# Overview: Advanced Power Electronics and Electric Motors (APEEM) R&D

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# APEEM Activity Focuses on Spectrum of Vehicle Application

## Current R&D portfolio applies to the following vehicle platforms:

- **ICE Hybrid Electric Vehicle (HEV)**
  - **Near-term path for introduction of technologies (and fuel savings)**
  - **Focus on mid-size and larger full hybrid**

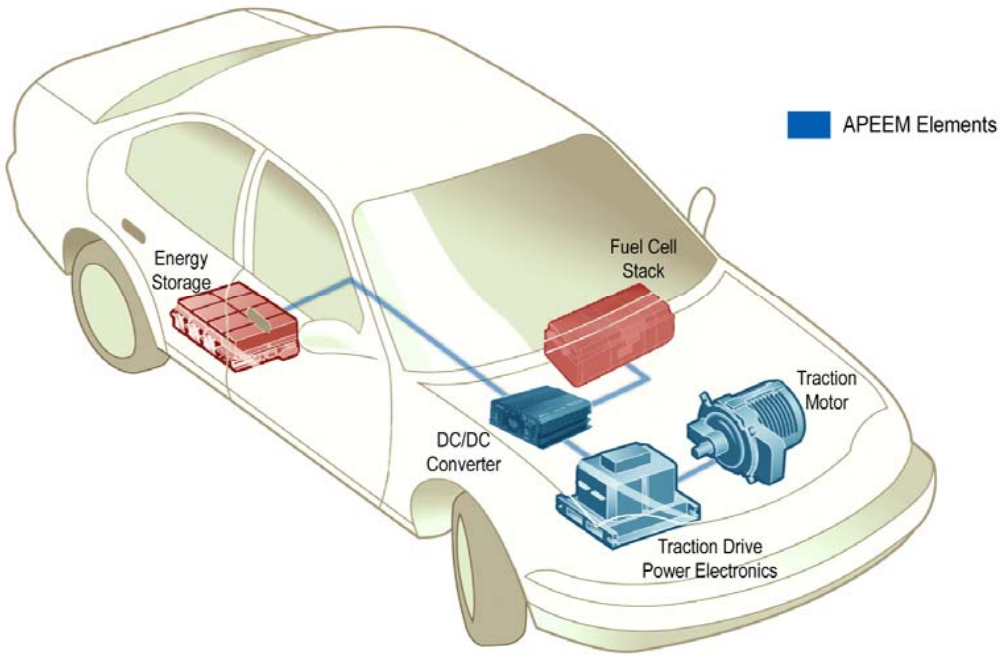
- **Plug-in Hybrid Electric Vehicle (PHEV)**
  - **Specific needs include charging, voltage swings, and more highly stressed thermal control**
  - **Additional R&D needs being evaluated**

- **Fuel Cell Vehicle (FCV)**
  - **Long term partnership objective**
  - **Focus on subcompact through SUV**

