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Economic Analysis of Stationary PEM Fuel Cell Systems

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Project ID # FC 48

Overview

Timeline

Project start date: November 2003

Project end date: September 2007

Percent complete: 32% (May 2005)

Barriers

All distributed generation systems barriers

All fuel-flexible fuel processor barriers

All fuel cell component barriers

Budget

Total Project Funding: DOE Share $3,163,800 and No Contractor Cost-Share

Funding received in FY04: $515,851

Expected Funding for FY05: $700,000

Partners

More than 30 companies and agencies have participated in expert focus groups and facilitated discussions

Focus Group and Workshop Participants

Industry: Plug Power, Chevron Texaco Technology Ventures, Caterpillar, Ion Power, Ballard, UTC Fuel Cells, Nuvera Fuel Cells, Methanex, Proton Energy Systems, W.L. Gore, DuPont, 3M, Porvair, Hydrogenics, Engelhard, ReliOn, GrafTech, Johnson Matthey Fuel Cells

Users: Verizon Telecom, Verizon Wireless, LOGAN Energy, FirstEnergy, American Electric Power, Cinergy, Telecordia

Government, Universities and Non-Profits: Department of Energy, U.S. Army Fuel Cell Program, The Ohio State University, Electric Power Research Institute, Ohio Fuel Cell Coalition, NASA Glenn Research Center, Edison Welding Institute, Ohio Department of Development, Case Western Reserve University, NextEnergy, Rensselaer Polytechnic Institute, Mississippi State University, Edison Materials Technology Center, NIST, Battelle

Objectives

To assist DOE in the development of stationary fuel cell systems by providing an analysis of the technical and economic system drivers of PEM fuel cell cost and adoption

- To develop technical targets tables (user requirements) for likely early adopter markets in each application
- To identify and analyze factors critical to commercial success
- To determine major drivers of PEM fuel cell system and lifecycle costs
- To identify opportunities for technological breakthroughs in materials or manufacturing to reduce system costs
- To educate stakeholders and raise awareness of national programs

Approach: Economic Analysis of Stationary PEM Fuel Cells

Participating Stakeholder Groups

Industry | R&D Community | Key Influencers | Commercial Sector | Public Sector

Data Collection

Expert Focus Groups | Surveys and Interviews | User Focus Groups

Battelle Analysis

Scenario Analysis | Technology/Market Fit Analysis

Market Analysis	Economic Models	Technology Analysis
•Key Market Segments •User Requirements	•Engineering Cost •Lifecycle Cost •Economic Impact	•PEMFC Evaluation •Competing Technologies •Lifecycle Cost Comparison

Opportunities for Commercialization of PEM Fuel Cells

Technical Accomplishments and Progress: PEM Fuel Cell Markets

Completed analysis of user requirements of two early adopter markets; developed corresponding quantitative technical targets tables (user requirements)

Segmented markets and have identified potential early adopter markets by application type

Conducted over 115 stakeholder interviews and surveys; held four industry workshops and one user focus-group to discuss findings and secure additional input to the research

Identified principal scenarios for successful stationary PEM fuel cell commercialization using the Interactive Future Simulations™ Model

Technical Accomplishments and Progress: PEM Fuel Cell Cost and Technology Analysis

Completed engineering cost models for 5 kW direct hydrogen backup power system and a 50 kW propane reformer/fuel cell system at production volumes of 1k, 10k, and 100k; critically reviewed with expert stakeholder group

Completed sensitivity analysis of factors impacting cost of the 5 kW direct hydrogen system and the 50 kW propane reformer/fuel cell system; critically reviewed with expert stakeholder group

Began analysis of potential impact of technologies under development on fuel cell system costs

Initiated lifecycle cost analysis; approach is being made consistent with the H2A modeling method

Most Likely Customers and Applications (By 2015)

1. Commercial and light industrial consumers of electricity where there are applications for high quality and reliable power when the grid is not available, not reliable, and not attractively priced. The likely size will be 50-200 kW.
2. Residential and light commercial consumers who have access to the grid but need backup power and load management capabilities. The likely size will be smaller than 50 kW

*Battelle selected **the commercial market segment** to identify application opportunities in the Telecom and Hotel Market Sectors.*

Specifically, opportunities for <u>*backup power*</u> *(5 kW direct hydrogen) and* <u>*grid parallel power*</u> *(50 kW propane reformer/fuel cell) within these market segments were targeted for initial development of technical targets (user requirements) and economic analysis*

	TECHNOLOGY EVALUATION, TECHNICAL TARGETS & STATUS TABLE			
	Market Requirements	**Technology Status**		
	Telecom, Backup	**Fuel Cells**	**IC Engines**	**Batteries**
Cost ($/kW)	1000-2000	2,500-4500	700-13,000	300-16,000 (48V, 5-20 kwh)
Installation Costs	2,000-4,000	6,000-13,500	2,000-10,000	1,500-22,000
Size	1-25 (kW)	1-5 (kW)	1-25 kW	48V, 5-20 kwh
Durability (hours of operation)	1500	6000	10000	20000
Lifetime (years)	10	10	15	5-7
Reliability (% time available)	99.99 - 99.9999%	Unknown	99.99%	99% - 99.999%
Survivability (ºC)	Varies Based on Location	-20-40	0-50	25-40
Coldstart (Time to rated power)	Immediate	2-5 minutes	2-5 minutes	Instant if fully charged
Transient Response (msec)	Varies based on design of power plant	<3 seconds	7-10 seconds	Instant
Efficiency (%)	50-65	25-45	20-33	>90

