Advanced Alkaline Electrolysis

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GE Global Research Center

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Project# PD8

Overview

Timeline

Project start date 1 April 2004

Project end date 30 Dec. 2005

Percent complete 100%

Budget

Total project funding	M$2.1
• DOE share	M$1.4
• Contractor share	M$0.7
Funding received in FY04	M$1.05
Funding for FY05	M$0.35

Barriers addressed

Q. Capital Cost of Electrolysis Systems

T. Renewable Integration

Technical Targets:

2010: Electrolyzed Hydrogen @ $2.85/ kg

Partners

SUNY Albany Nanotech

Objectives

- Develop a commercial strategy for low cost alkaline electrolysis
- Demonstrate a laboratory scale proof of concept

		Units	2010 DOE Target
Cell Stack	Efficiency	% (Voltage)	76% (1.6V)
	Cost	$ / kg H2	$0.39
Electricity (System)	Cost	$ / kg H2	$1.89
O&M	Cost	$ / kg H2	$0.38

Approach

Quantify Market Requirements

- Establish customer and mission profile
- Determine target product size and configuration

Design System

- Set performance targets to meet customer requirements
- Identify technical barriers in development path

Electrochemical Cell Analysis

- Develop and test materials for low cost electrolyzer stack
- Optimize system cost, performance, and reliability

Bench Scale Testing

- Build and test proof of concept system

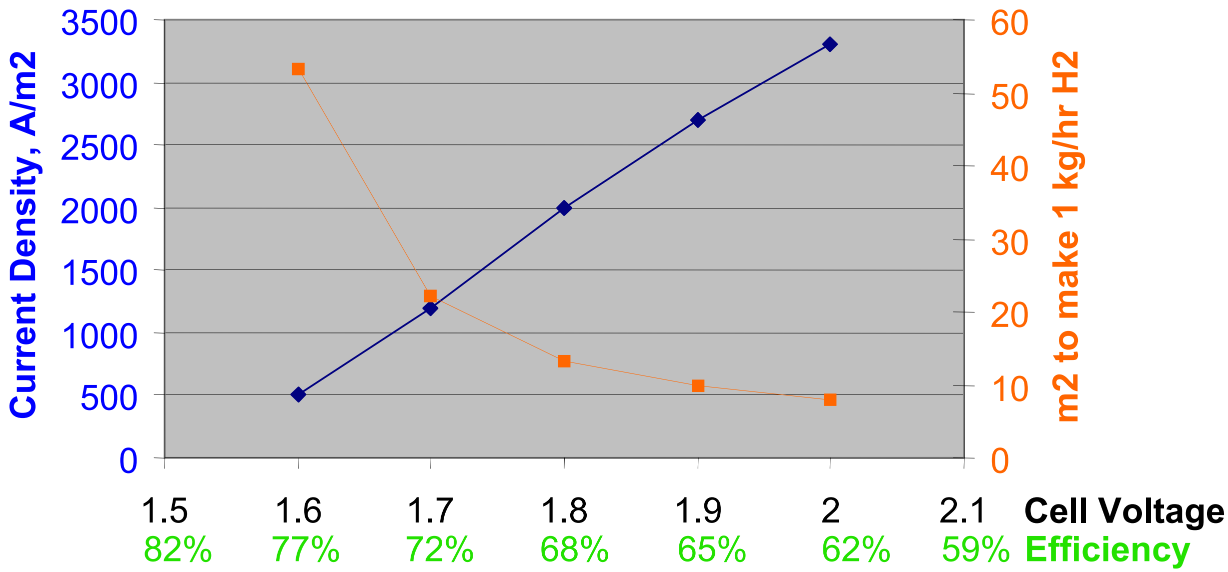
Full Scale Installation Concept

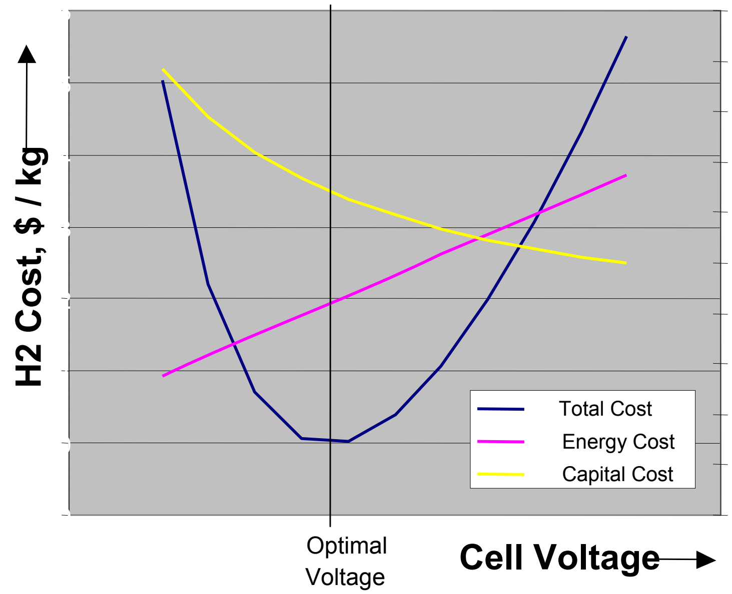
- Design reference plant

Optimizing H2 Cost Drives Tradeoffs

Voltage / Current Tradeoffs

Baseline IV curve





minimizes energy costs

minimizes capital costs

Lowest cost operating point varies with cost of electricity and specific cost of material

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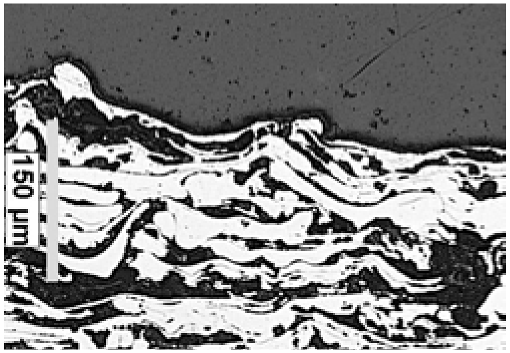
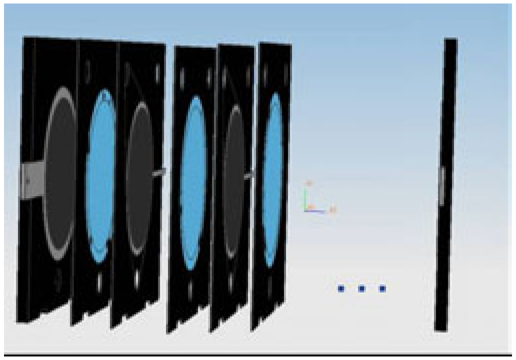
Technology Plan for Low Stack Cost