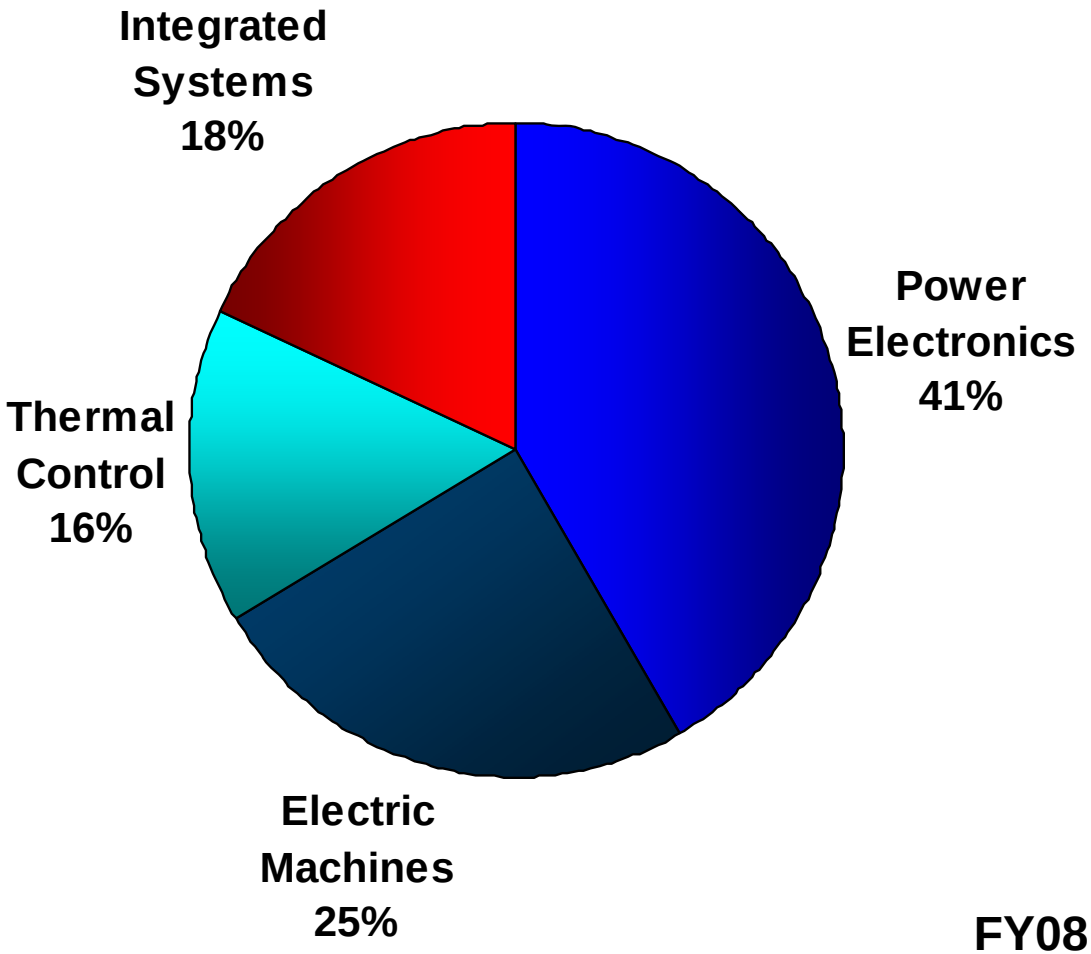
# APEEM R&D Scope

## APEEM Activity Includes

- Electric Traction Drive
  - Electric Machines - Motors and Generators
  - Power Electronics - Inverter and Boost Converter (if needed)
  - Thermal Control – Key enabling technology
- Vehicle Power Management
  - Bi-Directional Multi-Voltage DC-DC Converter



# FY 2008 Budget

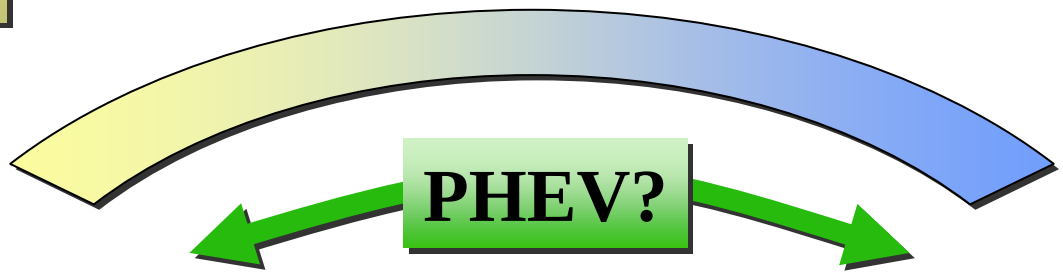



**FY08: $15,462K**

# APEEM Traction Drive R&D Portfolio Responsive to Full Spectrum of Electric Vehicle Applications

**HEV**

**FCV**




Blended ICE/Electric
– Power requirement ≥ 55 kW
– Parallel architecture
– Intermittent short operation

Sized for Electric Only
– Power required increases (up to 200 kW)
– Series architecture
– Always "on"

