The Leader in On-site Hydrogen Generation

High Performance, Low Cost Hydrogen Generation from Renewable Energy

P. I./Presenter Name: Dr. Katherine Ayers

Organization: Proton Energy Systems

Date: June 10, 2010

Project ID #PD071

Overview

Timeline

- Project Start: Oct 2009
- Project End: March 2011
- Percent complete: 50%

Budget

- Total project funding
  - DOE share: $951,500
  - Contractor share: $237,875
- Funding for FY10
  - DOE share: $634,333

Partners

- Entegris, Inc. (Industry)
- Penn State (Academic)

Barriers

- Barriers addressed
  - G: Capital Cost
  - H: System Efficiency
  - J: Renewable Electricity Generation Integration

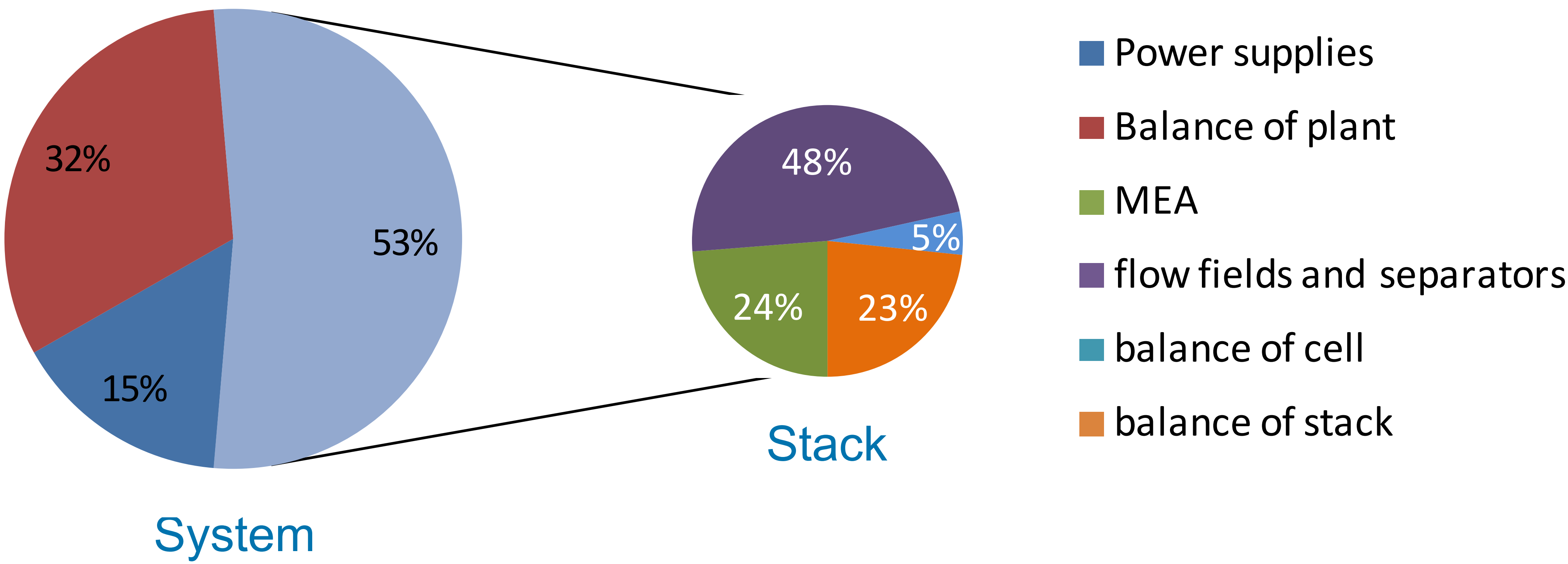
Table 3.1.4. Technical Targets: Distributed Water Electrolysis Hydrogen Production [a, b, c]

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
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: Alternative Bipolar Plates
  - Test material compatibility
  - Fabricate test parts
- Task 3.0: Evaluation of Flowfield Prototypes
  - Operate in electrolyzer
  - Compare performance
- Task 4.0: H2A Model Cost Analysis
  - Input design parameters
  - Assess impact of changes

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Progress on Milestones

Task	Milestone	Progress Notes	Completion	Due Date
1.0	Demonstrate a Reduced Loading Anode Electrode	Concept design completed	100%	Mar-10
2.1	Develop a Computational Electrolyzer Cell Model	Model being validated against experimental data	50%	Jan-11
2.2	Prototype New Cell Design for Production Release	Prototype cell stacks assembled and on test	100%	May-10
2.3	Design and Prototype Alternative Flowfields	Prototype cell stacks assembled and on test	100%	May-10
3.0	Use Operational Data to Select Best Candidate	Preparing decision matrix	10%	Jan-11
4.0	Determine Gas Gallon Equivalency with H2A Model	Compiling cost and efficiency data	10%	Jan-11
5.0	Final Report to DOE	Composing task level reports after each test	10%	Feb-11

Technical Accomplishments
Task 1.0: Catalyst Optimization

- Demonstrated new alternative application techniques
- Successfully operated prototype MEAs with new catalyst formulation in electrolyzer cells