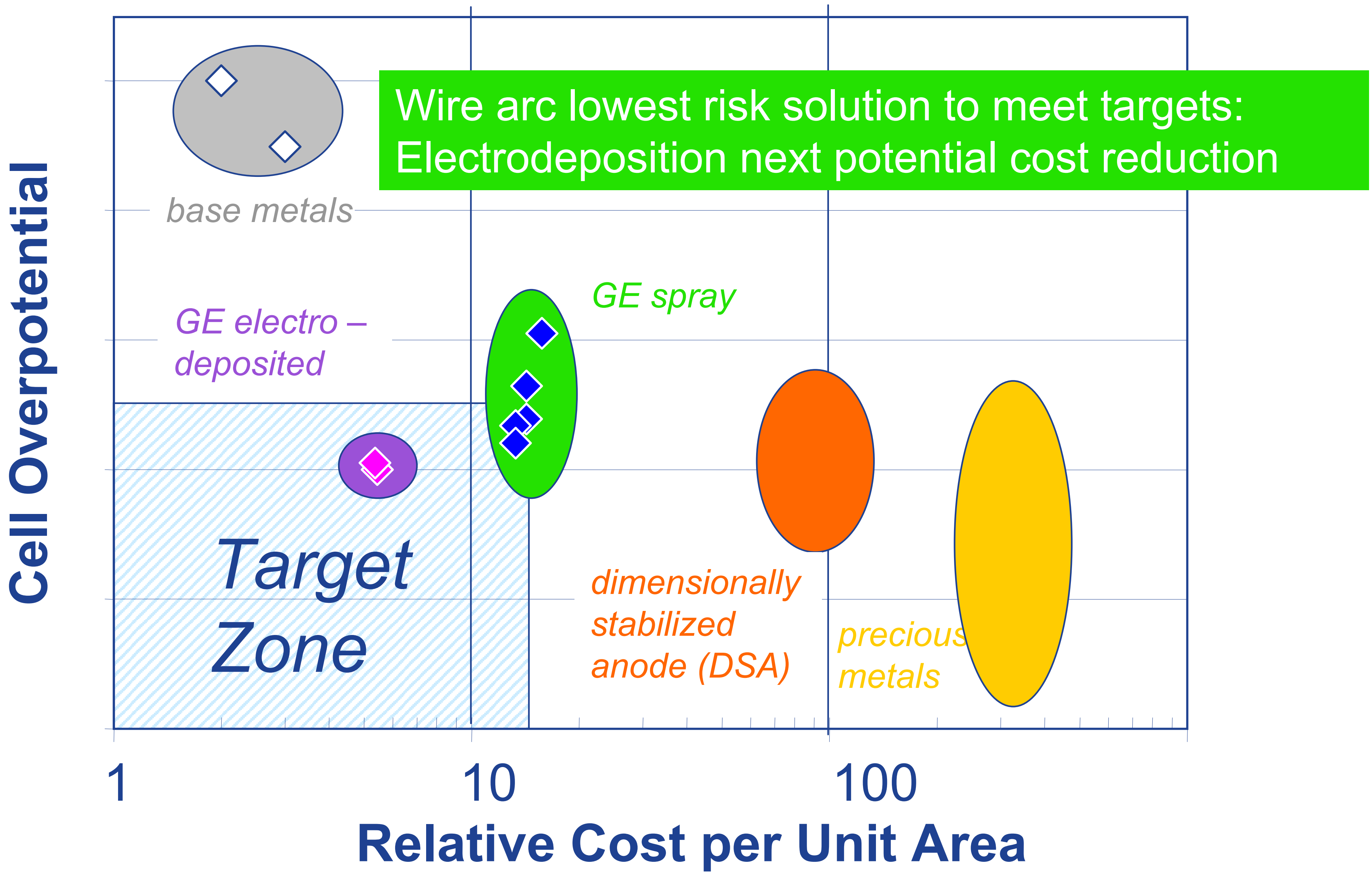
High surface area electrodes minimize stack size



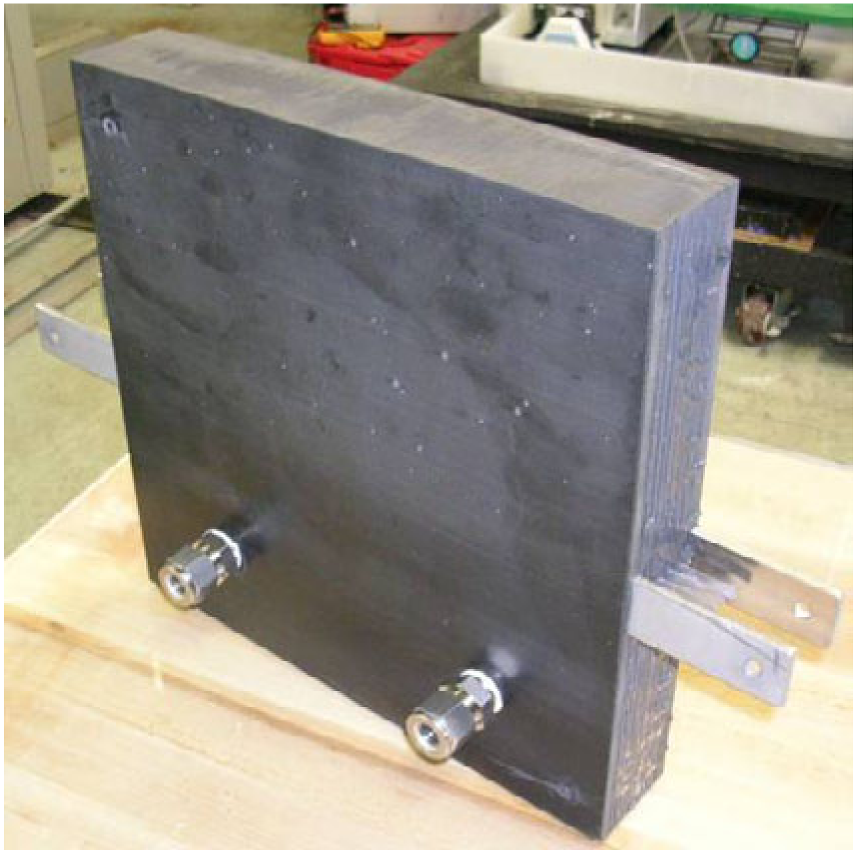
Advanced materials enable low assembly costs