PHEV Position in Spectrum Depends on Design

**Target attainment confirmation performed at 55 kW power requirement to ensure targets met at all power levels**

# New PHEV Industrial Activity Since Last Review

***PEEM PHEV Solicitation Awards Announced***

***Projects total $33.8 million***

- ***Team Lead: General Motors Corporation***
  - Award: ≤$7.9 million
  - Description: Integrated traction drive system meeting 2010 system target
- ***Team Lead: Delphi Automotive Systems***
  - Award: ≤ $4.9 million
  - Description: High temperature inverter addressing 2015 power electronics target
- ***Team Lead: Virginia Polytechnic Institute***
  - Award: ≤ $1.7 million
  - Description: Advanced soft switching inverter for reducing switching and power losses addressing 2015 power electronics target
- ***Team Lead: General Electric Global Research***
  - Award: ≤ $3.4 million
  - Description: Increasing traction motor power density and efficiency to address 2020 motor target
- ***Team Lead: U.S. Hybrid Corporation***
  - Award: ≤ $1.3 million
  - Description: Bi-directional dc-dc converter including vehicle system study to determine optimum battery and dc link voltages

# APEEM is Technology Development Effort

- **Multiple solutions required**
  - **Variety of vehicle platforms (compact to SUV)**
  - **Variety of architectures**
  - **Variety of vehicle applications (FCV, HEV, PHEV)**
- **Focus of R&D is to produce technology advances that become part of vehicle solutions**
- **R&D portfolio is technology driven not module driven**

# R&D Efforts will Produce Technology Used in OEM Solutions

***We Don't Make It***

***We Make It Possible***

# Partnership Goal

**Electric Propulsion System with a 15-year life capable of delivering at least 55 kW for 18 seconds and 30 kW continuous at a system cost of $12/kw peak with a 105°C inlet coolant temperature by 2015*.**