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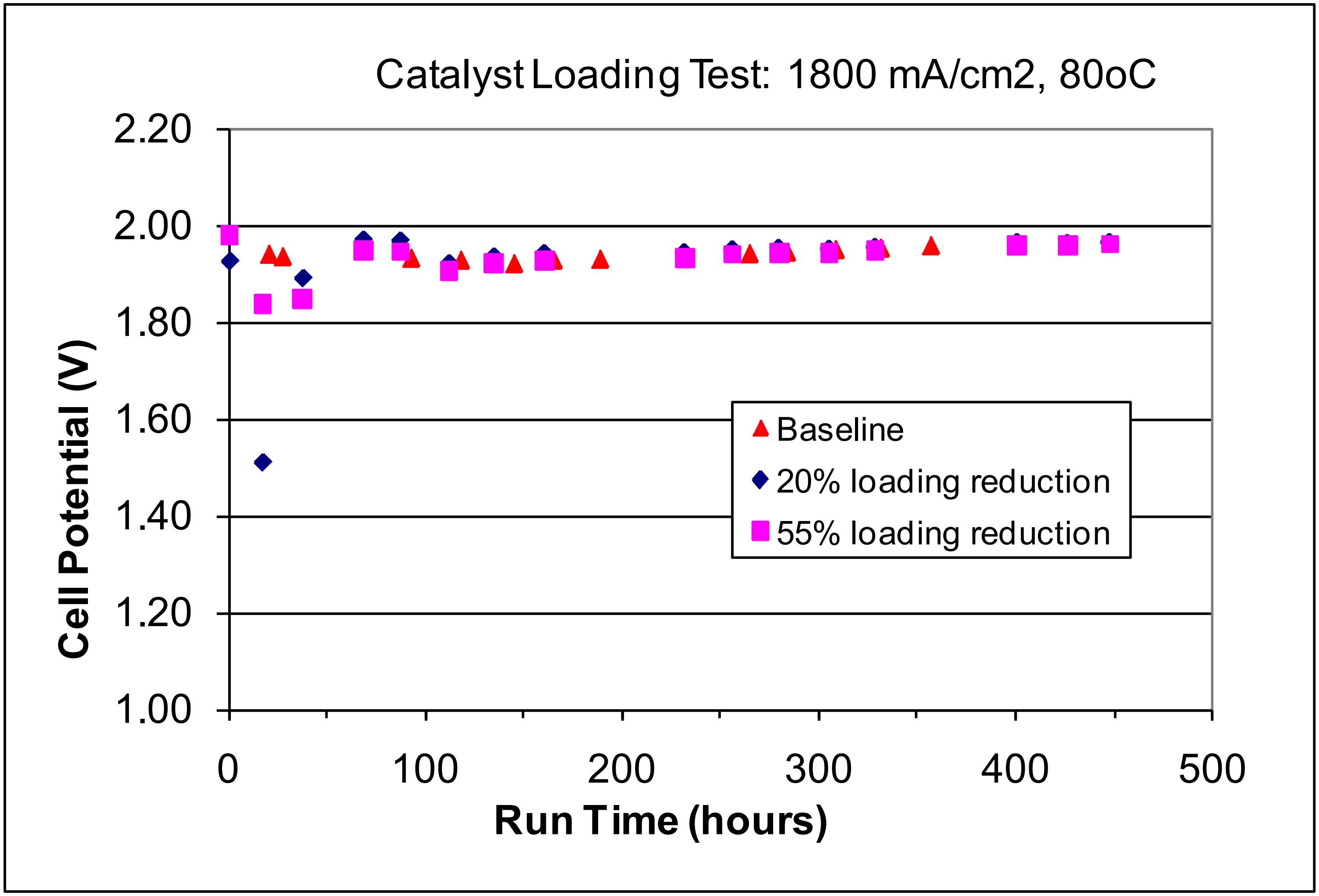
Relevance
Task 1.0: Catalyst Electrode Performance

