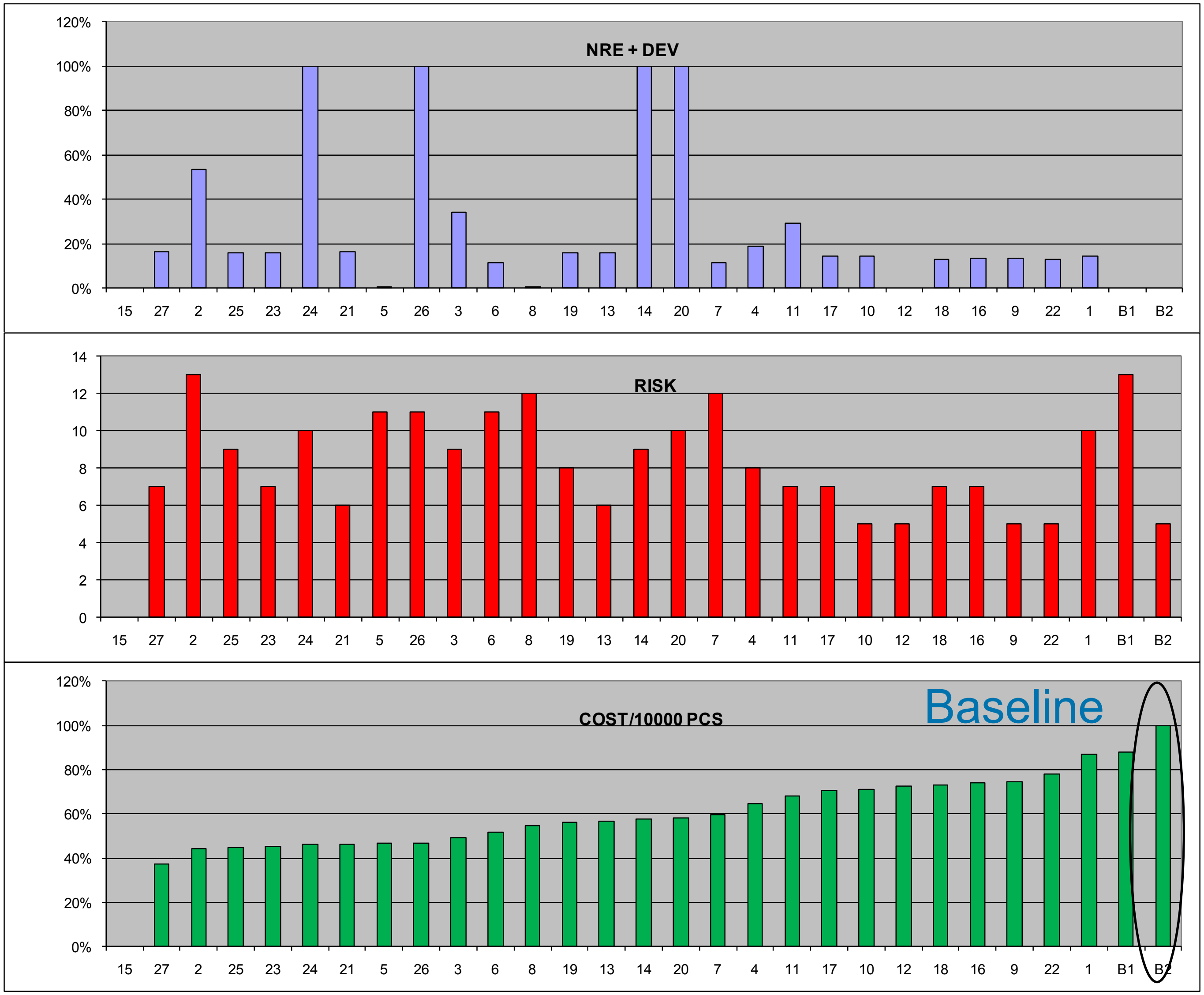
Relevance
Task 3: Alternative Concepts

- Over 30 concepts evaluated
- Ranked based on NRE cost, risk, and part cost
- Selected 2 additional concepts for prototyping
- Potential for additional 50% cost savings