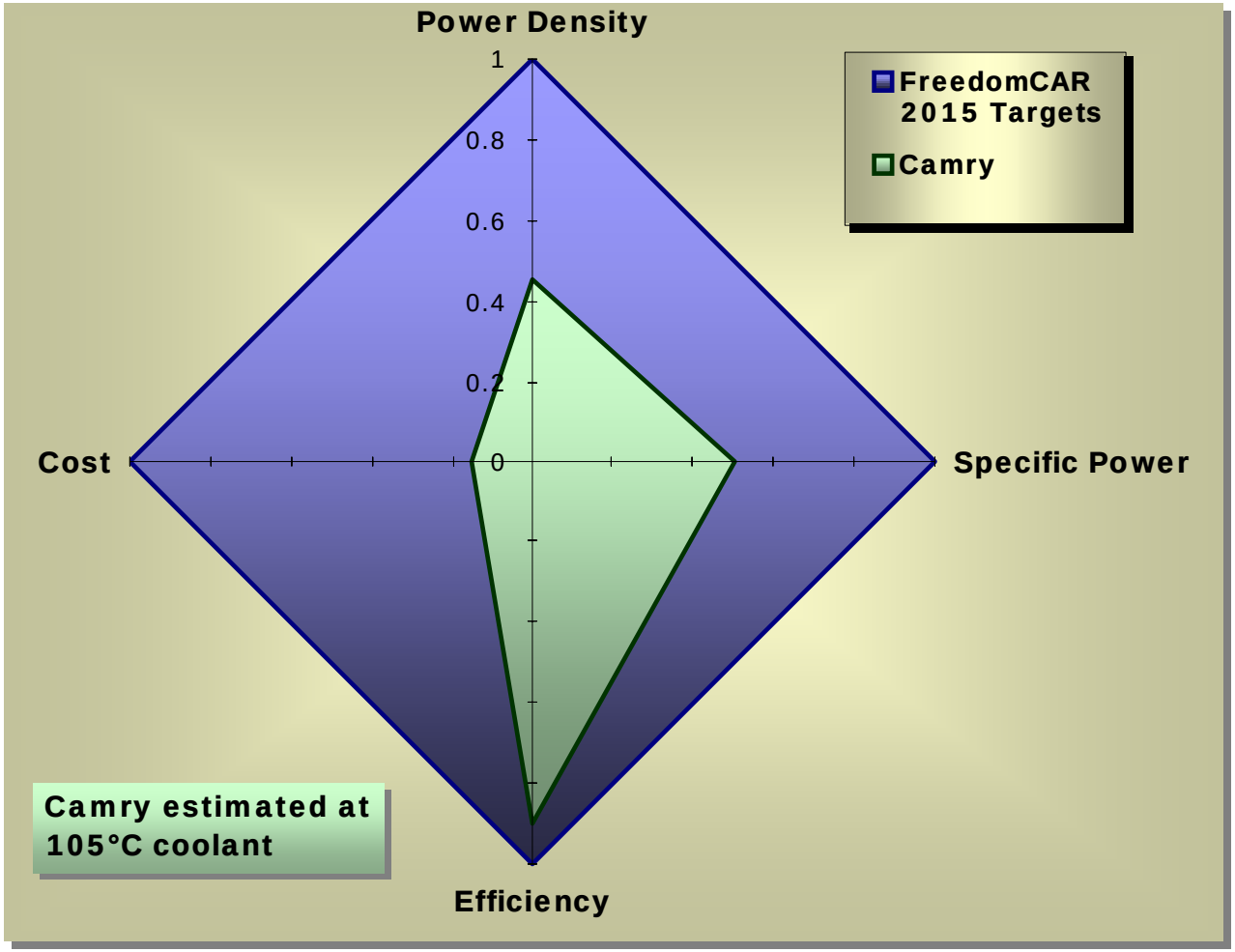
****Pending ESG approval***

# Large Oil Savings Are Possible

- **Vehicles using electric traction drives have the potential to significantly reduce oil consumption**
  - **HEVs can reduce petroleum use by as much as 50%**
  - **PHEVs can extend that savings to higher levels**
  - **FCVs eliminate oil use**
- **Large national benefits will depend on significant market penetration**
  - **Affordability is the key; extra cost must be offset by fuel savings**
  - **Weight and volume also drivers**
  - **PEEM systems currently about 10 times too expensive and two times too big**
- **Potentially vehicles using electric traction drives could reduce oil consumption by millions of barrels a day**
  - **R&D efforts that support attainment of targets can produce this result**

# Challenges

## Traction Drive System



# Traction Drive System Targets

| Traction Drive System Level Targets | | | | | |
|---|---|---|---|---|---|
| | *($/kW)* | *(kW/kg)* | *(kW/l)* | *Efficiency* | *Coolant* |
| **2010** | 19 | 1.06 | 2.6 | >90% | 90°C |
| **2015** | 12 | 1.2 | 3.5 | >93% | 105°C |
| **2020** | 8 | 1.4 | 4 | >94% | 105°C |

*Traction Drive System Efficiency Target is for 10% -100% speed @ 20% of Rated Torque*

# Targets Cascaded Down From System

| | Power Electronics | | | Motor | | | Traction Drive System | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *($/kW)* | *(kW/kg)* | *(kW/l)* | *($/kW)* | *(kW/kg)* | *(kW/l)* | *($/kW)* | *(kW/kg)* | *(kW/l)* | *Efficiency* | *Coolant* |
| **Targets** | | | | | | | | | | | |
| **2010** | 7.9 | 10.8 | 8.7 | 11.1 | 1.2 | 3.7 | 19 | 1.06 | 2.6 | >90% | 90°C |
| **2015** | 5 | 12 | 12 | 7 | 1.3 | 5 | 12 | 1.2 | 3.5 | >93% | 105°C |
| **2020** | 3.3 | 14.1 | 13.4 | 4.7 | 1.6 | 5.7 | 8 | 1.4 | 4 | >94% | 105°C |

*Traction Drive System Efficiency Target is for 10% -100% speed @ 20% of Rated Torque*

# Targets Established for Power Management DC-DC Converter

| DC-DC Converter | | | | |
|---|---|---|---|---|
| | ***$/kW*** | ***kW/kg*** | ***kW/l*** | ***Efficiency*** |
| **Targets** | | | | |
| **2010** | 75 | 0.8 | 1 | 92% |
| **2015** | 50 | 1 | 2 | 95% |
| **2020** | 25 | 1.2 | 3 | 96% |

# APEEM R&D Pathways

**Established from Function Analysis System Technique (FAST) Analysis**

- **Driven primarily by volume and cost targets**
- **Technology specific pathways will follow**

# Multiple Pathways are Pursued

## Multiple Pathways Included in R&D Portfolio

- Each pathway contains significant technical risk and challenges
- Multiple research pathways mitigate technical risk and address different technology needs related to vehicle architecture
- Project portfolio mapped against pathways; all projects align with one or more pathways