- Achieved 55% reduction in loading with no performance loss



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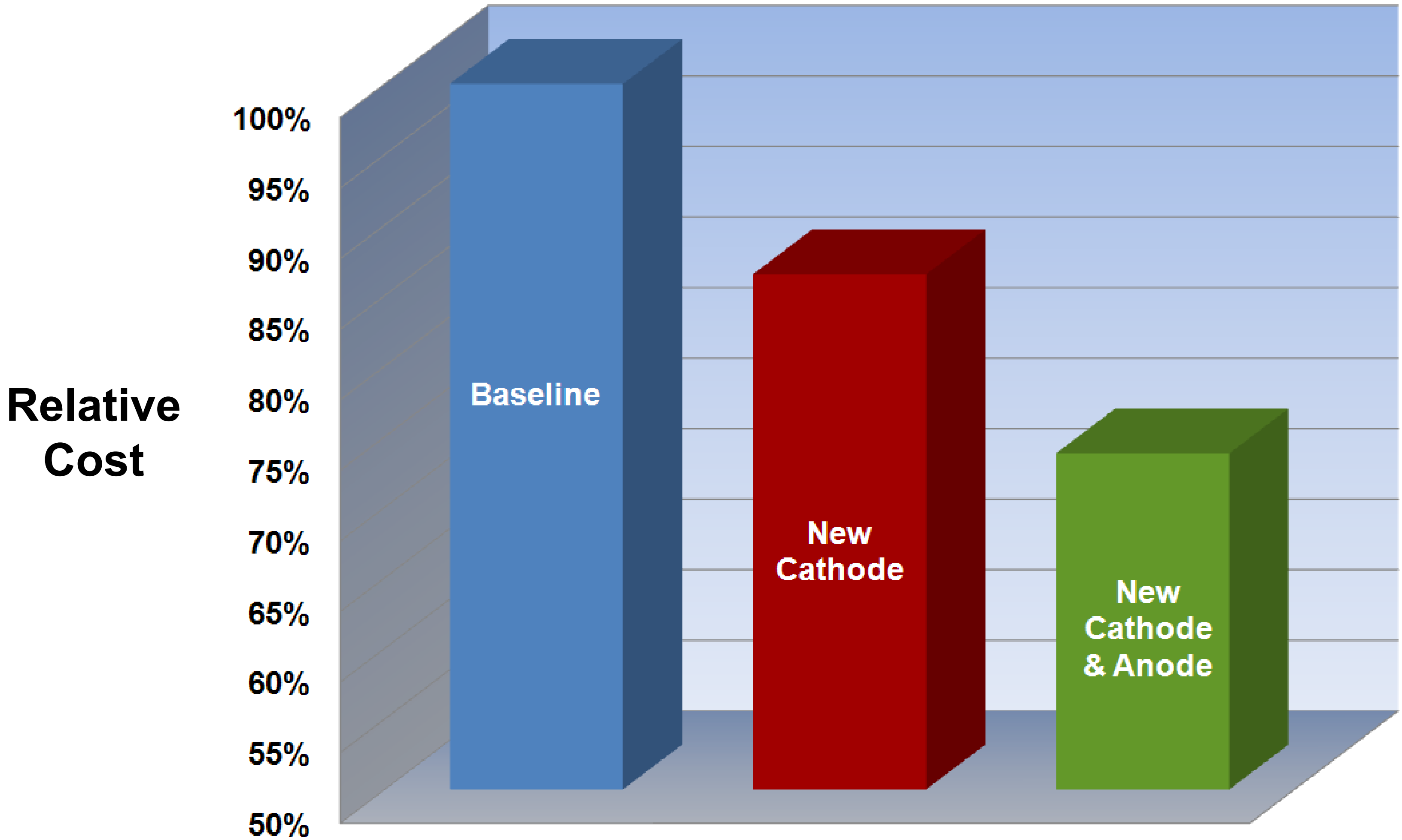
Relevance
Task 1.0: MEA Cost Evaluation

- Present program work impact on MEA costs



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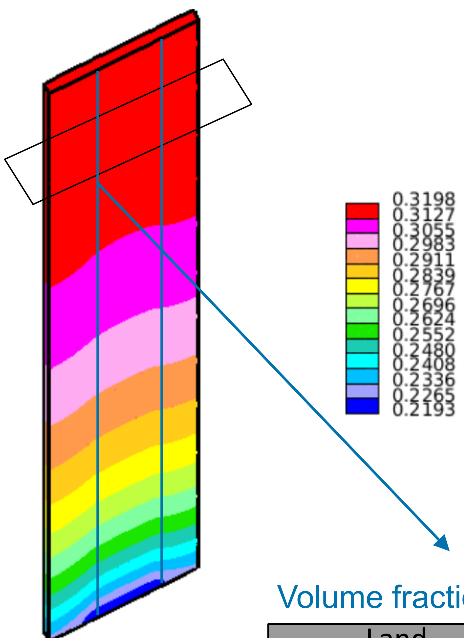
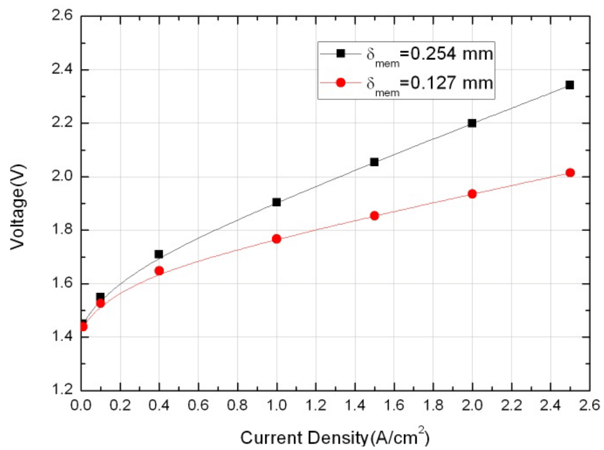
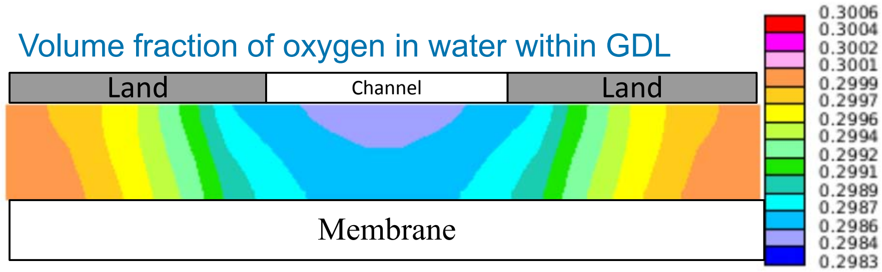
Technical Accomplishments
Subtask 2.1: Computational Model