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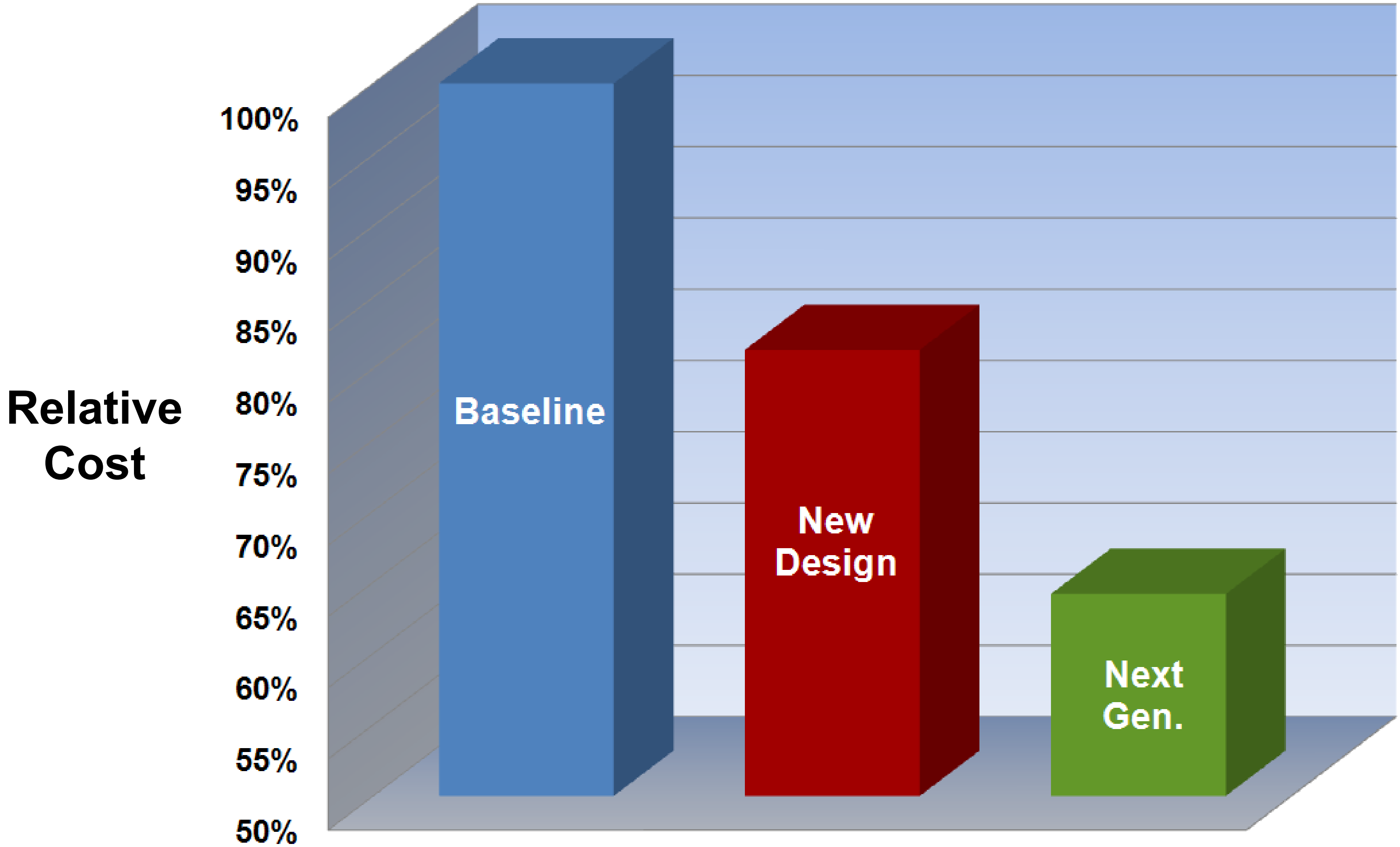
Relevance
Tasks 2 and 3: Cell Cost Reductions

- Present program work impact on cell cost



Collaboration

- Partners
  - Entegris (Industry): Demonstrating alternative materials and coating techniques for reduced cost flowfields
  - Penn State (Academic): Developing a full computational model of a functioning electrolyzer cell
  - Oak Ridge National Laboratory: (Federal) Investigating advanced coating materials and deposition techniques

Future Work

- Task 2.3 Continue materials compatibility screening and evaluation of Entegris designs
- Task 2.4 Evaluate ORNL nitride coatings
- Task 3.0 Obtain and test alternate design concepts
- Task 4.0 Prototype testing in stacks and scale up
- Task 5.0 Final downselect and manufacturing process development
- Task 6.0 Manufacturing qualification
- Task 7.0 Perform H2A analysis for end design

