



Strategy for Reducing Fuel Cell Component Costs to Enable Commercialization

George M. Roberts
UTC Power

October 30, 2008



UTC Power

A United Technologies Company



Outline

- Early PEM FC Markets
- Status of Cost Reduction Efforts
- Cost Reduction Strategies
- Supplier Engagement/Status
- Conclusions



Early PEM Fuel Cell Markets

- **High value stationary**

- Back-up power:

- Telecom
- Broadband
- Data Centers



 **MODEL 5**
PureCell® System

- **Fleet vehicles**

- Buses
- Delivery Vehicles
- Industrial Utility Vehicles



PureMotion®
Model 120 Fuel
Cell System





Bridging Strategy

- **Higher, cost-tolerant markets can be used to “bridge” the cost/volume gap**
 - Can lead to market traction that will allow growth into larger markets.
 - Does not require breakthroughs or reliance on high-volume manufacturing.
 - Volume will naturally increase over time, which will in turn result in manufacturing scale-up, reduced manufacturing costs and improved supply chain efficiencies.
- **Once foundation is established, follow-on applications can be established**
 - Provided no significant technology changes are needed
 - Products with similar components and assembly processes



High Value Stationary- Backup

PureCell® Model 5 Fuel Cell Backup Power System

- 5 kW PEM back-up power module
- Current back-up fuel cell system prices approx. \$3,000/kW
- Cost reduction progress
 - Balance of plant cost reduction
 - System simplification (Reduce/Eliminate components)
 - Cell stack cost reduction
 - Component cost reductions

Operation Time at HARC

>3,200 hours

>8900 kW-hours

>600 start-stop cycles

(As of Q3 2008)