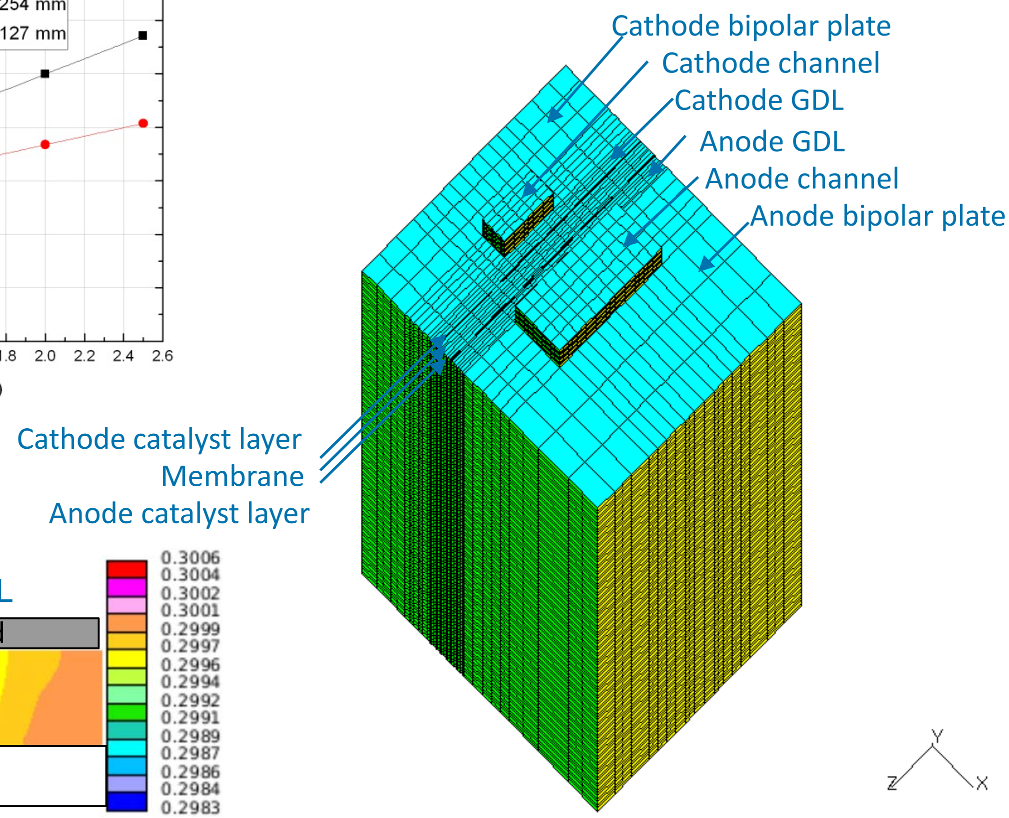
- Computational model being validated against test data





Volume fraction of oxygen in water within GDL





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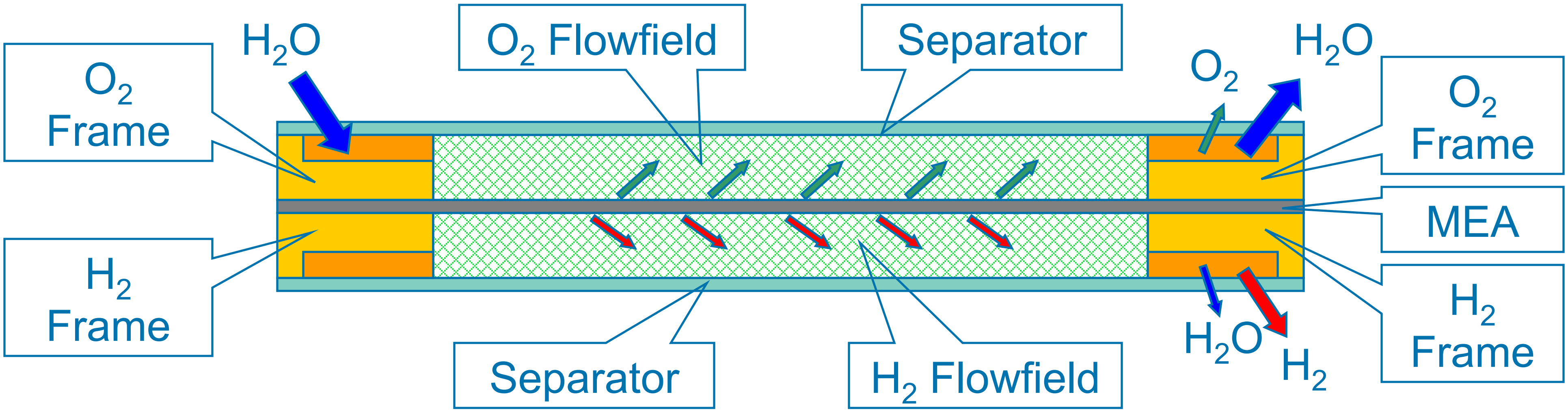
Relevance
Task 2.1: Performance Prediction