5 kW Fuel Cell vs. Battery Backup Power: Lifecycle Cost Analysis (20 Years)

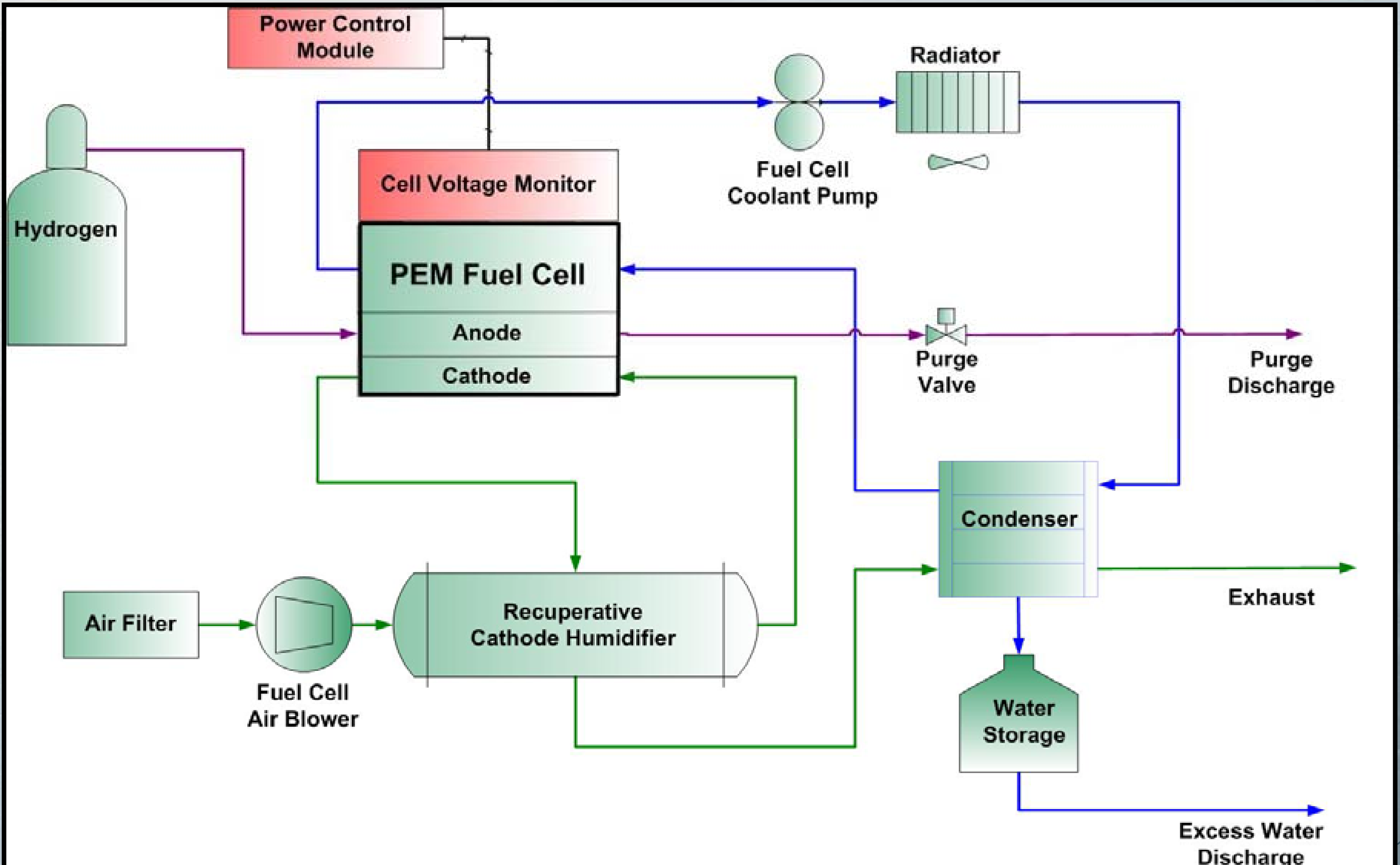
Fuel Cell	
Fuel Cell	$30,000
Installation	$7,000
Fuel	$1,832
Demurrage	$3,066
Batteries	$1,600
Disposal	$100
O&M	$2,000
Cash	$45,598
Net Present Value	$29,092

Battery	
Batteries	$28,800
Installation	$3,000
Disposal	$400
Charger, Load Transformer Equipment & Electricity	$1,880
Generator	$8,800
O&M	$13,900
Cash	$56,980
Net Present Value	$28,172

Assumptions: 5 year battery life; 2-4 hour ride-through battery; 10 year PEMFC life with fuel sufficient for 8 hour backup; one 8-hour outage each 10 years; 10% discount as defined by H_2A model.