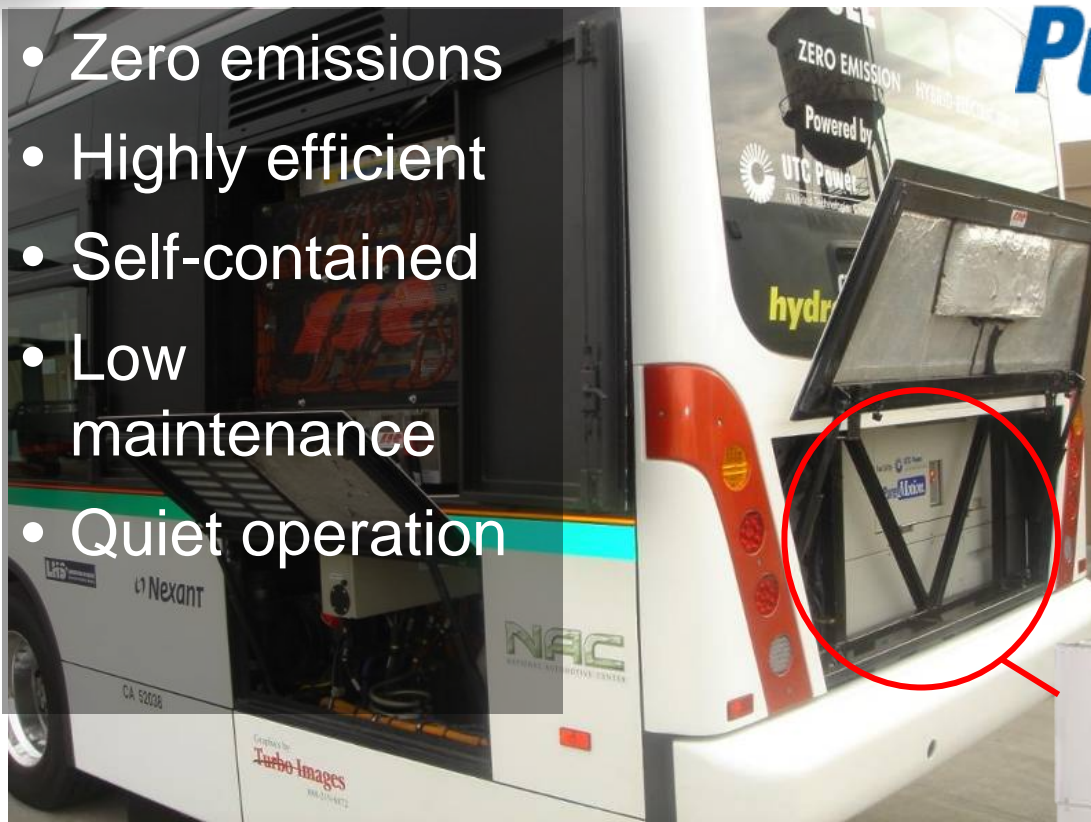




Transportation - Fleet

PureMotion® Model 120 Fuel Cell System

- Zero emissions
- Highly efficient
- Self-contained
- Low maintenance
- Quiet operation



PureMotion®

Model 120 Fuel Cell System



Over 190,000 vehicle miles
Over 18,000 operating hours
(As of Sept 1, 2008)