Manufacturing Development

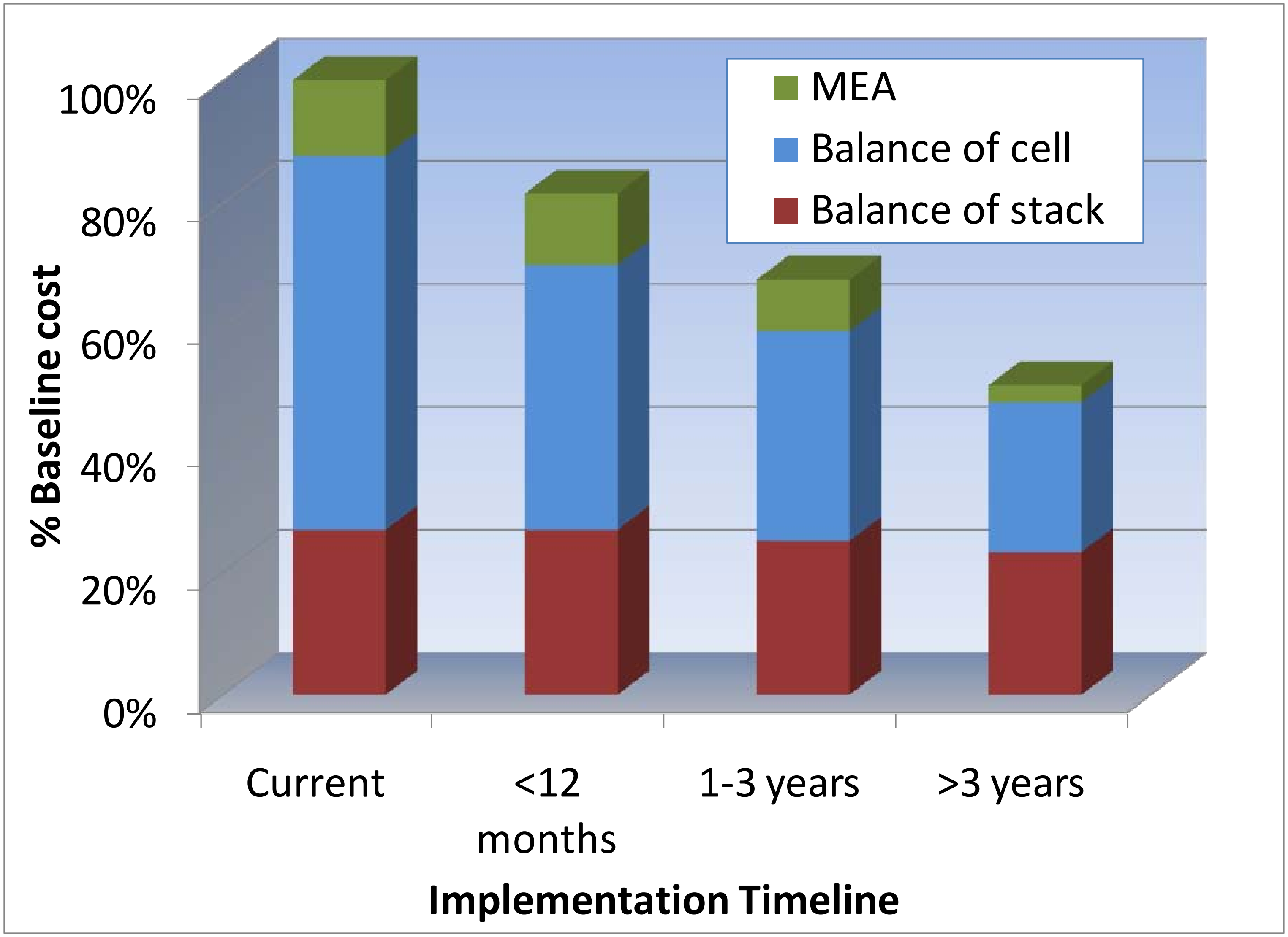
- End goal of program to scale up new flow field
- Utilize existing stack design and system capability

