Hybrid Electric Buses: Today,Tomorrow and the Future

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General Motors Corporation

PNNL Northwest Hydrogen Conference
June 16, 2003

ALLISON HYBRID ELECTRIC DRIVES

Presentation Outline

- Background – hybrid vehicles/GM plan
- Hybrid electric buses
  - Today
  - Tomorrow
  - Future

What are the Best Vehicles to Offer Hybrid Variants?

- Hybrid technologies are fuel saving technologies
- Offer hybrid variants for vehicle segments that consume the most fuel
  - Larger vehicles
    - Higher idle consumption, more braking energy
  - Stop and go driving
    - More frequent idling, more frequent shifting, more frequent braking

GM's Hybrid Application Strategy

Objective: Generate maximum fuel consumption savings at lowest possible cost

- Apply first to vehicles with higher fuel consumption used in stop-and-go driving
  - Greatest fuel savings
  - Greatest environmental benefit
- Create models that maximizes value to the customer
  - "No compromises" vs. base model offering

Vehicle Type	GM's Hybrid Model
City Buses	Oct 2003 System Available to Bus Mfg
Fullsize Trucks	2004 MY Chevrolet Silverado 2004 MY GMC Sierra
Medium SUVs	2006 MY Saturn Vue 2007 MY Chevrolet Equinox
Sedans	2007 MY Chevrolet Malibu
Small Cars	None planned at this time

Hybrid Electric Buses

- Today: They're here and they work.
- Tomorrow: We need to get more on the road. Not waiting for the fuel cell.
- Future: Looks bright for the fuel cell. GM is committed to its development.