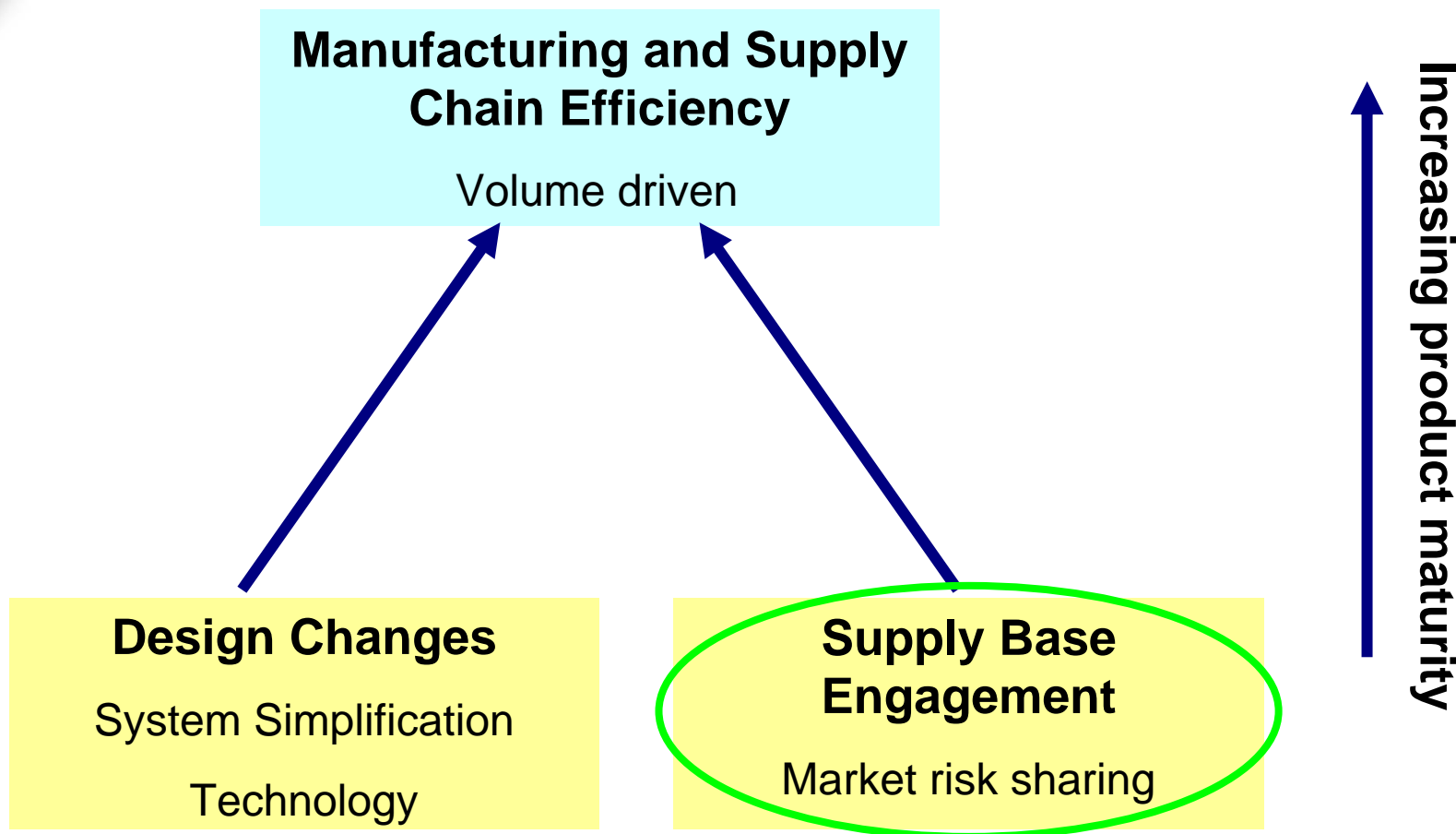


UTC Power

A United Technologies Company



Cost Reduction Approaches



Supplier/OEM relationship is critical



Supply Base Engagement

Two Options

1. “Should Cost Model”

- Cost of raw materials, labor, etc.
- Assign an allocation of total powerplant cost
 - Limited visibility of other components to supplier
 - Limits level of engagement by supplier

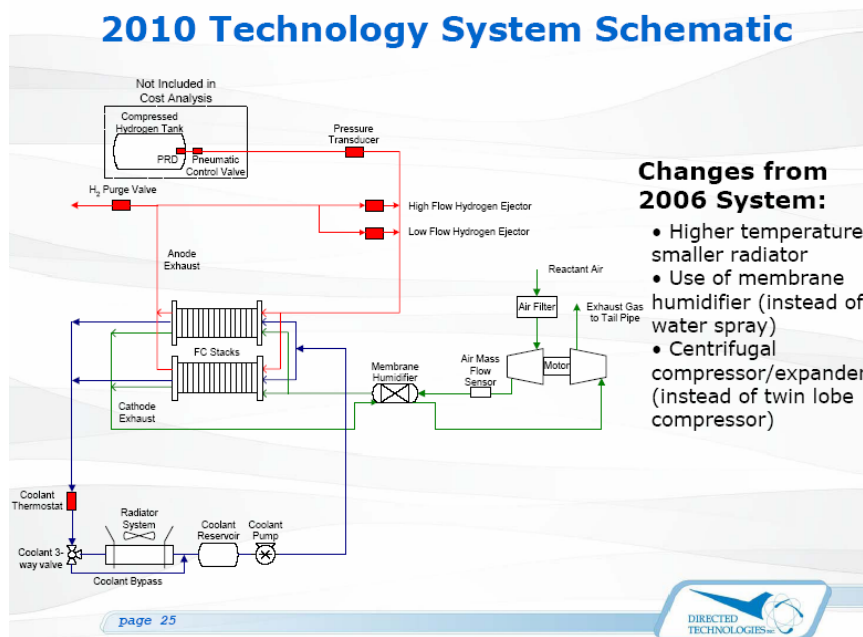
2. External Cost Models

- Based on industry input
- Provides a basis for cost allocation of components
- “Unbiased” view of costs



DOE - Sponsored Cost Study

- Conducted by Directed Technologies, Inc.
(B. James, et. al. DOE Contract #DE-AD36-06GO26045 DOE Annual Merit Review, June 2008)
- Study included participants from industry and research
- Direct hydrogen 80-kW PEM Fuel Cell System for automotive applications
 - Volumes ranging from 1,000 to 500,000 systems/year
 - Atmospheric-pressure system with external humidification



UTC Power

A United Technologies Company

Source: B. James, et. al. DOE Contract #DE-AD36-06GO26045, DOE Annual Merit Review, June 2008

