

# “Solid Oxide Fuel Cell Development for Auxiliary Power in Heavy Duty Vehicle Applications”

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**DELPHI**

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**Sponsor:** U.S. DOE – Hydrogen, Fuel Cells and Infrastructure Technologies

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**Partners:** PACCAR, Volvo Trucks North America (VTNA), & Electricore

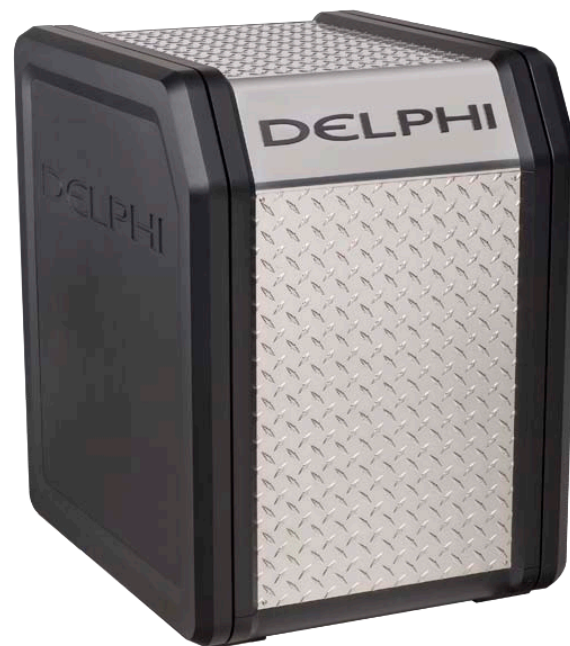
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## Agenda

- **Overview**
- **Objectives**
- **Milestones**
- **Approach**
- **Technical Accomplishments and Progress**
- **Future Work**
- **Summary**



## Overview

### Timeline

- September 2004
- April 2010  
(Project was on 18 month hold from 2006-2007)
- 100% Complete

### Budget

- Total project funding
  - DOE - \$3,000,000
  - Delphi - \$1,750,000
- \$ 981,591 received in CY09
- \$ 79,384 planned for CY10

### Barriers

- Barriers addressed:
  - Sulfur Remediation
    - Reformer Operation
    - Stack Sensitivity
  - Carbon Issues
    - Catalyst plugging
    - Combustion Start plugging
  - System Pre-combustion
  - System Electrical Integration

### Partners

- Paccar and Volvo Truck
- Electricore Inc.