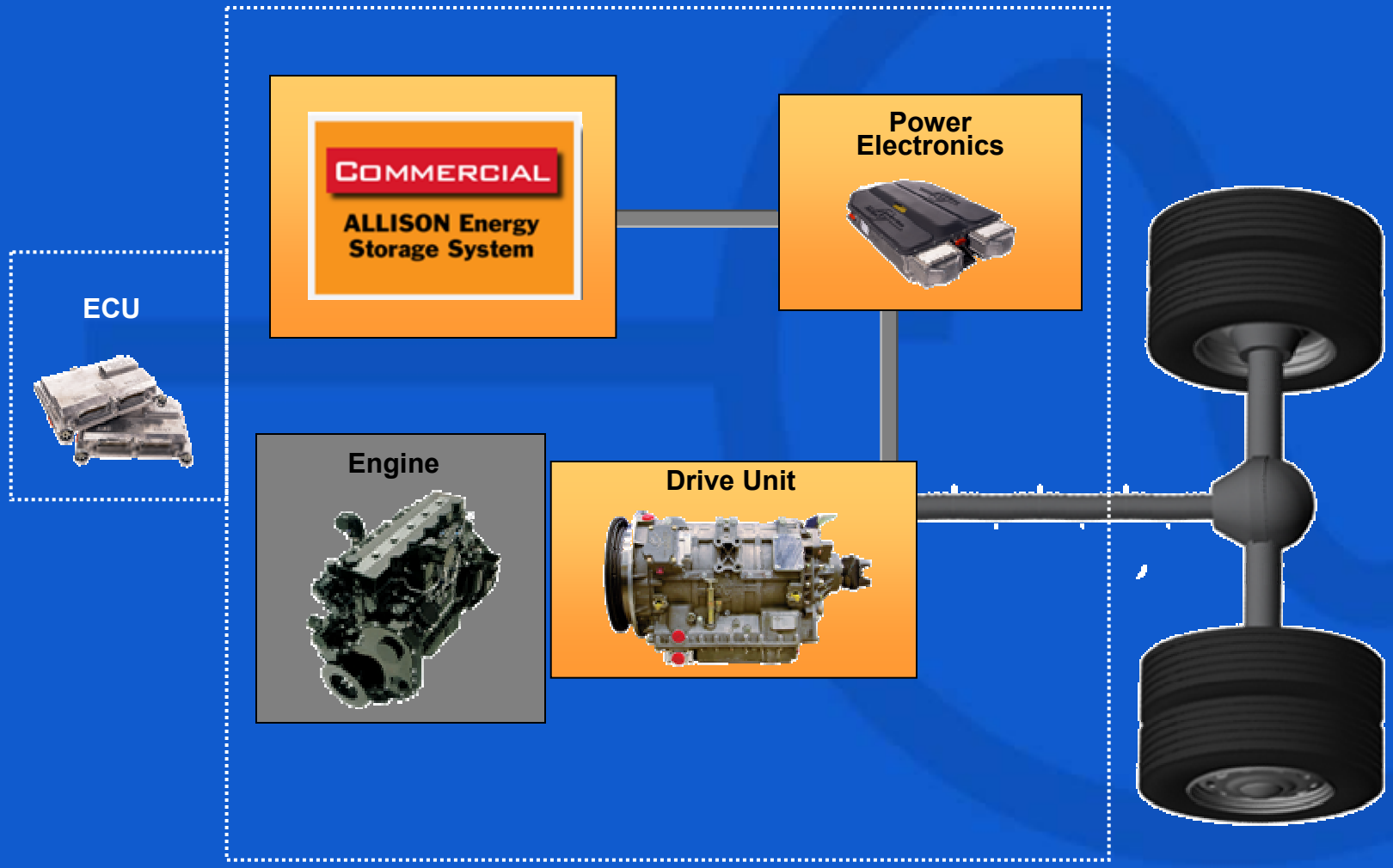
Hybrid Electric Buses

- Today: They're here and they work.