65 kg/day system,
operating Proton fueling station

0.6 ft^2 cell stack, >10,000 cell hours, ~1 kg/day/cell

Future Cell Stack Cost Reduction

- A pathway has been identified to significantly lower cell cost



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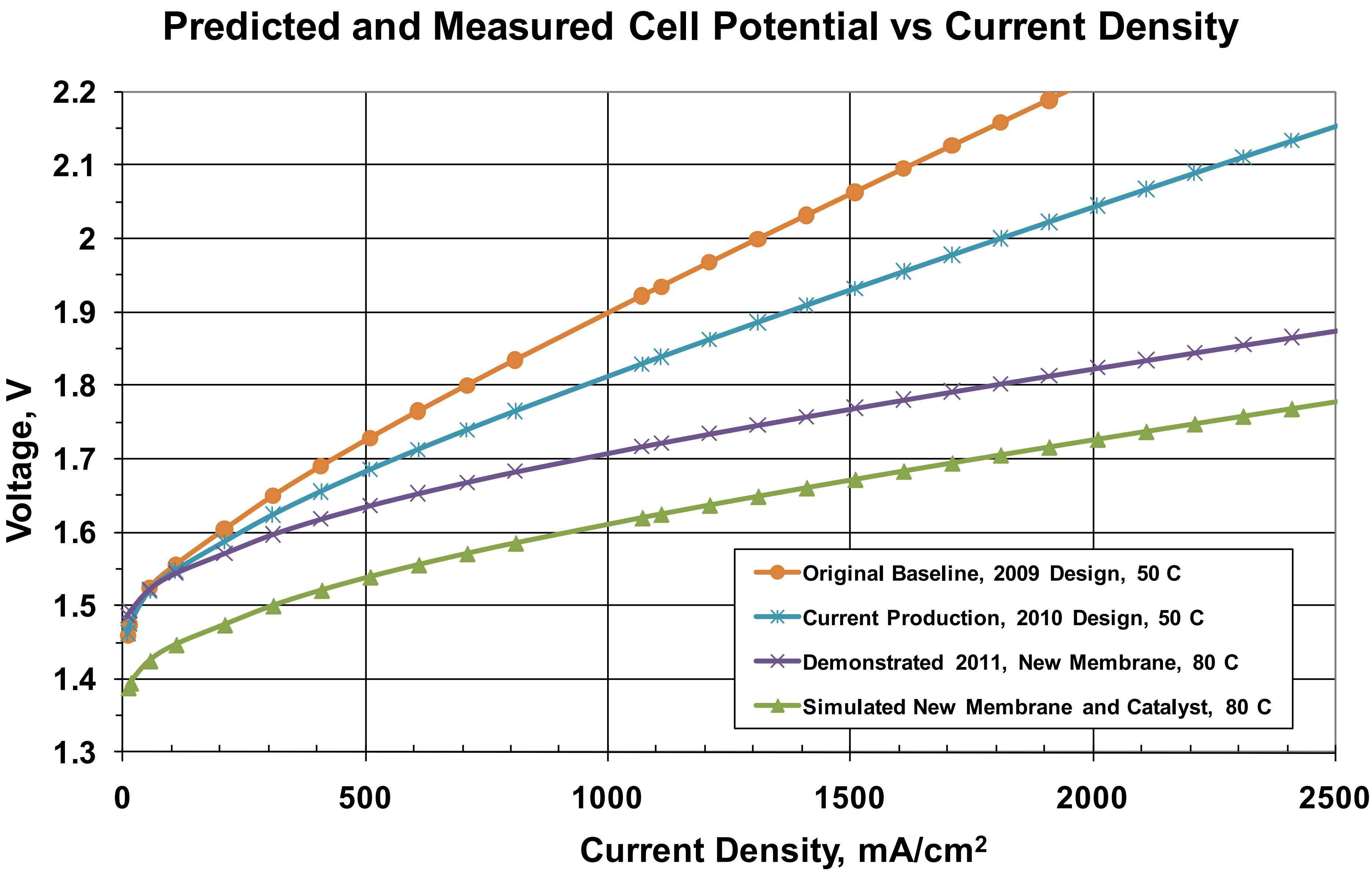
Future Cell Stack Efficiency Improvements