Electrode Concept Selection



Proof of Concept Plastic Stack



5 x 153 cm2 cells

500W input power

10 gph output

Noryl plate / epoxy construction

Wire arc Raney electrodes

Dual inlets to eliminate shunts

First “true monolith” – design details per product concept

“500W” Bench Scale System

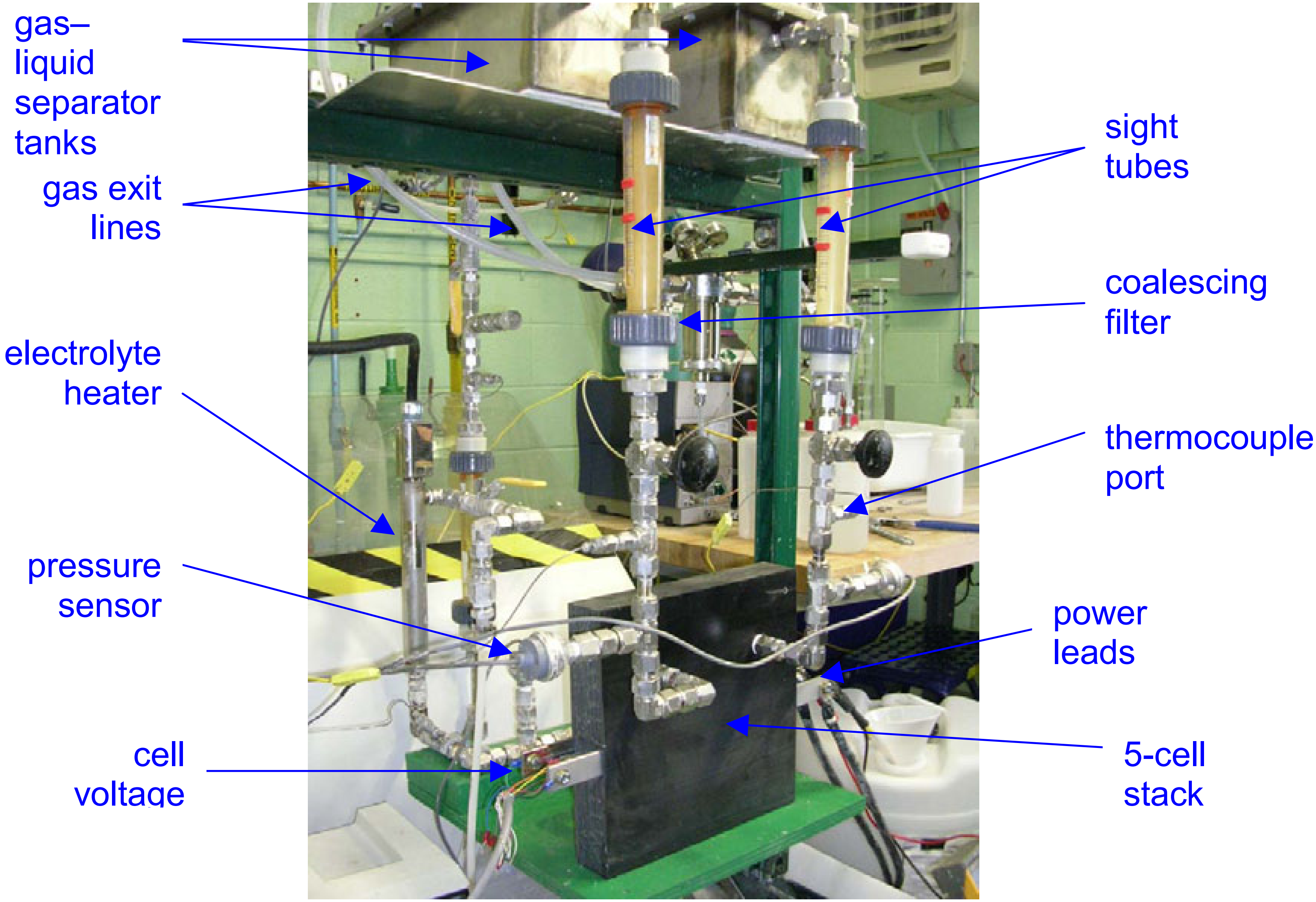
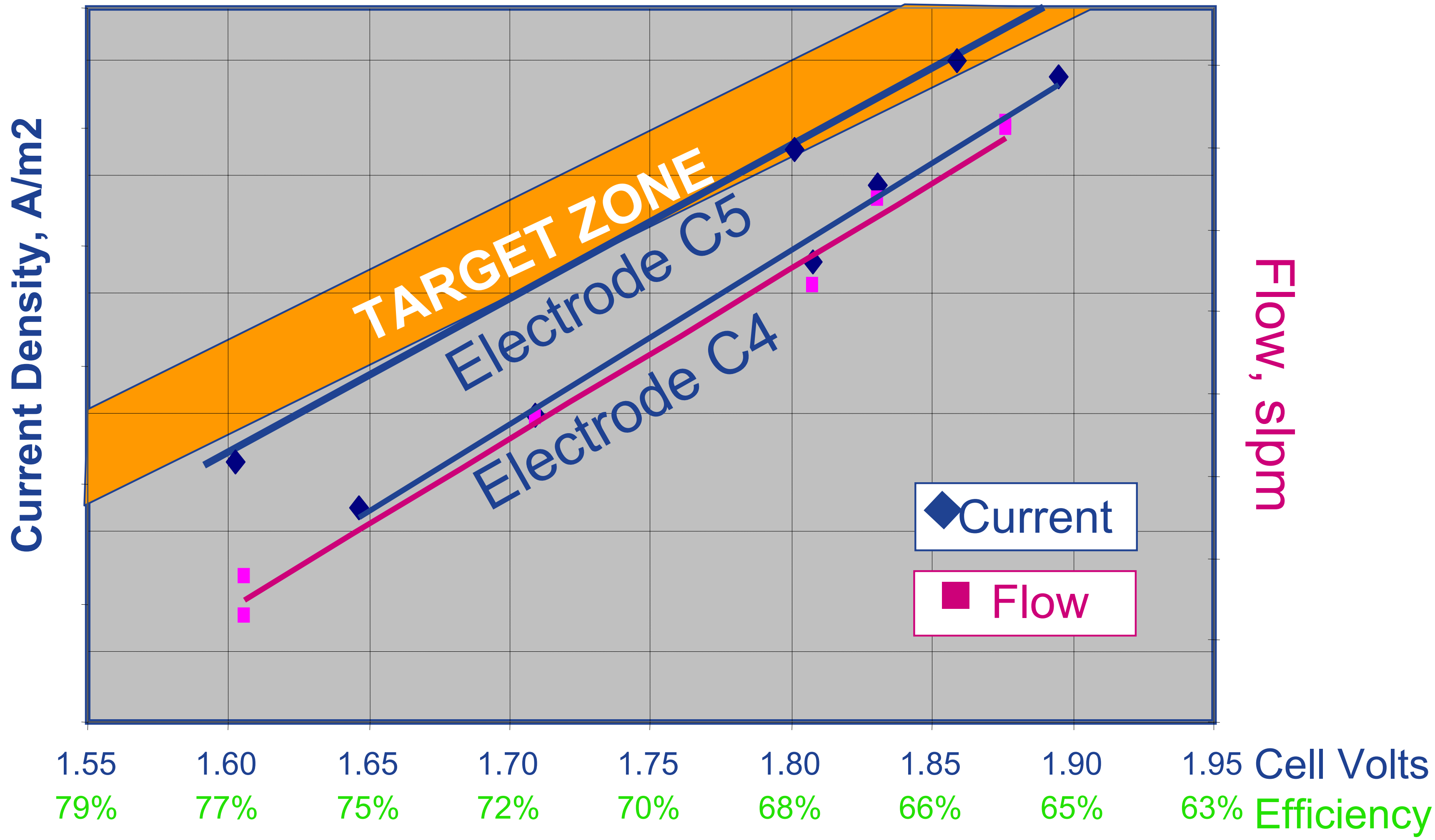