- Cell component architecture can be refined in light of model predictions for:
  - Current density distribution
  - Electrical potential distributions
  - Volume fraction of water and gases
  - Heat distribution

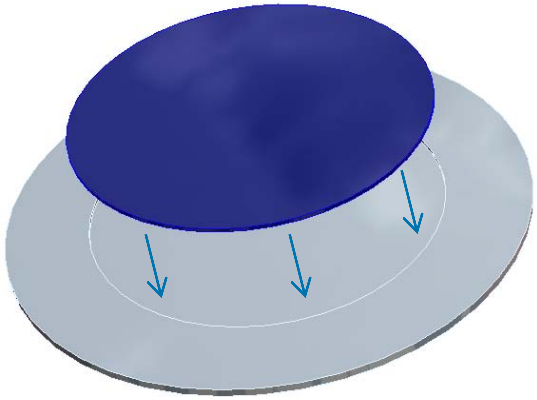
Technical Accomplishments Subtask 2.2: Cell Improvements

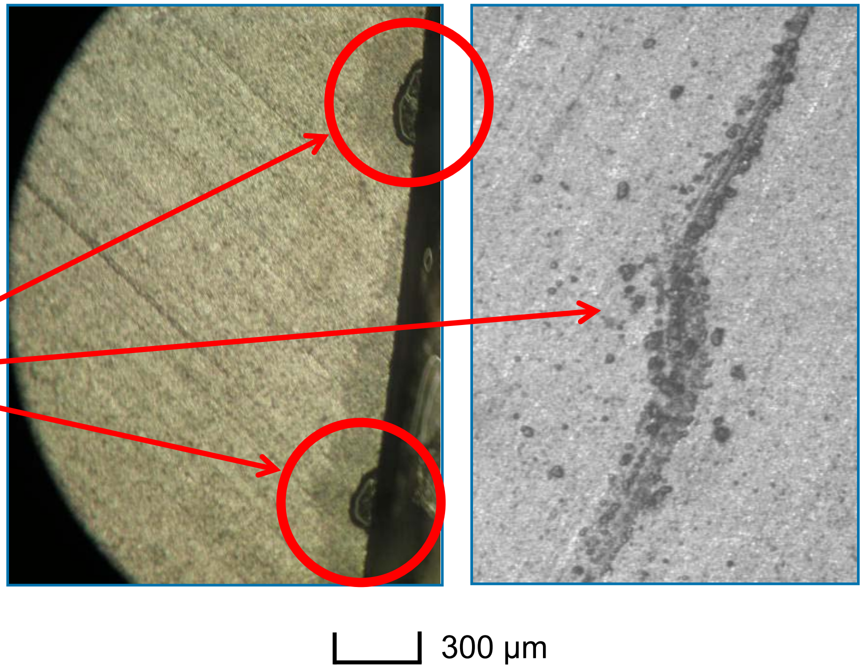
- New design successfully reduces part count and assembly time while improving cell robustness
- New frames with integrated features qualified and used for prototype cell build
- Prototype flowfields fabricated using production tooling and techniques



Technical Accomplishments
Subtask 2.3: Alternative Materials

- Test wafers imbedded within modified cell parts
- Preliminary results show favorable performance
- Coating is protective when present and continuous
  - Some defects observed before operation
  - Evidence of corrosion observed post operation
  - Corrosion rate not yet fully quantified, microscopic levels