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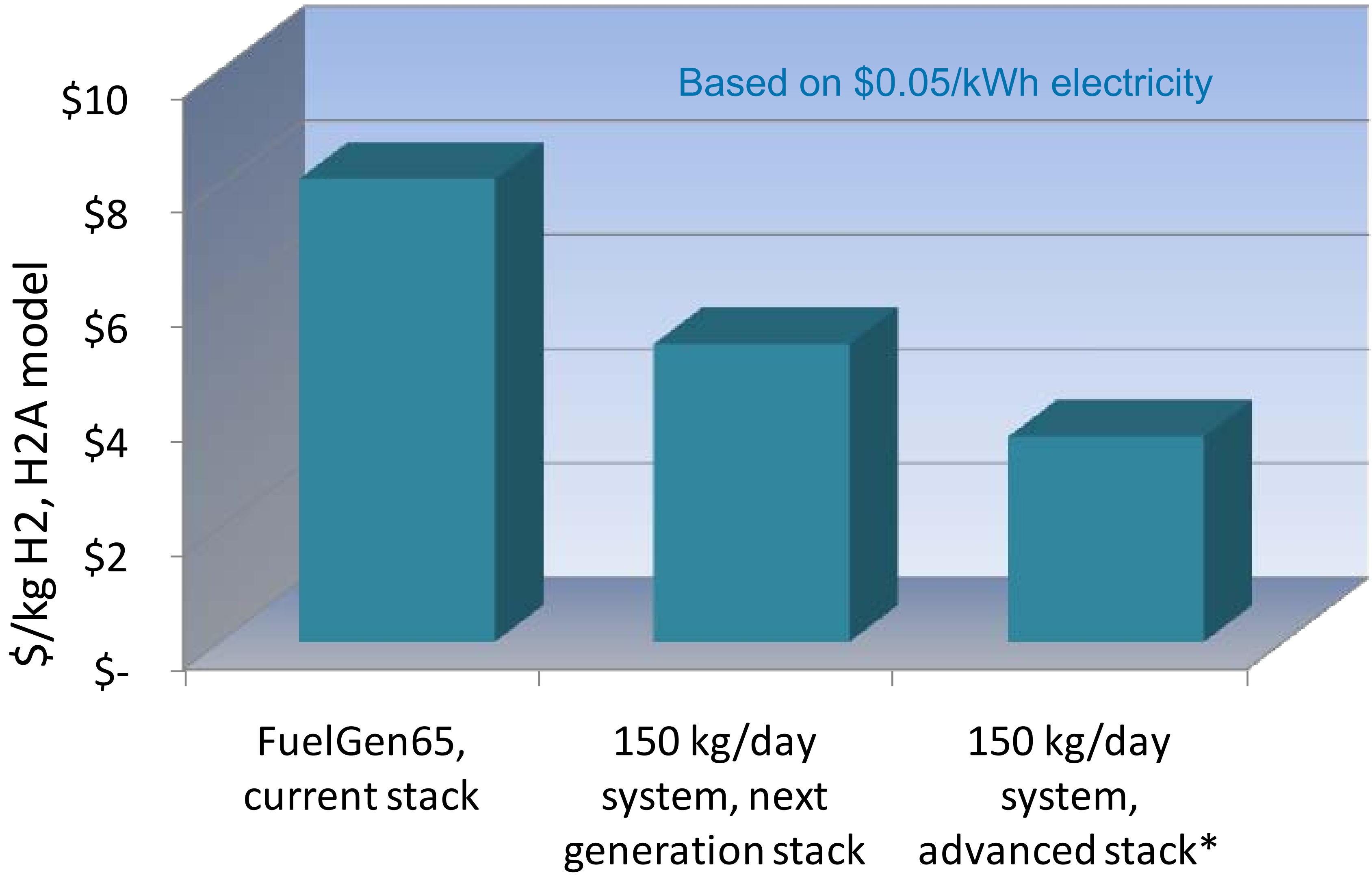
Resulting Hydrogen Cost Progression



*Assumes volumes of 500 units/year

Summary

- Relevance: Cost savings at the electrolyzer cell level directly impacts hydrogen production costs
- Approach: Reduce cost of largest contributors first
- Technical Accomplishments:
  - Catalyst: Demonstrated reduced catalyst loading (55% anode, 90% cathode reduction) while maintaining desired electrical performance
  - Flowfield: Implemented Phase 1 (25% part cost savings) and demonstrated new prototypes, evaluated new manufacturing methods with >50% savings
- Collaborations:
  - Cell Model: Will allow for optimization/verification of designs
  - Entegris: Concepts show good durability and >50% flow field cost savings
  - ORNL: Providing detailed information on nitrided layers, starting alloy work
- Proposed Future Work:
  - Continue development and verification of unitized flowfield architectures

Team

- Blake Carter
- Luke Dalton
- Brett Tannone
- Andy Roemer
- Mike Niedzwiecki
- Tom Mancino (Entegris)
- Mike Brady (ORNL)
- Todd Toops (ORNL)

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