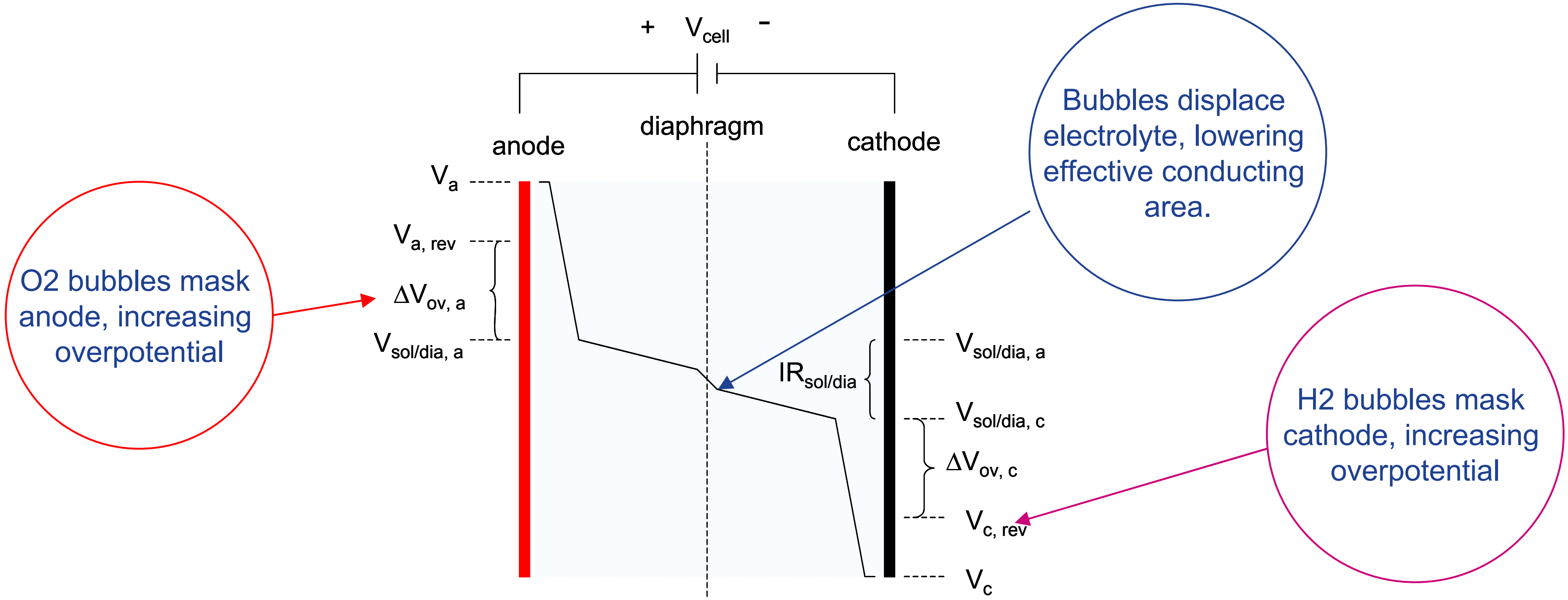
Figure 5: Bench Scale Test Stand

Bench Scale Test Results



- Operable across wide efficiency range
- Performance meets requirements

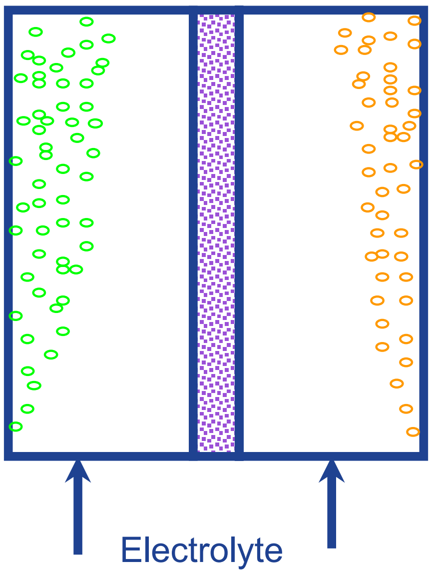
Computational Study of Cell Performance



Highly non-linear problem requiring development of advanced models

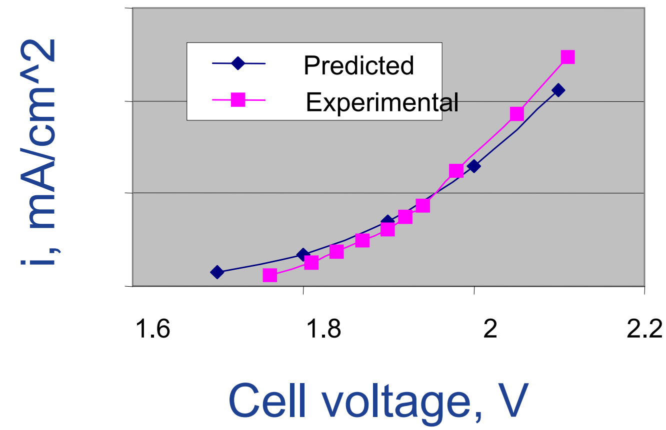
- Multi-phase turbulent flow
- Porous media
- Electrochemical reactions
- Electron/Ion transport
- Dissolved species