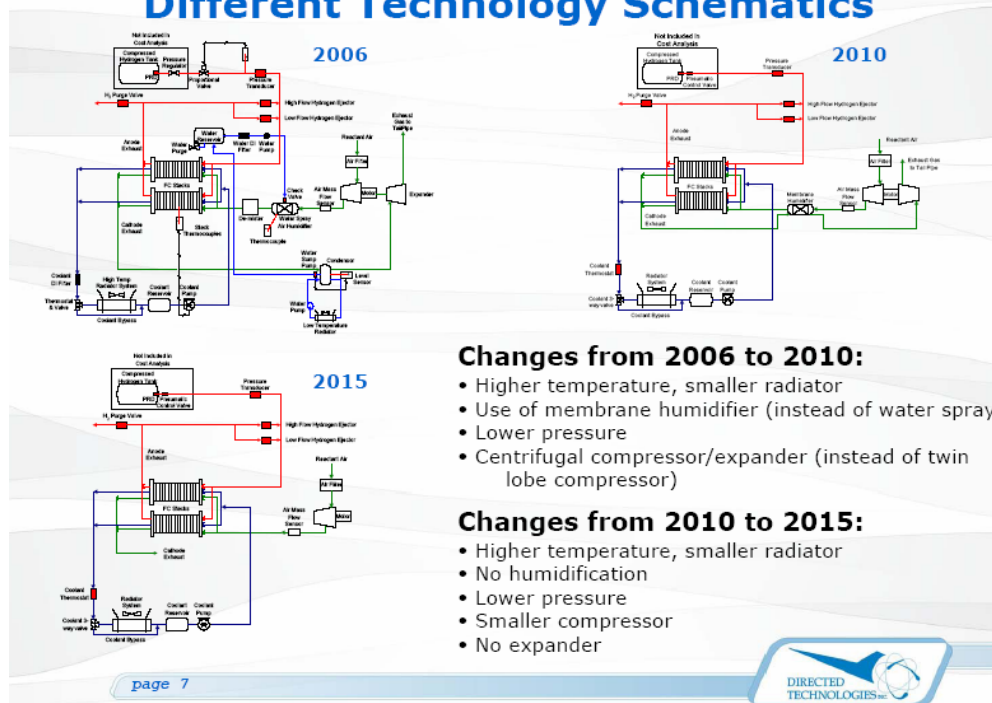




DOE - Sponsored Cost Study

Balance of Plant Cost Reduction

Different Technology Schematics



Source: B. James, et. al. DOE Contract # #DE-AD36-06GO26045, DOE Annual Merit Review, June 2008

Reducing or simplifying components drives cost reduction for Balance of Plant

UTC Power Balance of Plant is simplified

- No external water-management devices
- No air compressor, simple air blower
- No fuel-recycle compressor

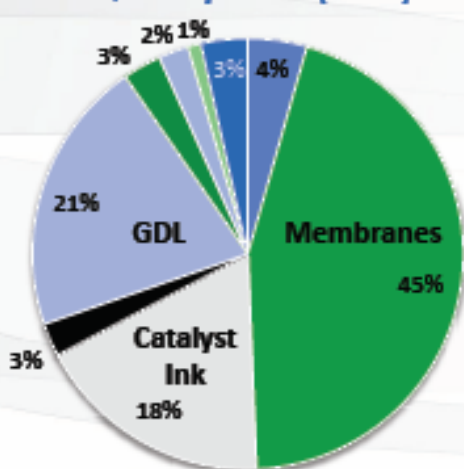


DOE - Sponsored Cost Study

Cell Stack Cost Reduction

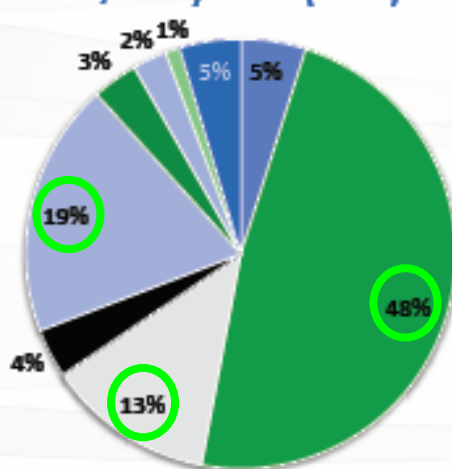
Stack Component Cost Distribution

1,000 systems (2007)