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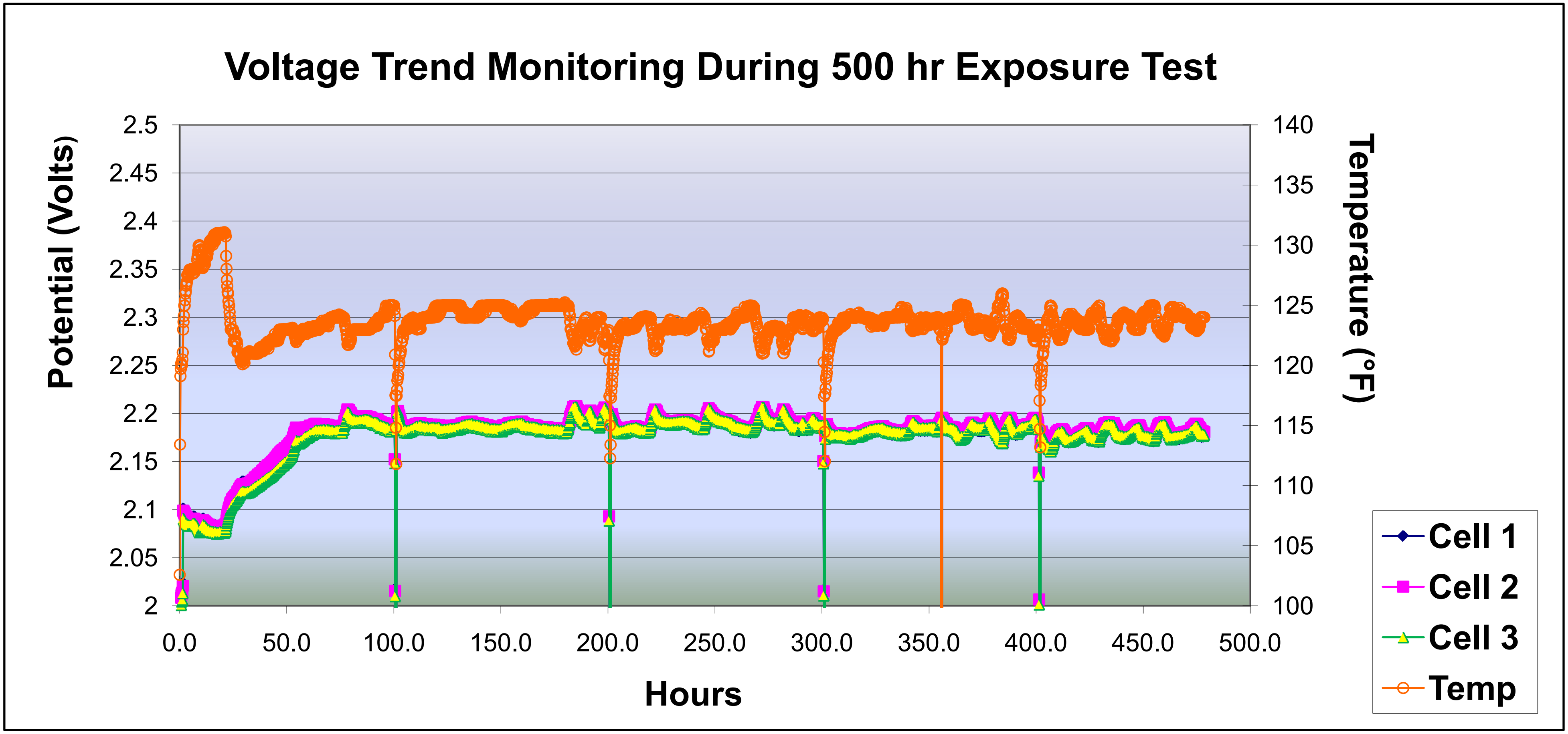
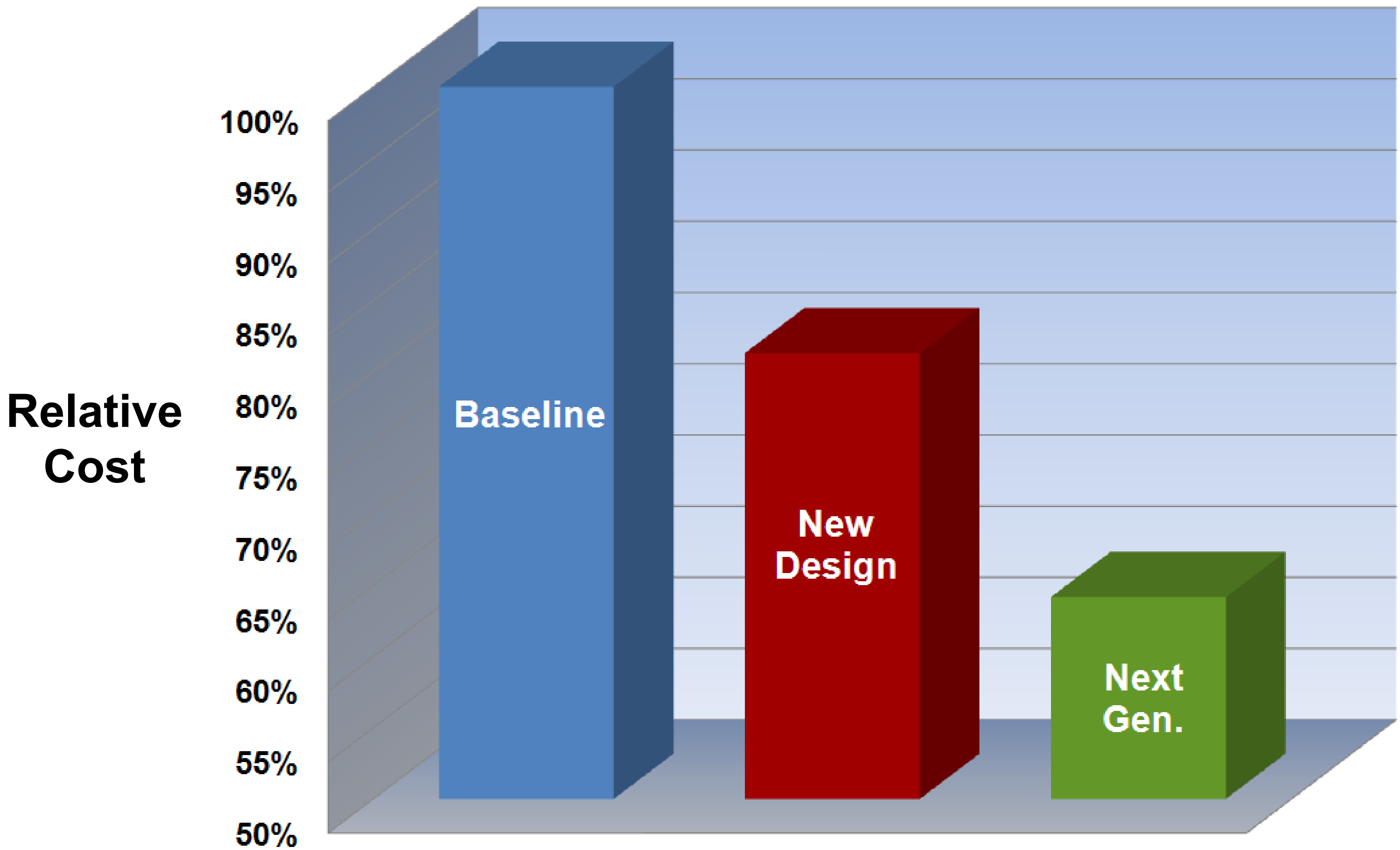
Relevance
Task 2.3: In-Cell Coating Performance