Interim findings

Design Overview of the 5 kW Direct Hydrogen PEM Fuel Cell System



Specifications: 5 kW Direct Hydrogen PEM Fuel Cell System

Goal: Maximum reliability backup power at least cost

Membrane active area/cell: 150 cm^2

No membrane or catalyst lost to gasket border

Inverter efficiency: 0.9

Peak power density: 0.5 W/cm^2

Design life: 0.57 yrs (5,000 hours) over 10 years

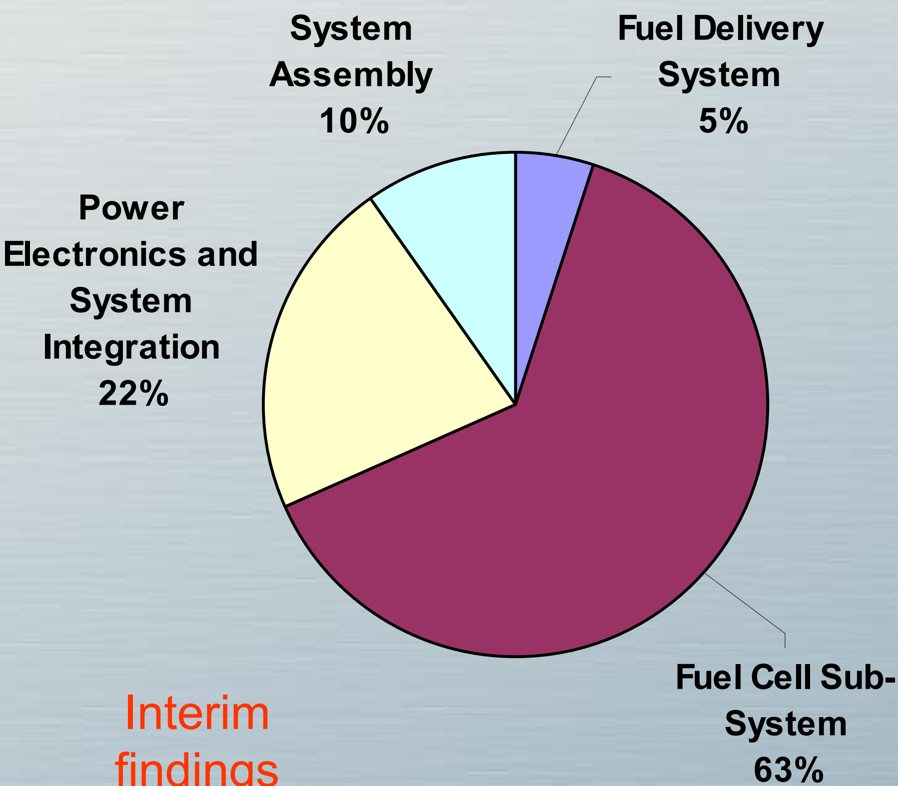
Power degradation factor: 0.2

Current density: 0.8 A/cm^2

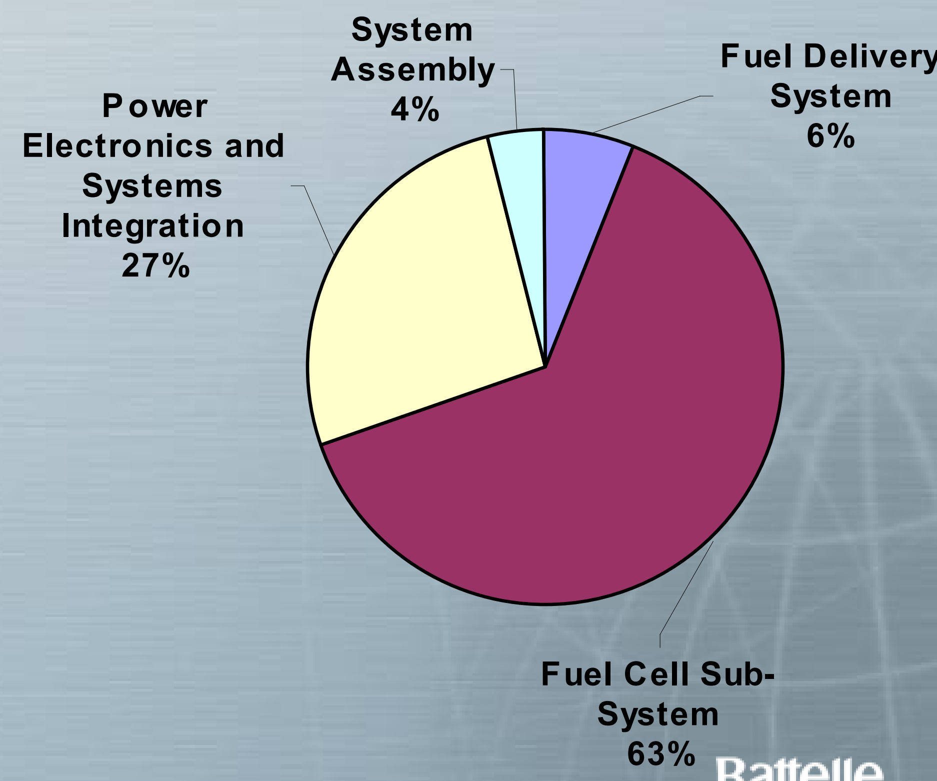
Catalyst loading: 0.8 mg/cm^2

5 kW Direct Hydrogen PEM Fuel Cell System Volume Based Cost Analysis

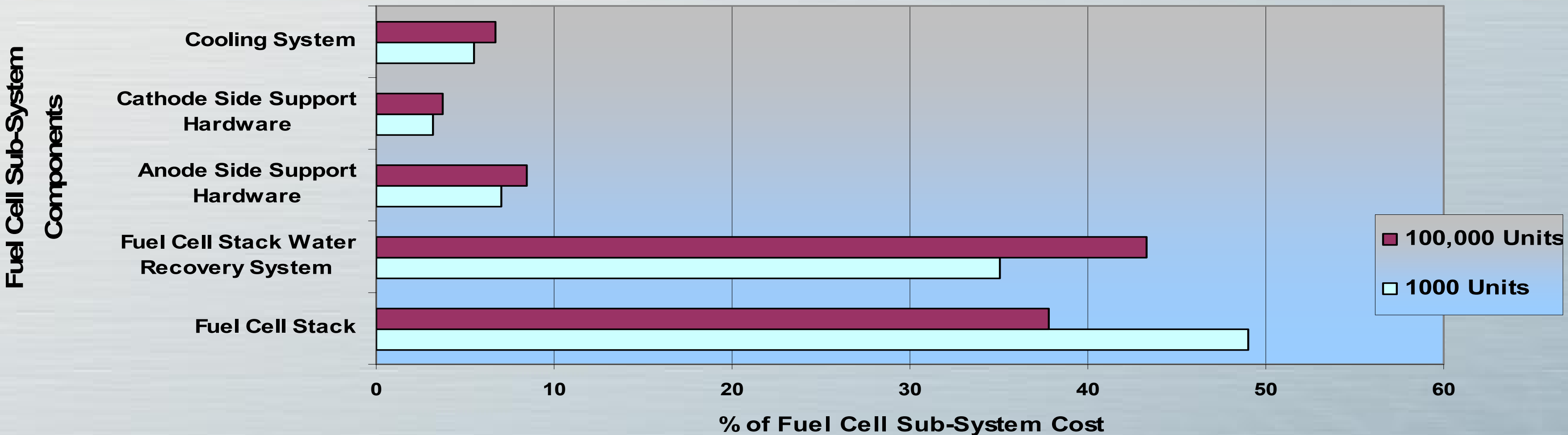
1000 Units	100,000 Units
System Cost: $10,381	System Cost: $5,329
Cost per kW: $2,076	Cost per kW: $1,066