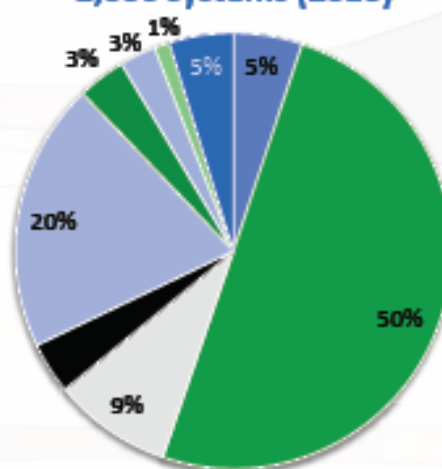
Stack Cost
(kW_{net}) ~\$170

1,000 systems (2010)



~\$115

1,000 systems (2015)



~\$110

- Bipolar Plates (Stamping)
- Membranes
- Catalyst Ink
- Catalyst Application
- GDLs
- MEA Frame/Gaskets
- Coolant & End Gaskets
- Endplates
- Other

Cell Stack Cost Drivers

- Membrane
- Catalyst Ink
- Gas Diffusion Layer (GDL)



DOE - Sponsored Cost Study

Cell Stack Cost Reduction

Cost Reduction Status

- Membranes
 - Modest cost reductions have been realized through supplier/OEM relationships
 - Technology development programs ongoing
- Catalyst
 - Larger cost contributor at high volumes
 - Technology development programs ongoing
- GDL (carbon paper with micro-porous layer)
 - Need to reduce cost for low volumes (<1,000 systems/year)
 - Technology development for reduced cost materials/processes is needed





Gas Diffusion Layer (GDL)

Opportunities for Cost Reduction

- What drives the cost of GDLs?
 - Carbon Fiber
 - ~\$5/m² of GDL (assuming \$20/Lb fiber price)
 - GDL Manufacturing Process
 - Paper, Non-Woven, Woven
 - Low volume, pilot production
 - Post Treatment
 - PTFE coating
 - Micro-Porous layer
- Potential Areas of Focus
 - Reduce complexity of GDL (eliminate post treatments)
 - Explore alternate processing methods
 - Reduce functional requirements of GDL through technology development
 - Standardization of GDL offerings





How is the Supply Base Doing?

Commercialization Barriers		Progress	
		2006	2008
R&D / Operations	Performance	+	++
	Durability	++	++
	Collaboration with OEMs	+	+
	Manufacturing Yield	+	+
	Quality	++	++
Commercial / Business	Cost/Volume	-	0
	Warranty/Risk Sharing	-	0

+ Positive Progress
 0 Some Progress
 - No Progress



Conclusions

- Strategy to enable commercialization
 - Focus on cost reductions for early fuel cell markets (low initial volumes)
 - Supplier/OEM relationships are critical
 - Independent/external cost studies can be valuable tool to stimulate open discussions between component suppliers and OEMs
 - Strategy can be applied to other components within fuel cell system
- Cost Reduction Progress to Date
 - Balance of Plant: System simplification is critical
 - Cell Stack: Progress is being made on some components
- Continue to revisit cost targets based on changing technology



Acknowledgements

- Directed Technologies, Inc.
- United States Department of Energy

George Roberts
UTC Power
Email: George.Roberts@UTCPower.com