- Maintained stable potential of above 2 Volts for 500 hr test



Relevance
Tasks 2.2 and 2.3: Cell Cost Reductions

- Present program work impact on cell cost



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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 (Phase 2)

PENNSTATE
Electrochemical Engine Center
1 8 5 5

Entegris

OAK RIDGE NATIONAL LABORATORY
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Future Work

- Task 2.1 Optimize catalyst application process
- Task 2.2 Monitor operational prototype stack
- Task 2.3 Continue long term materials compatibility screening and evaluation of alternative designs
- Task 3.0 Operate various flowfield designs
- Task 4.0 Perform H2A analysis for end design

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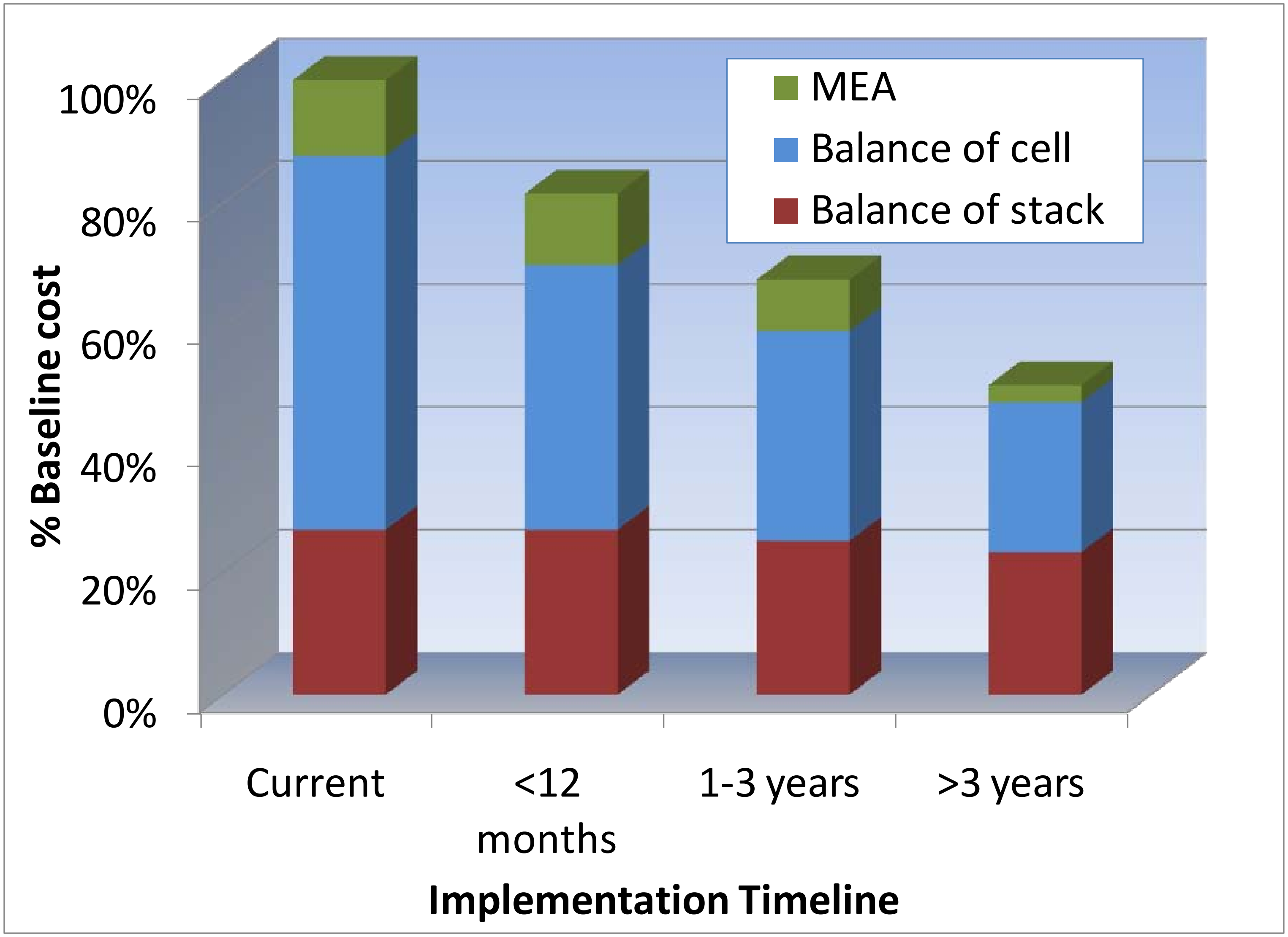
Future Cell Stack Cost Reduction