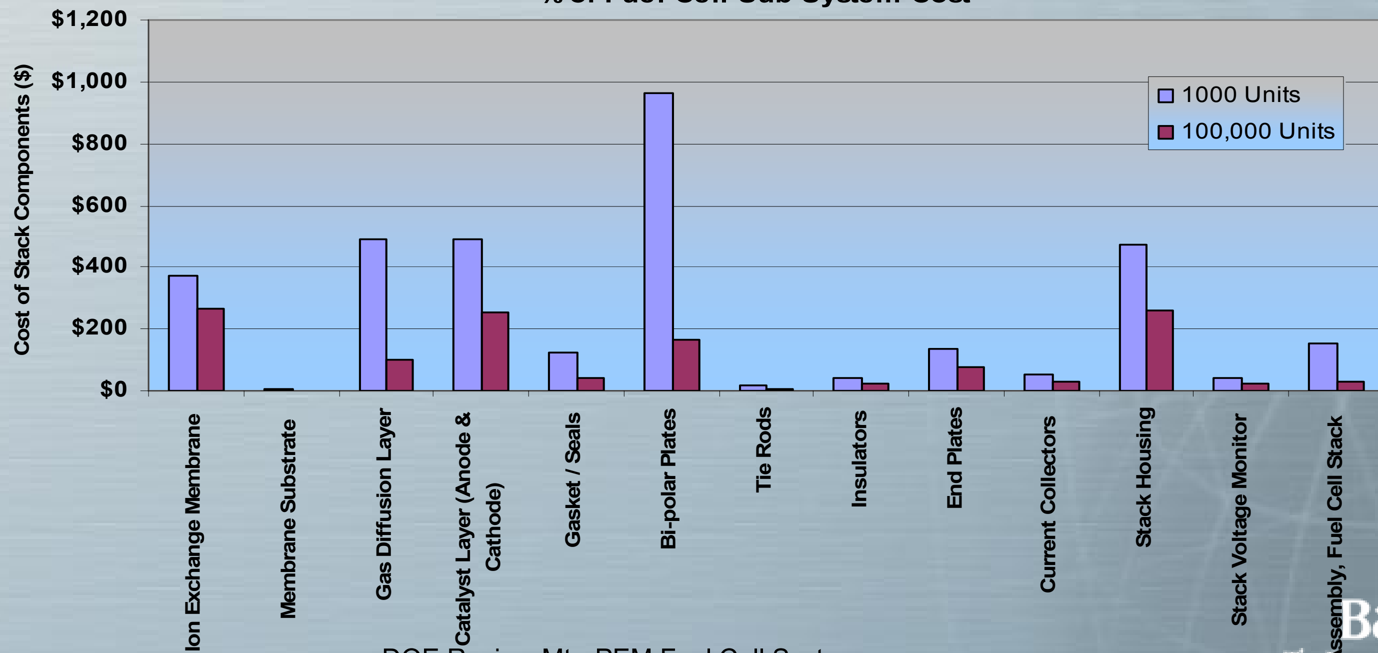


Interim findings



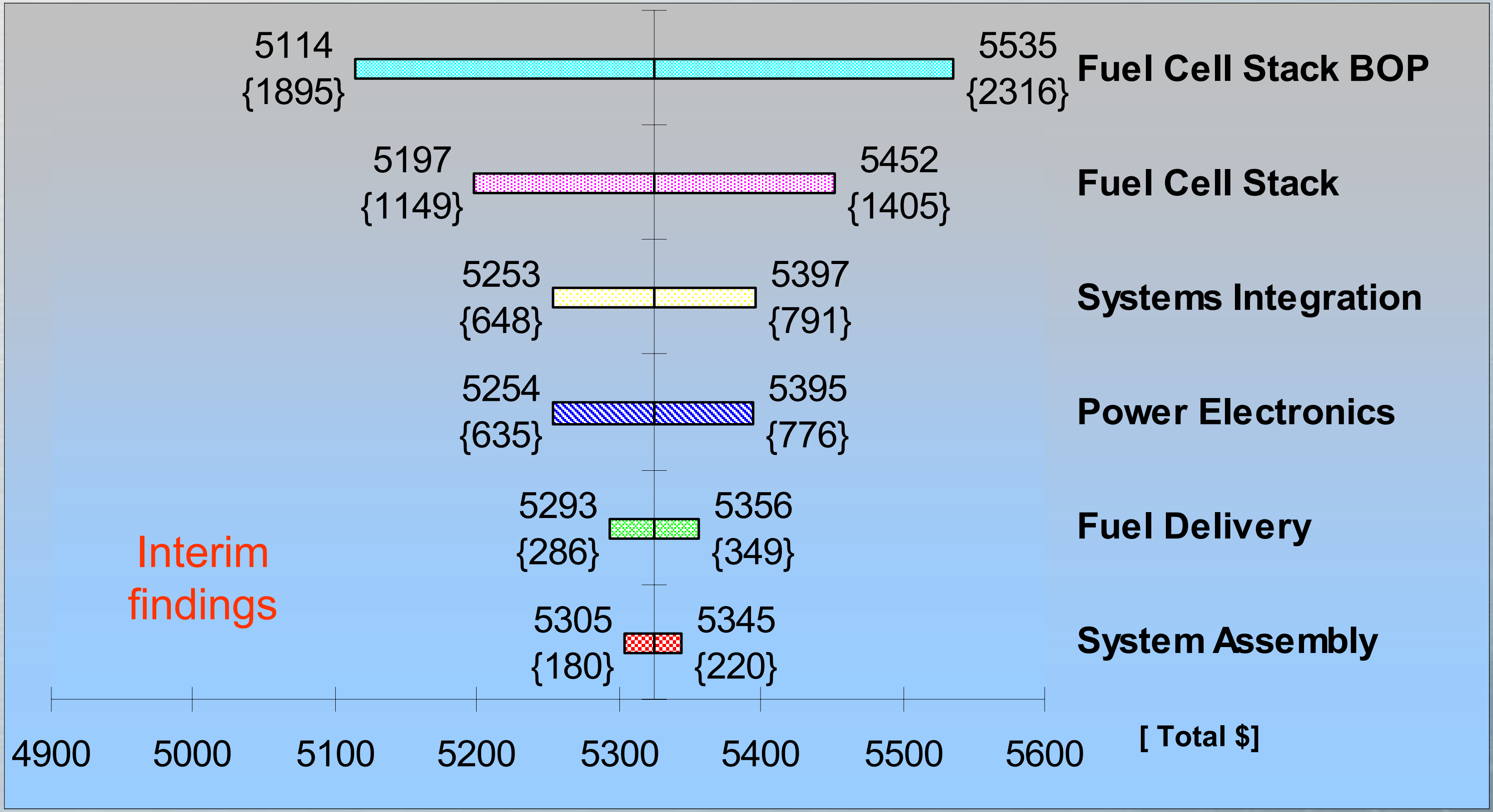
5 kW Direct Hydrogen PEM Fuel Cell Sub-System and MEA Cost Analysis