Learning from Two Dimensional CFD

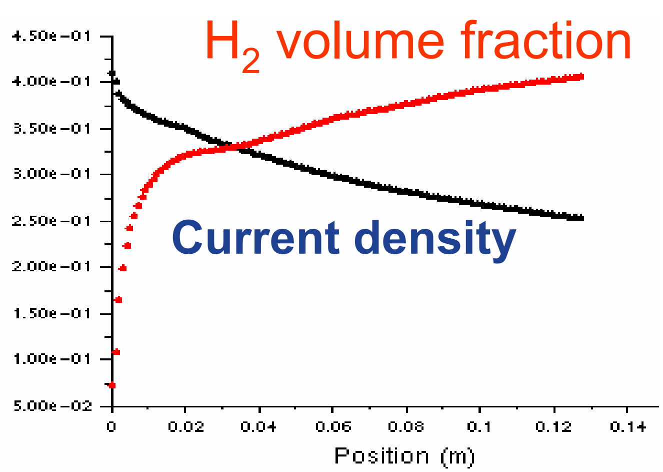


Simplified model / experimental geometry

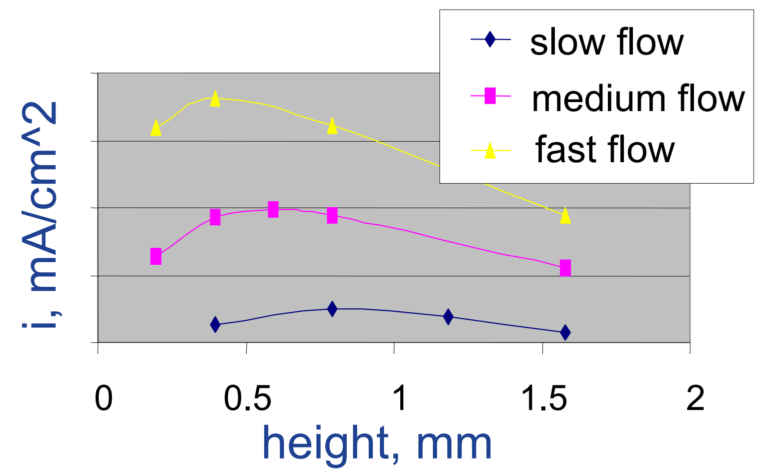
Experimental Validation



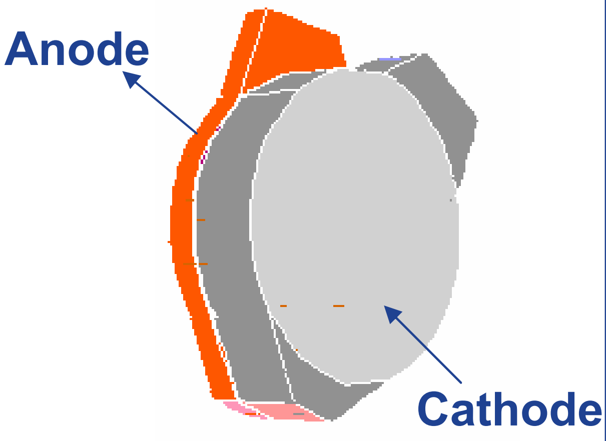
Effect of gas coverage

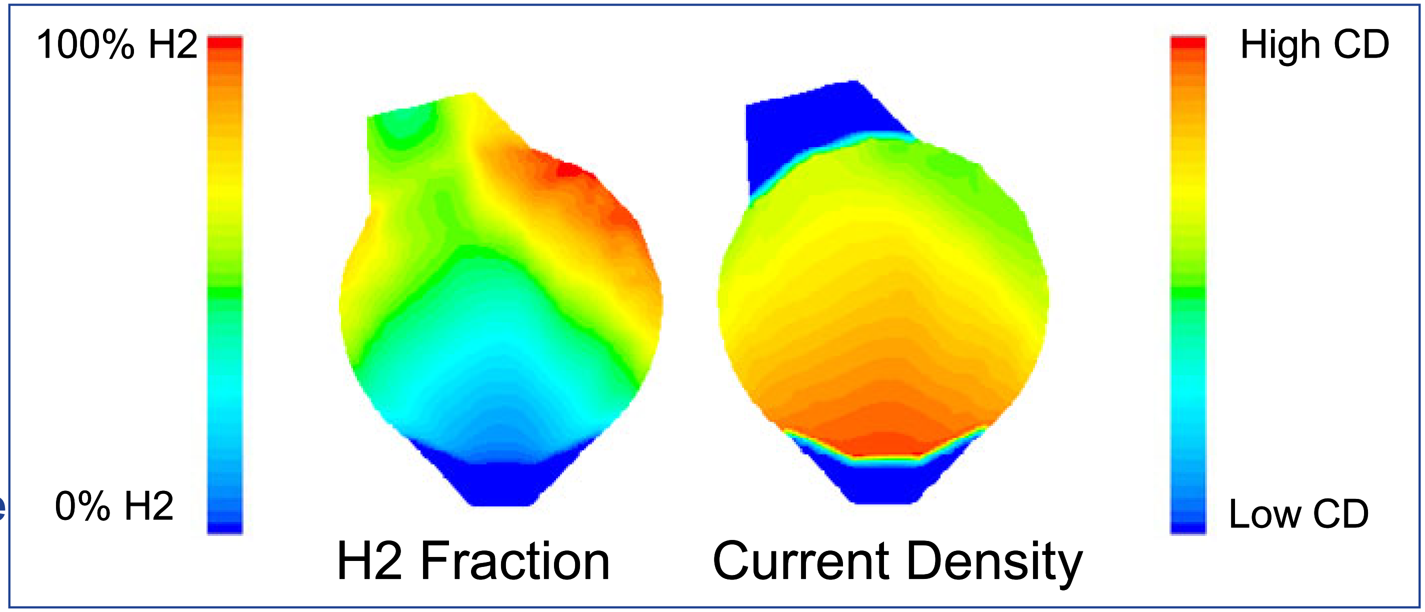


Optimize Passage Height



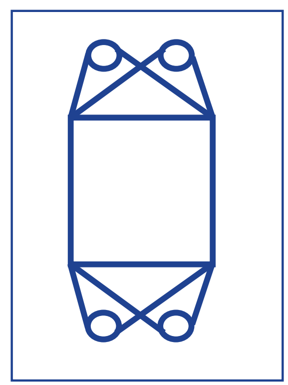
Stack Scaleup to 1 kgph system

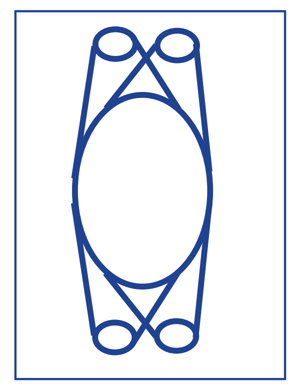




baseline round cell

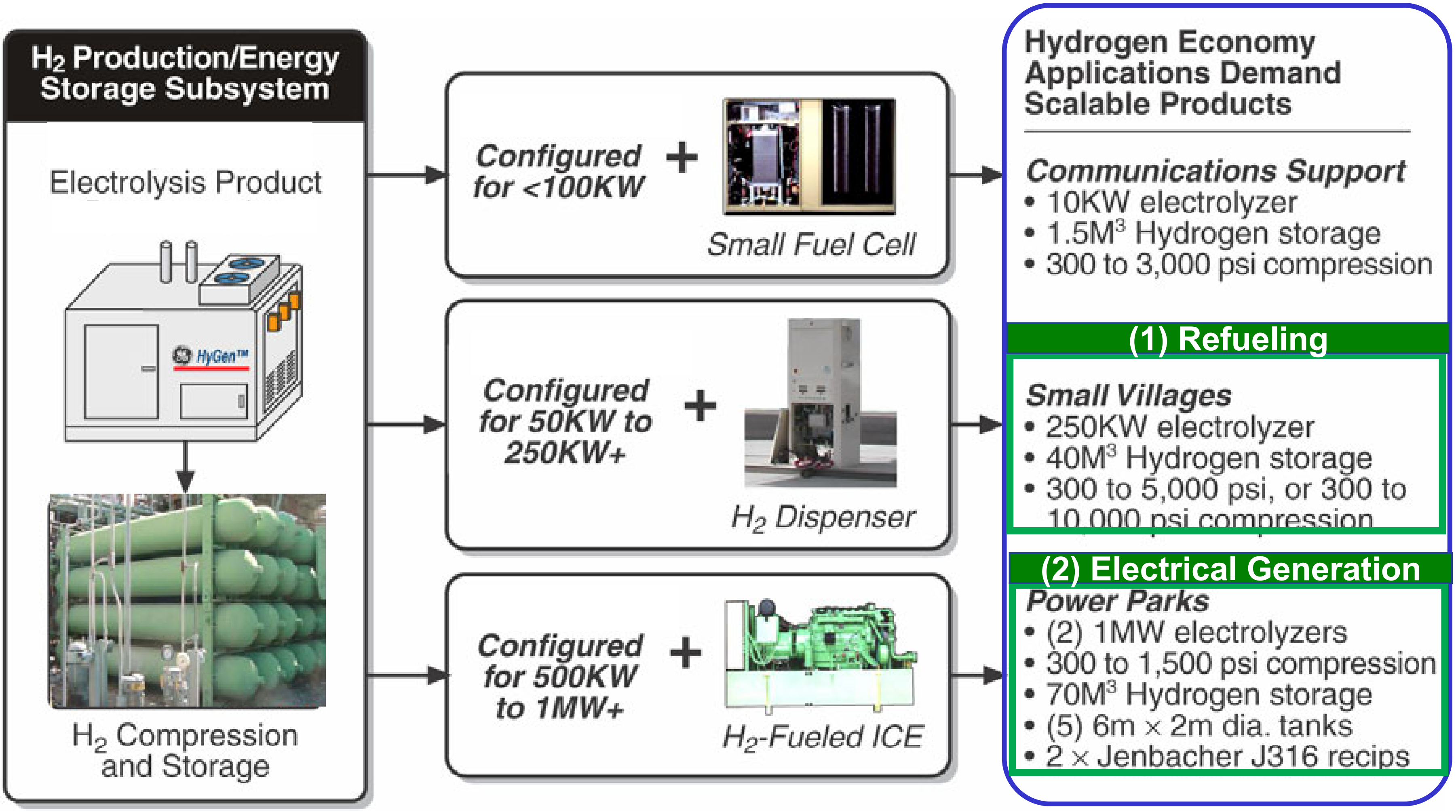
3D electrochemical CFD capability enables fast geometry optimization