- A pathway has been identified to significantly lower cell cost



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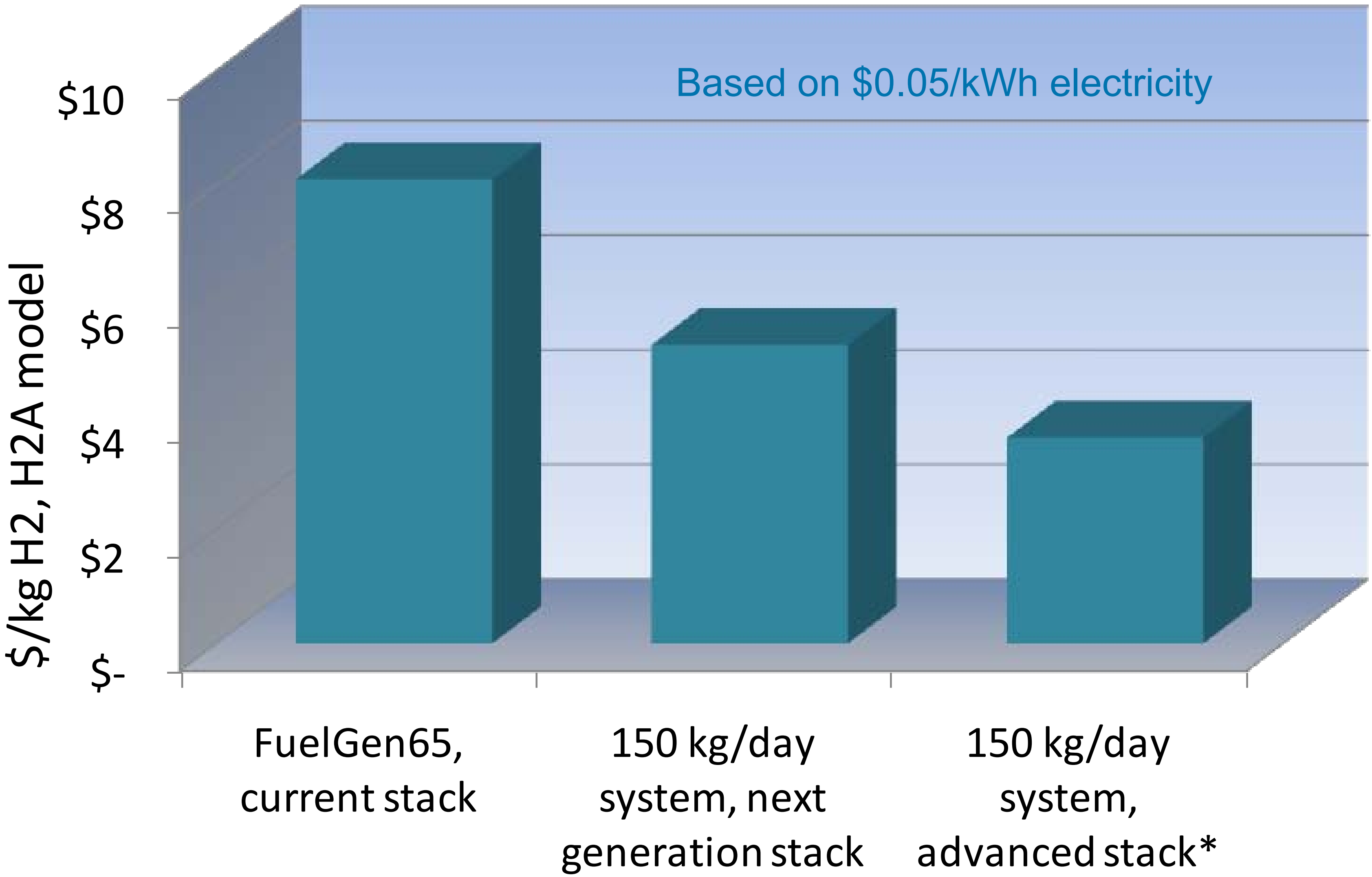
Resulting Hydrogen Cost Progression



*Assumes volumes of 500 units/year

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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 while maintaining desired electrical performance
  - Flowfield: Reduced part count through integration and elimination of complex subassemblies
- Collaborations:
  - Cell Model: Will allow for optimization of components
  - Entegris/ORNL materials: Can provide alternatives to costly metals
- Proposed Future Work:
  - Continue development and verification of unitized flowfield architectures

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