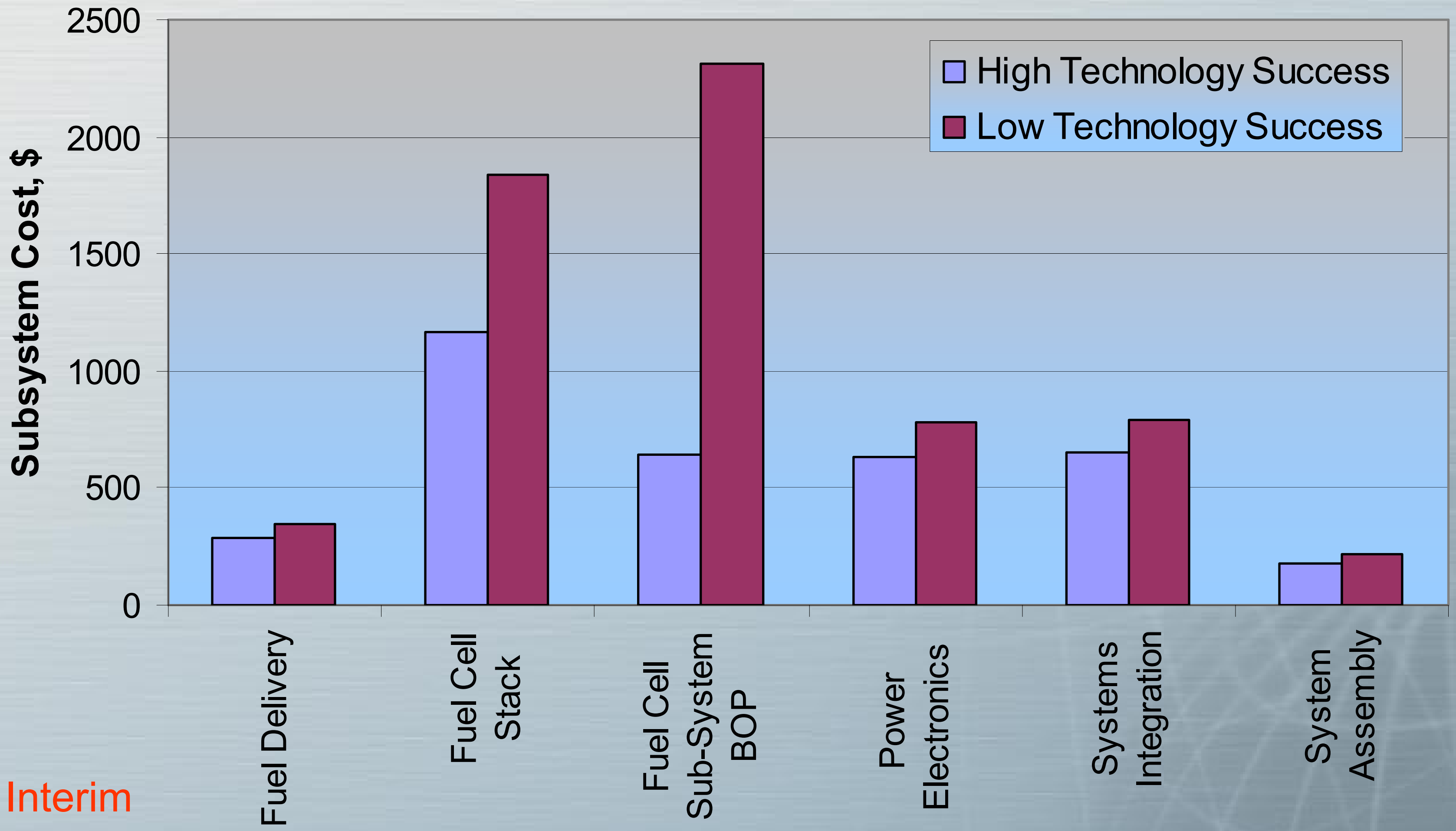
Interim findings

Sensitivity Analysis: 5 kW Direct Hydrogen PEM Fuel Cell System at 100,000 Units*



*Data not complete without assumptions
Assumes 5000 hr durability, 100k production volume and range of ± 10%