square cell elliptical

Power Park Conceptual Design



Conceptual Design and Functional Modeling by Dr. Stephen Sanborn, GE

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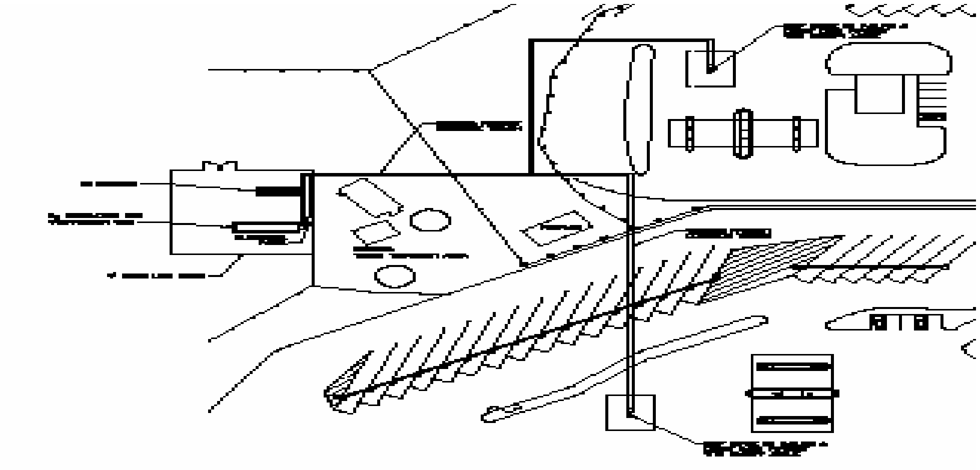
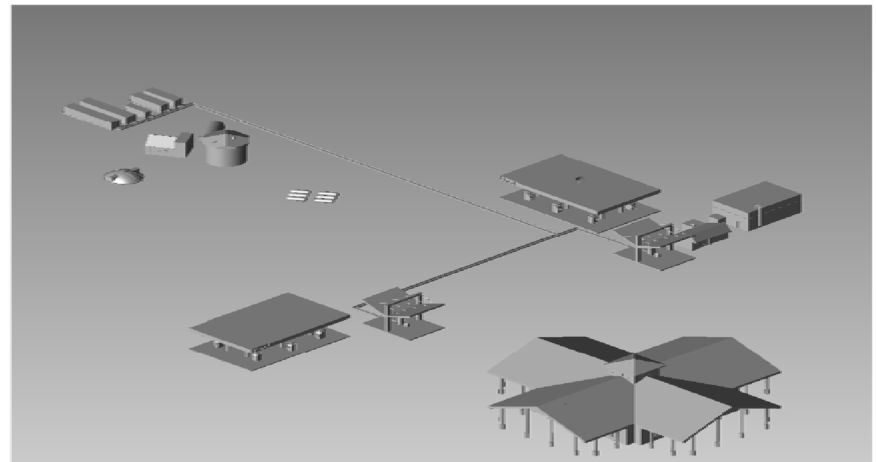
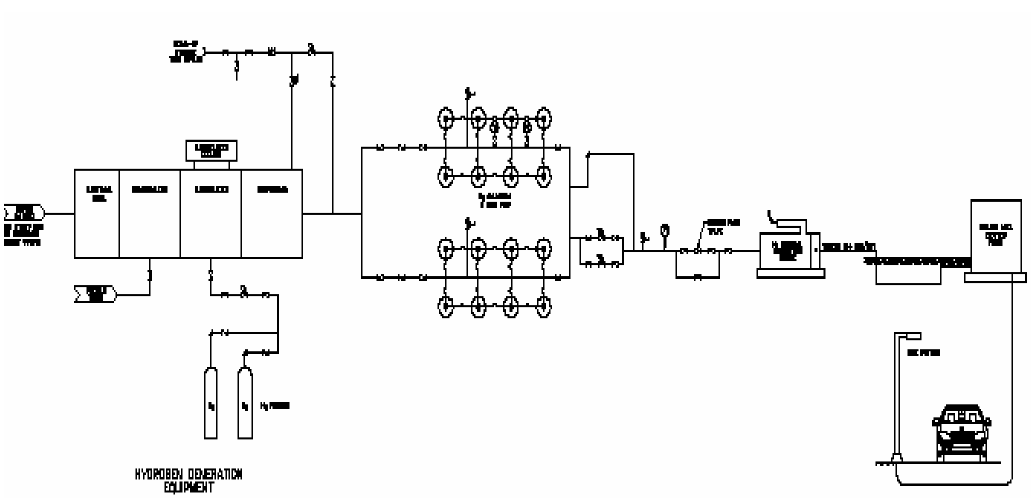
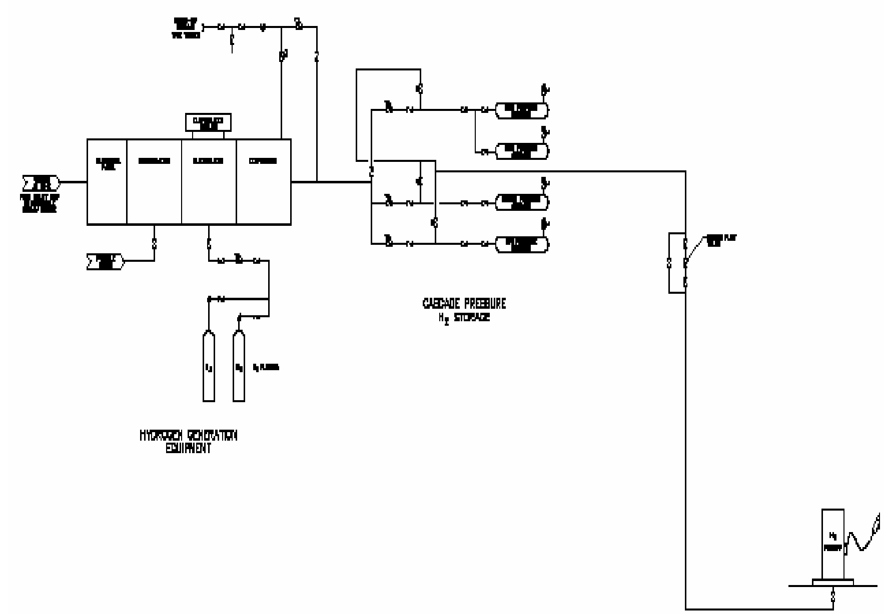
Conceptual Designs

Rendered in 2-D Drawings & 3-D "Virtual Tour"