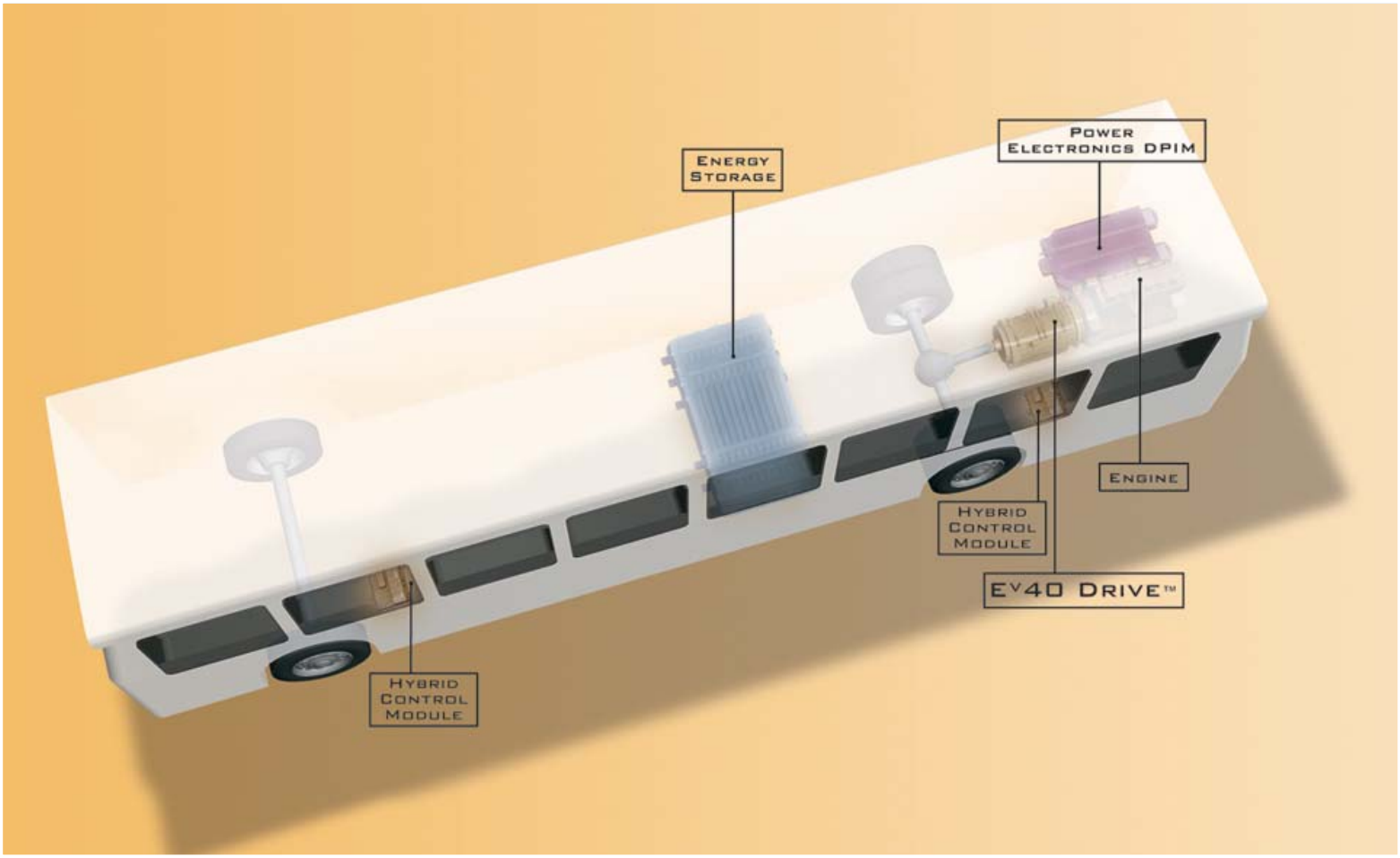
Current Hybrid Bus Applications

ALLISON HYBRID ELECTRIC DRIVES

EP SYSTEM™ Configuration

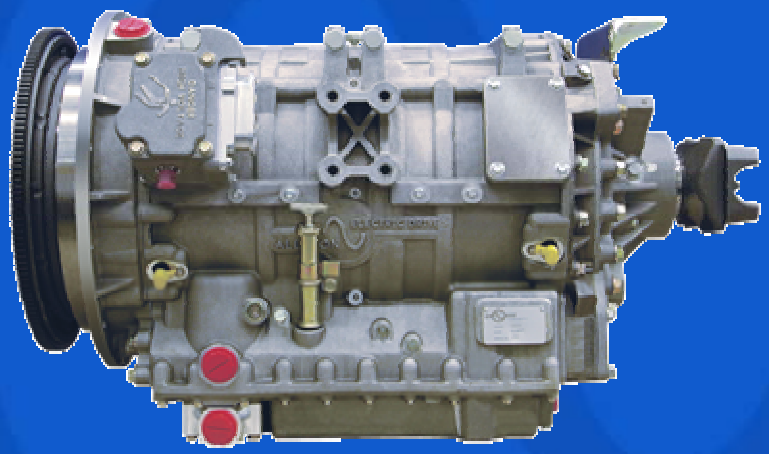


Packaging for 40-Foot Buses, Suburban Coaches and Articulated Transit Buses



EVDRIVE™ *for* EP SYSTEM™

- Traditional package
- Looks like a familiar B 400R
  - Therefore not intimidating to technicians
- Concentric electric motors provide electrically variable drive ratios
  - .40 overdrive
- "Two-mode compound split parallel hybrid architecture"

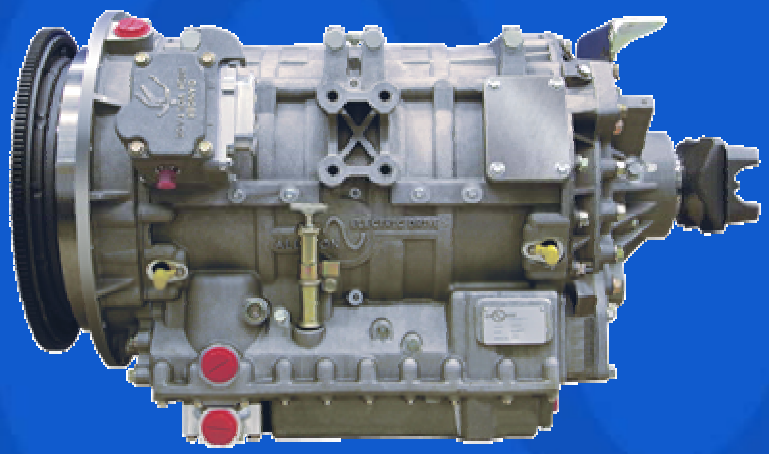


EV40 DRIVE™

EV50 DRIVE™

EVDRIVE™ *for* EP SYSTEM™

- Eliminates engine starter
- Input rating (continuous): 330 hp (246 kW)
- Rated input torque: 900 lb-ft (1220 Nm)
- Rated input speed: 2300 rpm
- Mass: 1022 lb (464 kg)