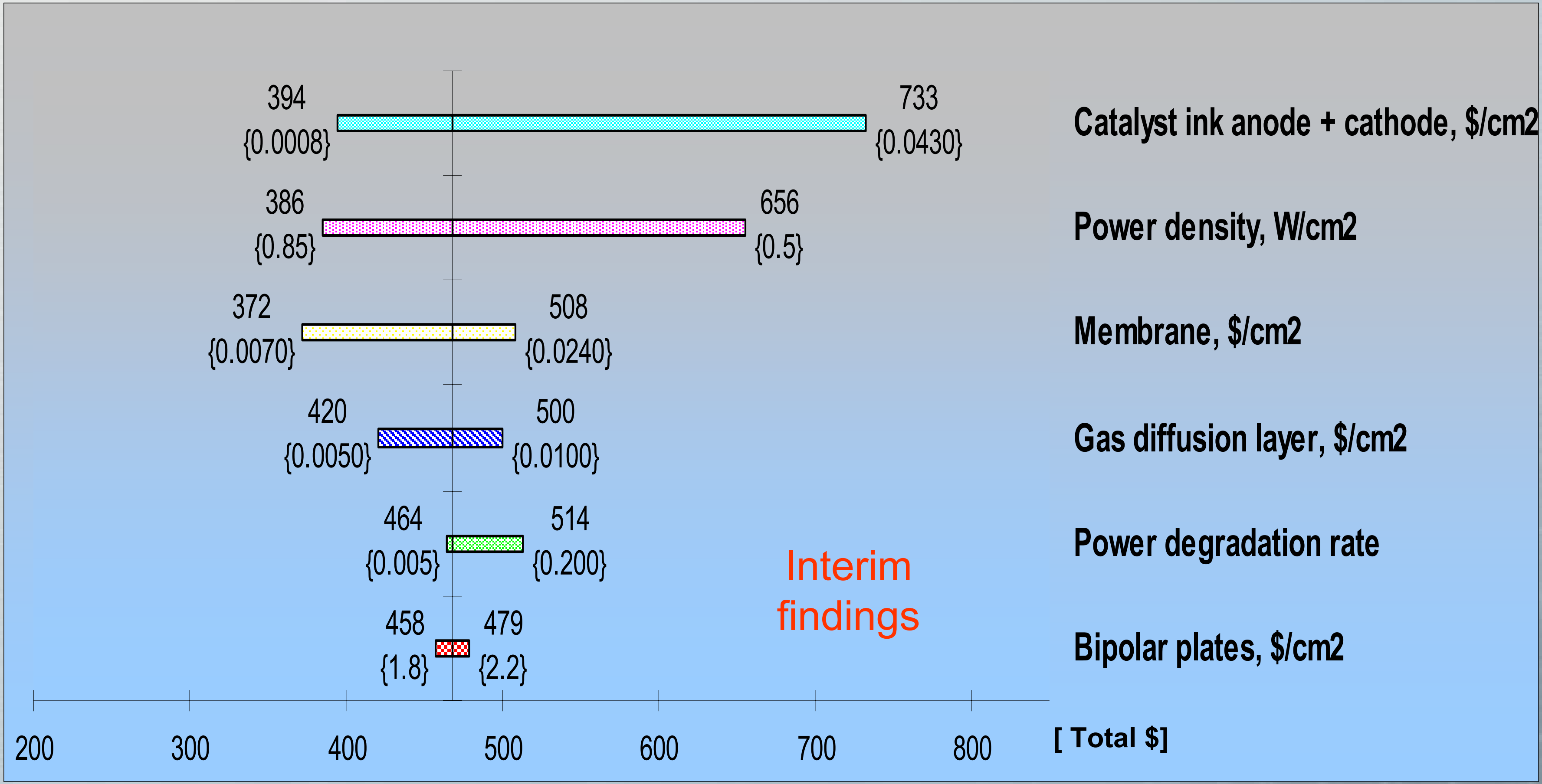
5 kW Direct Hydrogen PEM Fuel Cell: Potential Impacts of Breakthroughs on Costs*



Interim findings

*Data not complete without assumptions
Analysis assumes 5,000 hour MEA durability.