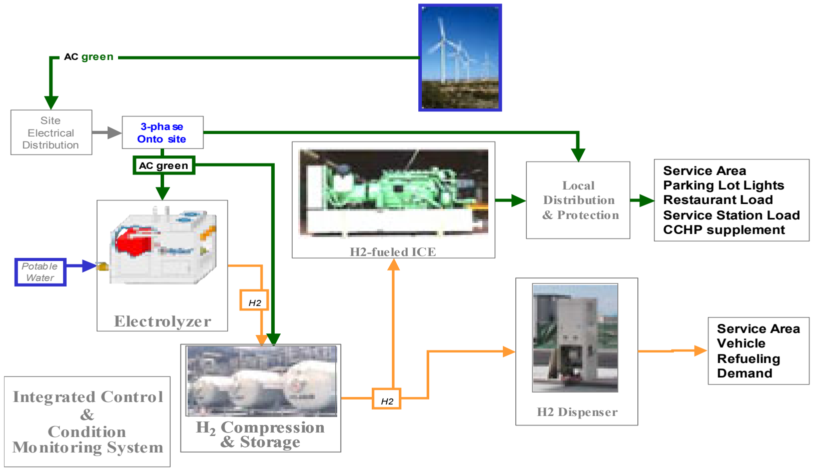




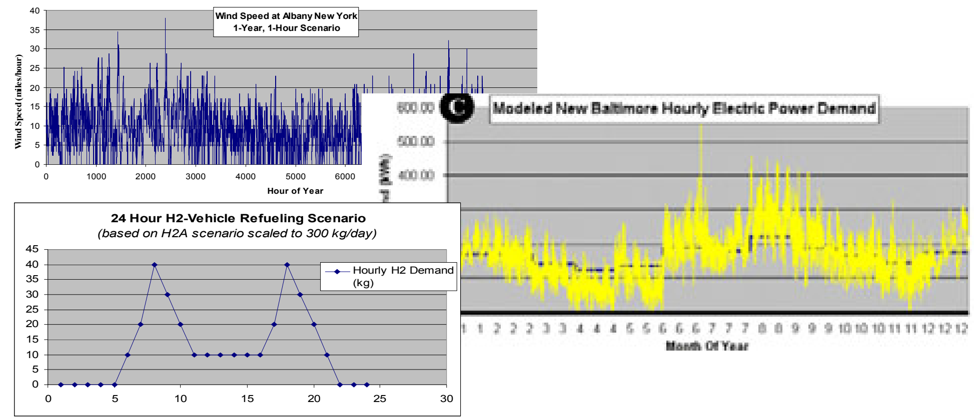




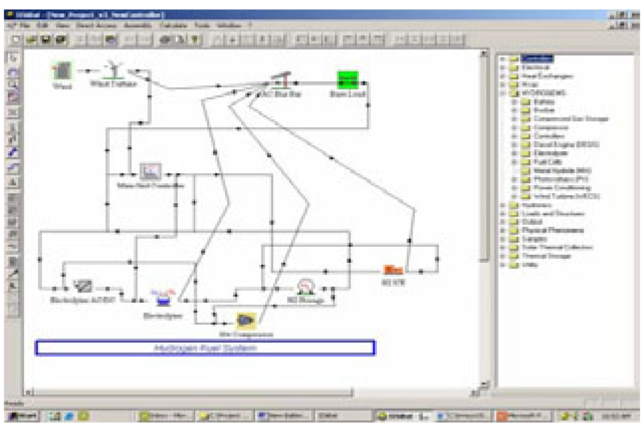
H2 Power Park Functional Modeling



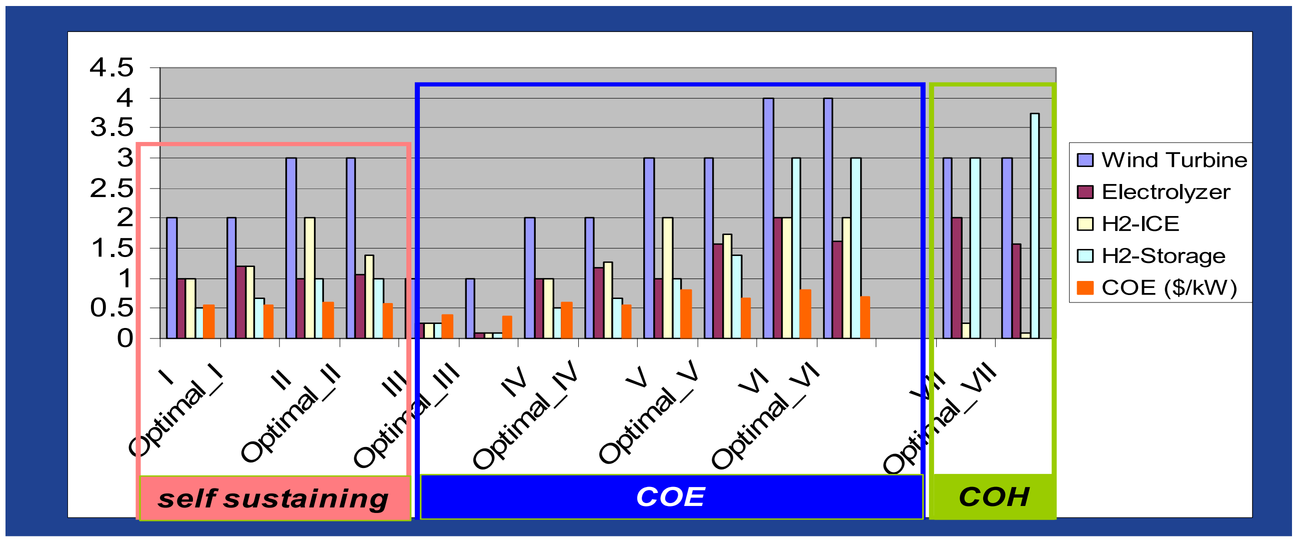
System Block Model



Wind Energy. Electricity and Fuel Demand Models



TRNSYS15 optimization code



Result: Optimized equipment selection for various scenarios

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Additional Work: “1 kgph” System

Capabilities:

- 1 kg H2 / hr production rate
- High pressure operation
- Automated controls
- P, T, massflow, purity measurements
- Upgradeable compression / storage capability

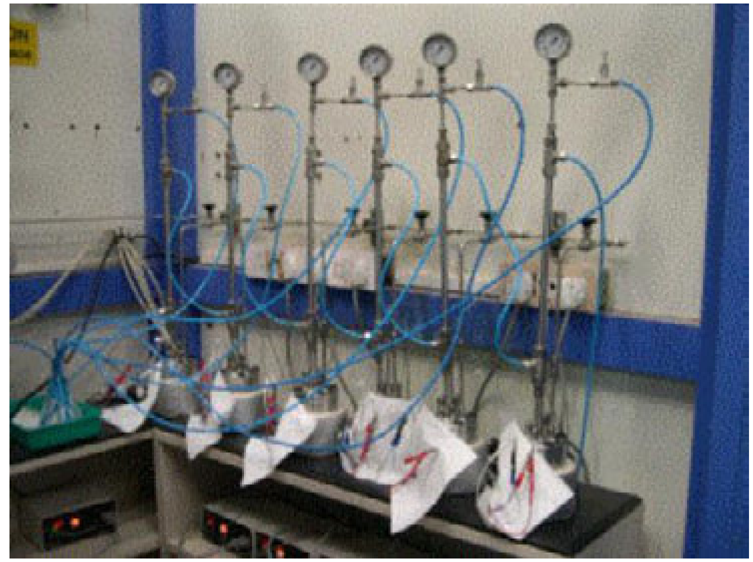
Opportunity for total instrumentation
Study operability & maintenance characteristics

Additional Work: Electrode Lifing

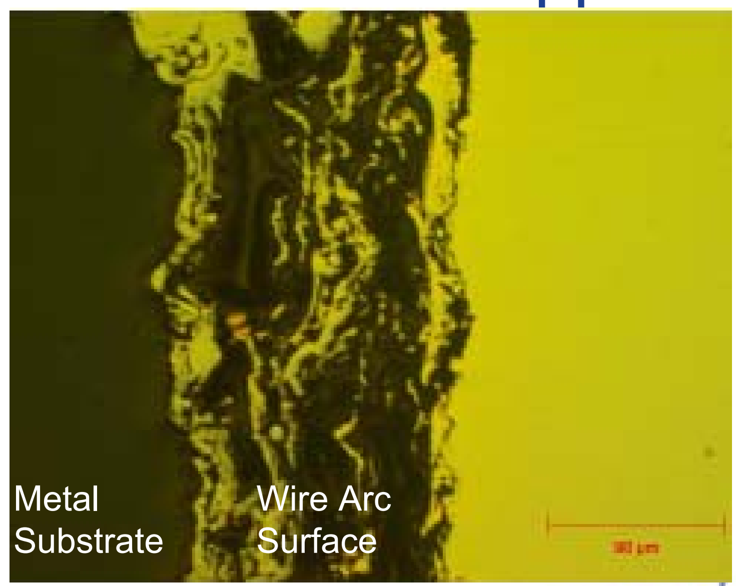
Multiple sample accelerated testing underway

350, 500, and 1000 mA/cm^2

Nearing 40k hours with no failures



Electrode Test Apparatus



Metallography

Future Work

First phase project has ended. Continuation of work with the 1 kgph system has been proposed to DOE and is pending.

Project Summary

Relevance: Provides a technical solution to the electrolysis capital cost problem.

Approach: Leverage GE expertise in advanced plastics and coating technology to dramatically reduce electrolyzer stack cost.

Progress: Demonstrated bench-scale proof of concept and scaled up to full size stack. Met efficiency target and projecting to meet 2010 cost target.

Technology Transfer:

Ready to consider demonstration projects.

Proposed Future Research:

System operations and reliability growth to prepare for demonstrations.