# Relevance - Solid Oxide Fuel Cells Market Opportunity



**Heavy Duty Truck**  
Diesel



**Recreational Vehicles**  
Diesel, LPG



**Truck and Trailer Refrigeration**  
Diesel



**US Military**  
JP-8

**MARKET DERIVATIVES** 



**European mCHP & CHCP**  
Natural Gas



**US Stationary - APU & CHP**  
Natural Gas, LPG



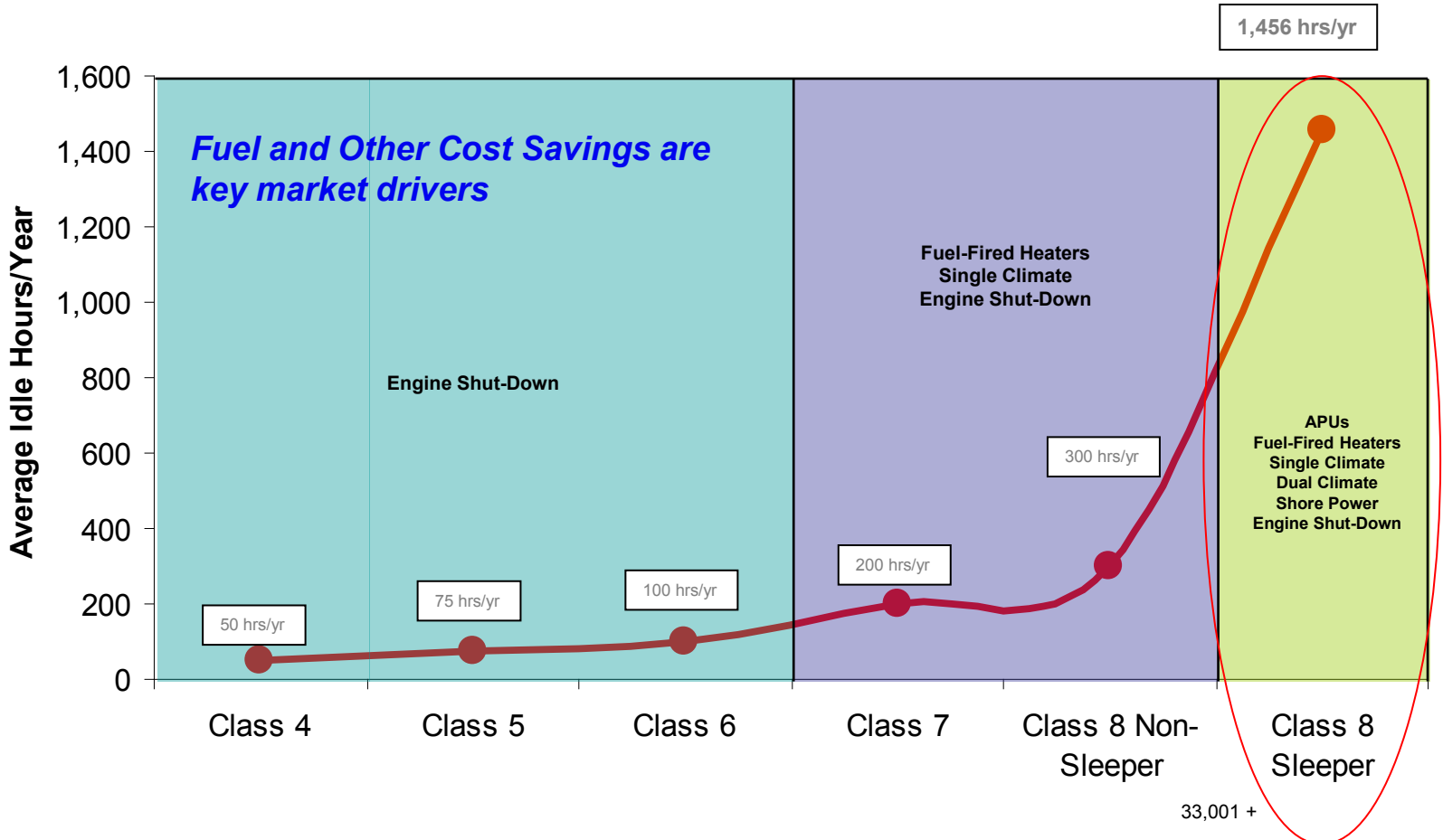
**Commercial Power**  
Natural Gas



**FutureGen Powerplant**  
Coal Gas

*Heavy Duty Truck represents Delphi's target initial development & application*

**Relevance - Heavy Duty Truck Market Idling Time**



## Relevance - Heavy Duty Truck Market Drivers

### Increasing Cab Electrical Loads



#### In-Cab Appliances Include

- CB Radios
- Cell Phones
- Televisions
- Refrigerators
- Stereos
- Lamps
- DVD / VCR Player
- Computer
- Microwave
- Coffee Maker
- Electric Blankets
- Electric AC / Heater

*OEM load profiles identify potential power requirements of 2.5kW and 4.0kW respectively*

# Relevance - Objectives

Complete a 48-month contract with the DOE EERE:

- ✓ 1. Develop APU system requirements and concepts with major truck OEMs input
- ✓ 2. Design, develop and test the needed subsystems for the approved concept
  - 1. Verification testing of brass-board APU system
  - 2. Form and packaging design
  - 3. Review Phase 2 system specification
- ✓ 3. Build and demonstrate a diesel fueled truck APU system

	DOE 2010 APU Technical Targets	DOE 2015 APU Technical Targets	Delphi Proposed SOFC APU Targets
System cycles #	150	250	150
Net System Power (kW)	≤ 5	≤ 5	3
Specific Power (W/kg)	25	25	25
Power Density (W/L)	25	25	25
Net System Efficiency	35.0%	40.0%	38.0%
Durability (hrs)	20,000	35,000	20,000
Start Up Time (min)	15-30	15-30	60
Factory Cost (\$/kWe)	\$1,000	\$500	\$1,000
Fuel	US '07 Diesel	US '07 Diesel	US '07 Diesel

DOE/Delphi SOFC Key Performance Metrics

Meeting these objectives will dramatically increase both the technical and commercial viability of fuel cell APU technology

## Approach - Milestones

Month/Year	Milestone and Go/No-Go Decisions	Complete
April 2008	<p><b>Sub-Milestone Review #2:</b></p> <p>This milestone focused on the APU design and layout; and Developing the subsystem requirements document and development plan.</p>	100%
Sep. 2008	<p><b>Sub-Milestone Review #3:</b></p> <p>This milestone focused on the SOFC APU hardware design and build; Subsystem test fixture hardware development.</p>	100%
<p>April 2009</p> <p>(As of March 20<sup>th</sup>)</p>	<p><b>Phase 2: Critical Milestone #3 Hardware Design &amp; Development</b></p> <p>This milestone focused on completion of the SOFC APU hardware build and procurement; Initiation of subsystem hardware testing and design iterations.</p>	100%
<p>August 2009</p> <p>(As of March 20<sup>th</sup>)</p>	<p><b>Phase 2 Milestone #4 System &amp; Subsystem Design Progress</b></p> <p>This milestone includes subsystem testing and controls development; Initial SOFC APU system brass board integration and design iteration.</p>	100%



## Approach

### Phase 1: OEM input Collection

- Delphi works with PACCAR and VTNA to understand the APU demands from the OEM point of view
- Information has been collected and is compiled into Delphi Requirements

### Phase 2: Design/Build/Development

- 2008 Phase 2 effort is design and component verification period
- Late Phase 2 work will include a brass-board system build and test (2009)
- OEM involvement will be reduced until Phase 3