Technology Sensitivity Analysis: 5 kW Direct Hydrogen PEM Fuel Cell Stack at 100,000 Units



*Data not complete without assumptions

* Major stack components costs only; assumes 5,000 hour MEA life; tradeoffs required by technology adoption are not reflected in system costs

Specifications: 50 kW Propane Steam Reformer PEM Fuel Cell System

Goal: Maximum durability for continuous operation at least cost

Membrane active area/cell: 600 cm^2

No membrane or catalyst lost to gasket border

Inverter efficiency: 0.9

Peak power density: 0.2 W/cm^2

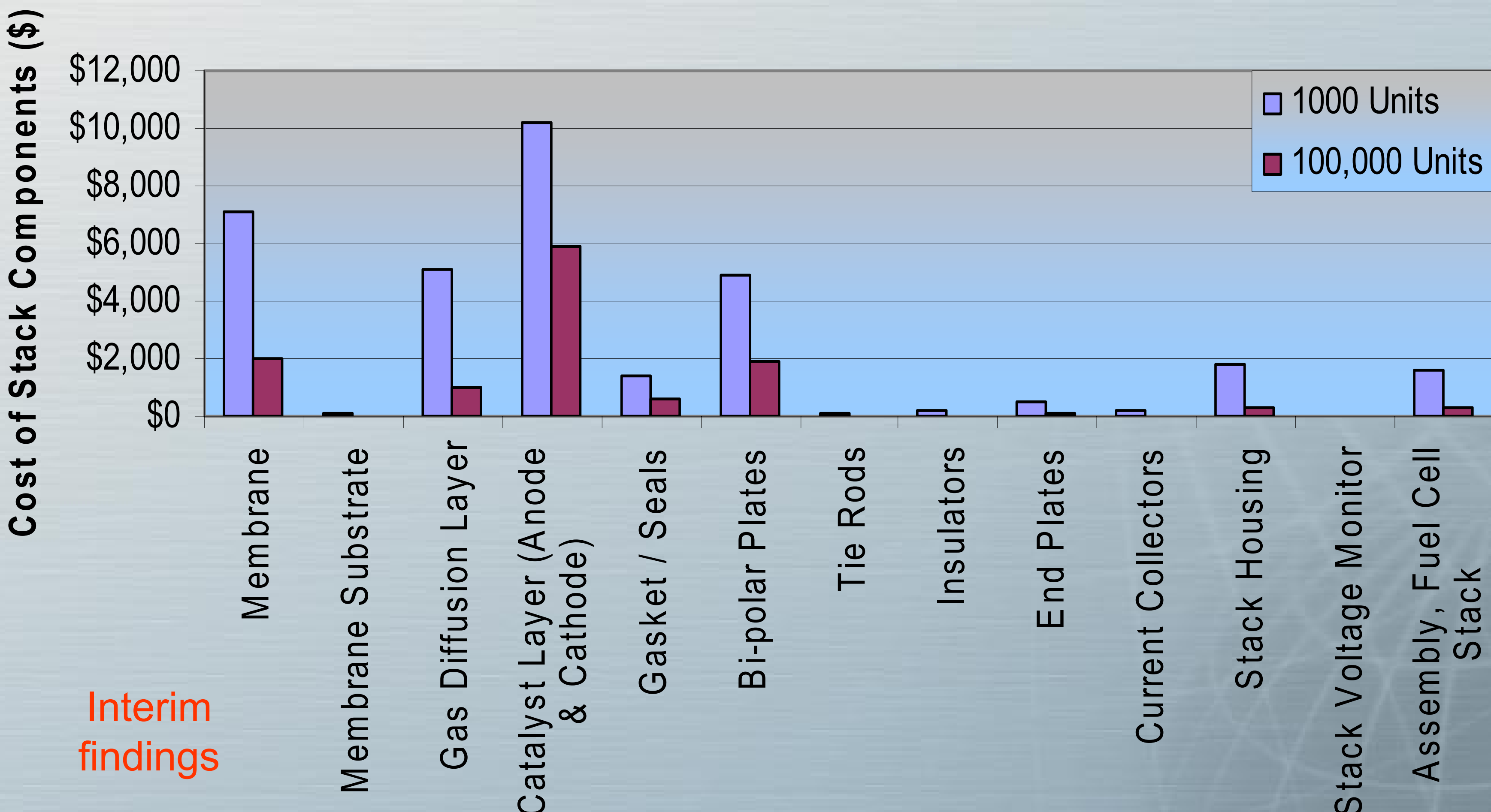
Design life: 0.91 yrs (8,000 hrs)