Backup Slides

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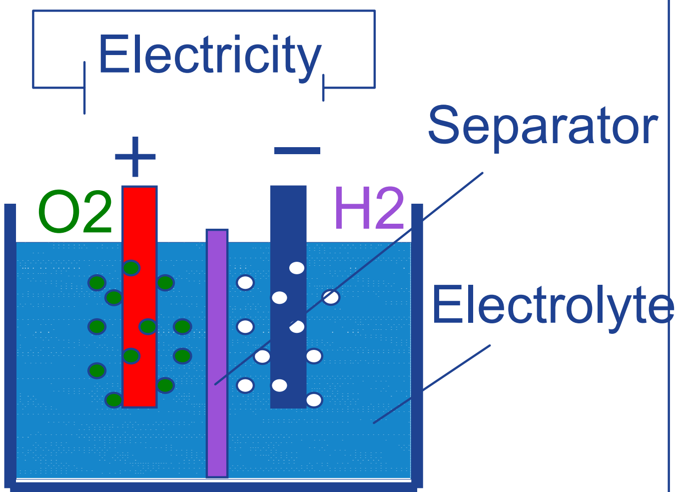
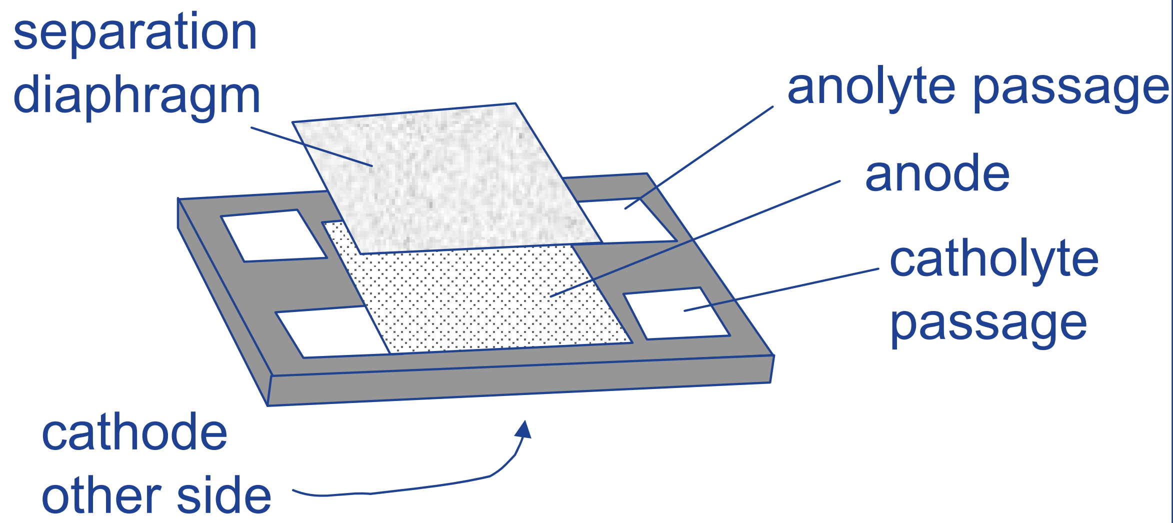
Alkaline Electrolyzer Design Basics



Single Unipolar Cell



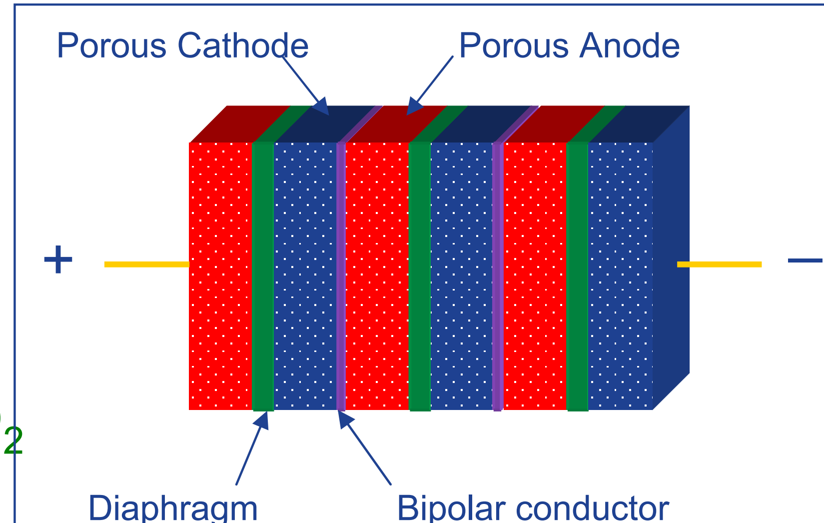
Bipolar type half-cells

<u>Cathode (-)</u>:

$$2H_2O + 2e^- \rightarrow 2OH^- + H_2$$

<u>Anode (+)</u>:

$$2OH^- \rightarrow H_2O + 2e^- + \frac{1}{2} O_2$$



Multicell Bipolar Stack

Publications

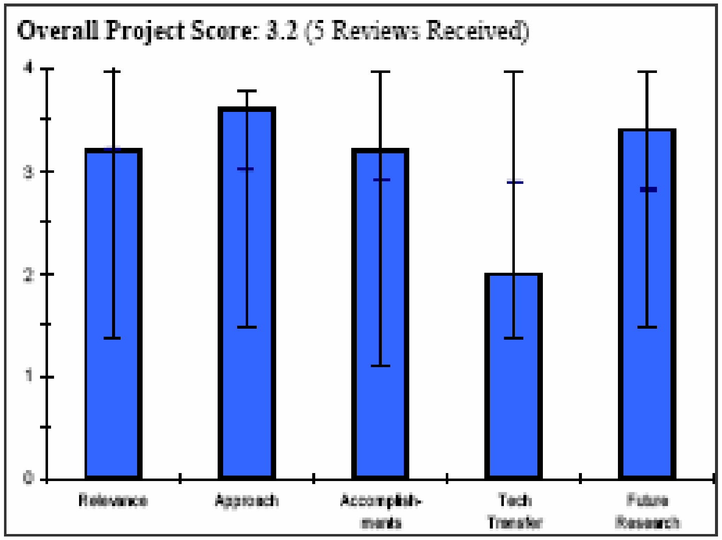
Advanced H2 sensor work by Dr. Michael Carpenter, SUNY Nanotech

1. Zhou, Z. and Carpenter, M.A. :“Annealing Advanced Hydrogen Absorption in Nanocrystalline Pd/Au Sensing Films”; Journal of Applied Physics 97, 124301 (2005)

2. Zhou, Z *et. al*: “All Optical Hydrogen Sensor Based On a High Alloy Content Palladium Thin Film”; Sensors and Actuators B, March 2005

Response to Reviewers' Comments

Rated as #PDP-10 : New York State Hi-Way Initiative



<u>Strengths:</u>

- Highly innovative
- Use of multiple GE technical capabilities
- Integrated GE team with skills and resources to "make this real"

<u>Reviewer's Comments and Response</u>

- Scope regarding New York's H2 infrastructure, sensors, etc. not aligned with HFCIT goals
  - — *2005 scope focused on electrolysis technology and scaleup.*
- "Show path to achieving HFCIT targets… using standard assumptions"
  - — *H2A model analysis presented to DOE for all GE H2 program work.*
- "Current demonstration is too small… 50 kW minimum
  - — *GE has built and is testing a 50 kW system, and has applied to continue the program with testing at that scale.*

Critical Assumptions and Issues

1) Electricity must be available at 5 cents / kWh or lower. This requires off-peak / industrial wholesale electricity at first, and the long term requires a cheap power solution.

2) Electrolyzers can be commercially successful without "waiting for a hydrogen economy". The right sector of the existing hydrogen market must be targeted, and demonstrations arranged with the needs of this market in mind.

3) A unified set of codes and standards for electrolytic H2 production is necessary so that a standardized packaged product may be deployed anywhere.