### Phase 3: System Integration & Test

- In 2010, system development will use OEM input for test planning
- Conduct bench top testing
- Add in “real-world” profiles from the changing APU marketplace

## Heavy Duty Truck SOFC APU

### Accomplishments

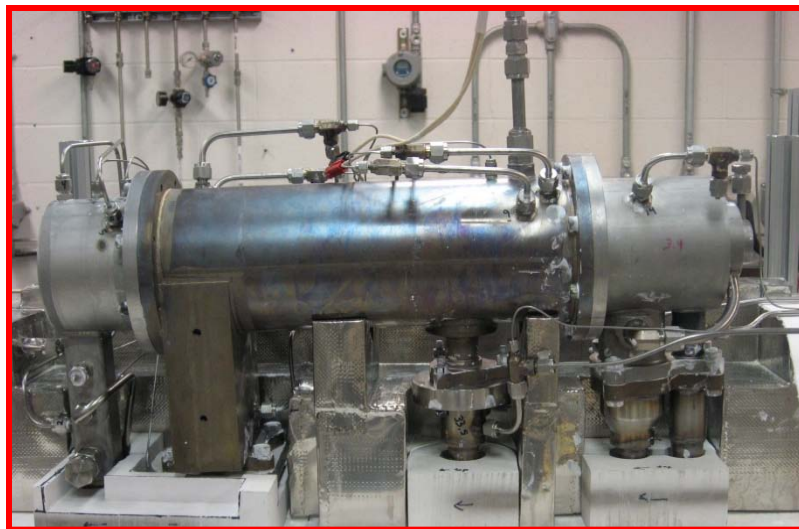
- 1.4kW Net Peak Load
- 18 ULSD Starts
- 7 Full Thermal Cycles on ULSD
- 18% System Efficiency Demonstrated
- System Noise Benchmark
- Unit tested on Natural Frequency Sine Sweep for Vibration Characterization
- Achieved Better Stack Performance Correlation to Stack Lab Data



# Technical Accomplishments and Progress

## Fuel Reformer Development

- ◆ The Next Generation Recycle Based Endothermic Reformer was successfully implemented in the Diesel APU



**Next Generation Endothermic Reformer**

# Technical Accomplishments and Progress

## Major Design Efforts in Diesel APU Development

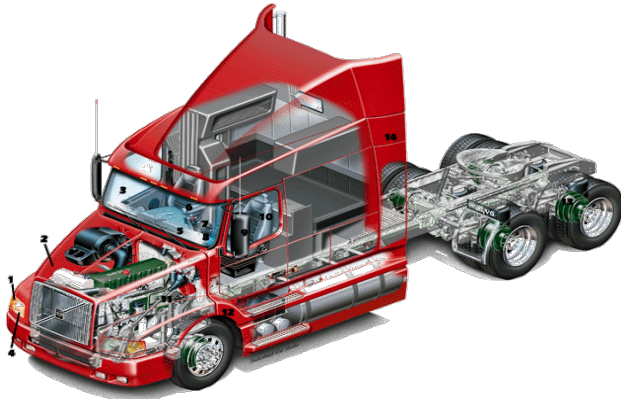


- Next Generation Stack Design with increase active area
- Enhanced Thermal Energy Management Controls
- Endothermic Reformer Integration
- Integrated Reformate Desulfurizer with Serviceability Enhancements
- Next Generation 12v Blower Design
- Multi-function Heat Exchanger
- Simplified Integrated Component Manifold

# Collaborations

*Delphi has teamed with OEM's PACCAR Incorporated and Volvo Trucks North America (VTNA) to define system level requirements for a Fuel Cell (SOFC) based Auxiliary Power Unit (APU) for the commercial trucking industry. As well as Electricore Inc, to help with the overall program management*

**VOLVO**



**Volvo Trucks North America (VTNA),  
 Greensboro, NC**

**PACCAR**

**KENWORTH**

*Peterbilt*

**DAF**



**Foden Trucks**  
an Division of PACCAR USA, Inc.



**PACCAR, Mt. Vernon, WA**



**ELECTRICORE**  
 POWERING THE FUTURE

**Electricore Inc, Valencia, CA**

## Past / Future Work

### 2009

- Finish Subsystem Testing and Development Iterations
- Conduct 24 Month Critical Decision Milestone Review (April 2009)
- Complete System Module Testing and Development
- Phase 2 complete – Conduct Milestone Review (August 2009)
- Demo Test, 24 hour truck user profile using battery interface and vehicle simulation

### 2010

- Phase 3 completed (build and demonstrate a diesel fueled truck APU system)
- Close out project

## Summary

- **Primary Market Drivers**
  - Anti-Idling Legislation
  - Emissions Legislation
  - Increasing Heavy Duty Truck Cab Electrical Loads
  - Transportation Fuel Cost
- **Completed Component Build and Testing of SOFC APU subsystems**
- **Completed Bench Top – Brass Board Demonstration**
- **Met both Program Timing and Budget**
- **Delphi is Committed to Introducing SOFC Diesel Technology in Full Scale Production for Heavy Duty Truck Applications**