Power degradation factor: 0.02

Current density: 0.2 A/cm^2

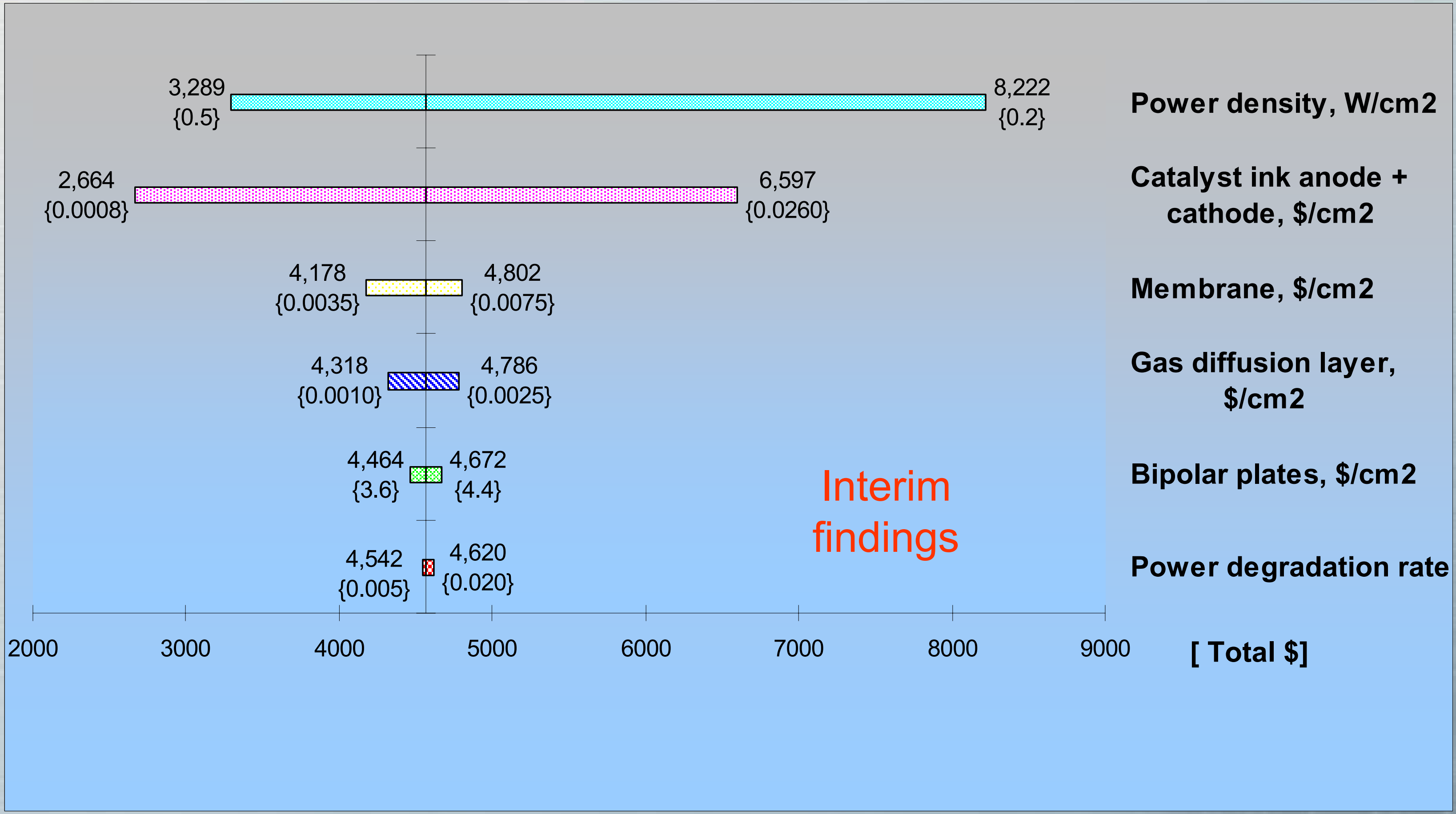
Catalyst loading: 0.8 mg/cm^2

50 kW Propane Steam Reformer PEM Fuel Cell Stack Cost Analysis



Interim findings

Sensitivity Analysis: 50 kW PEM Fuel Cell Major Stack Component Costs, 100,000 Production Volume*



*Data not complete without assumptions

*Assumes 8,000 hour MEA life; tradeoffs required by technology adoption are not reflected in system costs

Responses to Previous Year Reviewers' Comments

- Establish quantitative analysis of technology/target market fit
  - Identified early adopter markets (by application) and initiated analysis of quantitative user requirements

- Move from passive collection of data to active exercise of judgment drawing in Battelle fuel cell technologists
  - Battelle fuel cell technologists developing the reformer-based PEM fuel cell, high-temperature membranes and carbon monoxide tolerant electrode were formally involved in model development and in providing expert judgments on models and technologies
  - Economic model was based on Battelle's reformer-based fuel cell and critically reviewed with fuel cell manufacturers
  - Technology impacts/cross-impacts were identified by Battelle fuel cell technologists and critically reviewed with fuel cell manufacturers and technology researchers/developers to evaluate potential cost/performance leverage

Future Plans

Remainder of FY 2005

- Complete technical targets tables for early adopter markets in three additional applications
- Develop value proposition for PEM fuel cells in 5 market applications based on user requirements
- Complete economic and life-cycle cost analysis of 5 and 50 kW system to include trade-off analysis

FY 2006

- Develop economic and life-cycle cost analysis of 200 kW reformer based PEM fuel cell system
- Update technology breakthrough opportunities
- Use market penetration, by application, to begin evaluation of potential energy impacts of stationary PEM fuel cells
- Continue collaboration with stakeholders for insight and to validate findings

Publications and Presentations

Stone, Harry J. Economic Analysis of Stationary PEM Fuel Cell Systems. 2004 Annual Program Review Proceedings, Meeting May 24-27 in Philadelphia, Pennsylvania, 2004.

Millett, Steve, and Kathya Mahadevan. Scenario analysis of the commercialization of proton exchange membrane (PEM) fuel cells for stationary applications in the U.S. by the year 2015. 2004 Fuel Cell Seminar, San Antonio, TX, 2004.

Millett, Steve, and Kathya Mahadevan. Commercialization scenarios of PEMFC applications for stationary power generation in the United States by the year 2015. Journal of Power Sources (Accepted for publication).

Hydrogen Safety

The most significant hydrogen hazard associated with this project:

Our approach to deal with this hazard is:

Not Applicable – paper study