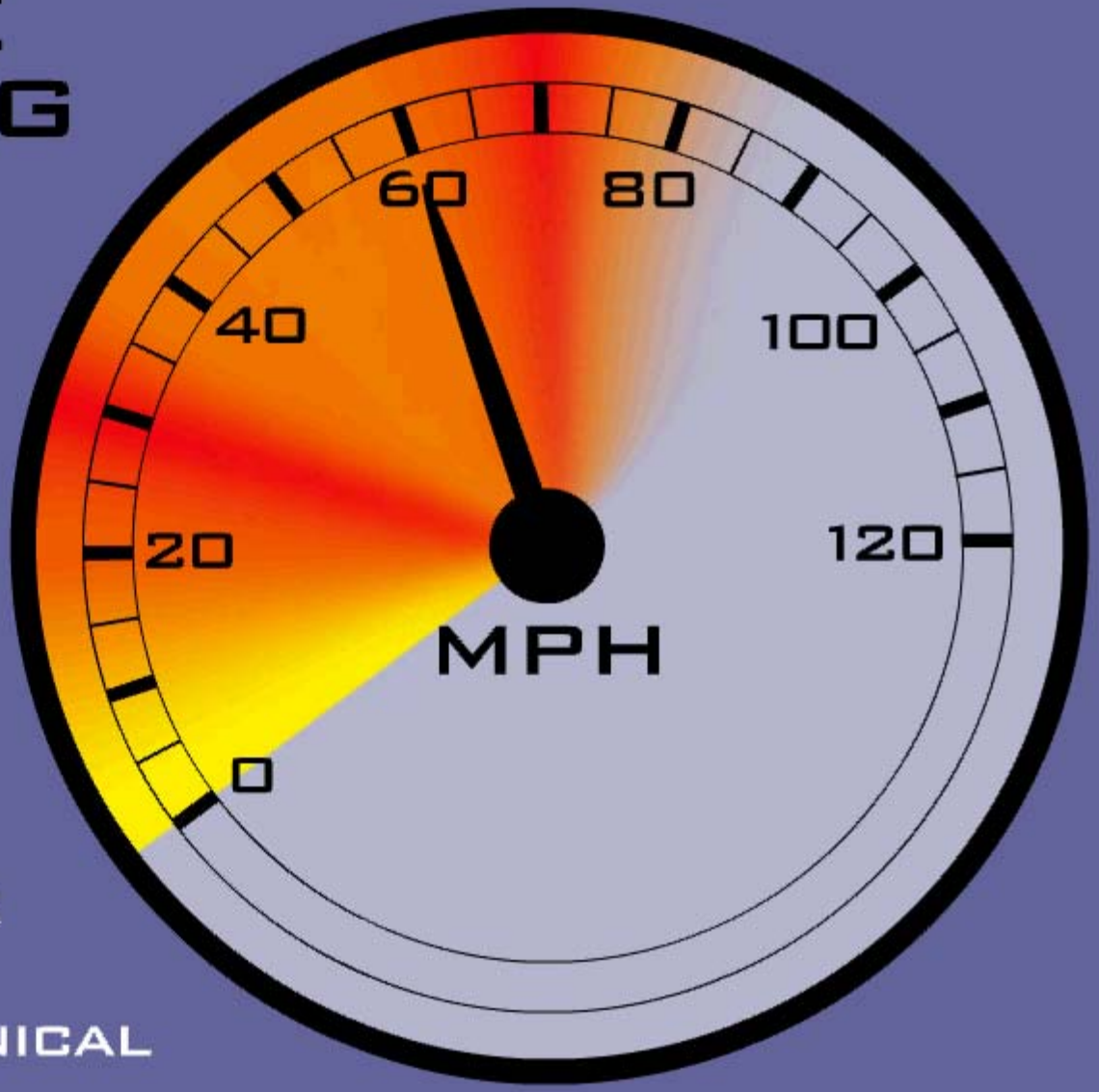


EV40 DRIVE™

EV50 DRIVE™

ALLISON HYBRID ELECTRIC DRIVES

Torque Blending



Pure Series
(Motor Torque Only)

Parallel Mix
(Motor/Engine Torque)

Pure Mechanical
(Engine Torque Only)

System Controllers

- Allison Transmission 1000/2000/2400 Series™ controller
  - As used in 2003 Silverado pickup truck
- Very high quality
- Automotive volumes
- Two used with E² SYSTEM™
- Mass: 5.1 lb (2.3 kg)

Allison Energy Storage System

6-Year Cell Life
1/3 the Weight
Only 900 Pounds!
1/2 the Size

Ultra-Capacitors

Lead Acid
1-2 year Max Life
3000-4000 Pounds

Allison Energy Storage System

Dual Power Inverter Module (DPIM)

- Specifically designed by Allison to meet customer needs
- Core Allison business
- One DPIM includes two inverters
- 430-900 volts DC
- 160 kW continuous 3-phase AC output
- Mass: <200 lb (91kg)
- SAE J1939 Control Communications

Hybrid Benefits
Reduced Emissions

During hybrid operation, emissions are reduced up to 90%, compared to conventional combustion engines.

Nitrogen Oxide (NOx) up to 50% less

Particulate Matter (PM) up to 90% less

Carbon Monoxide (CO) up to 90% less

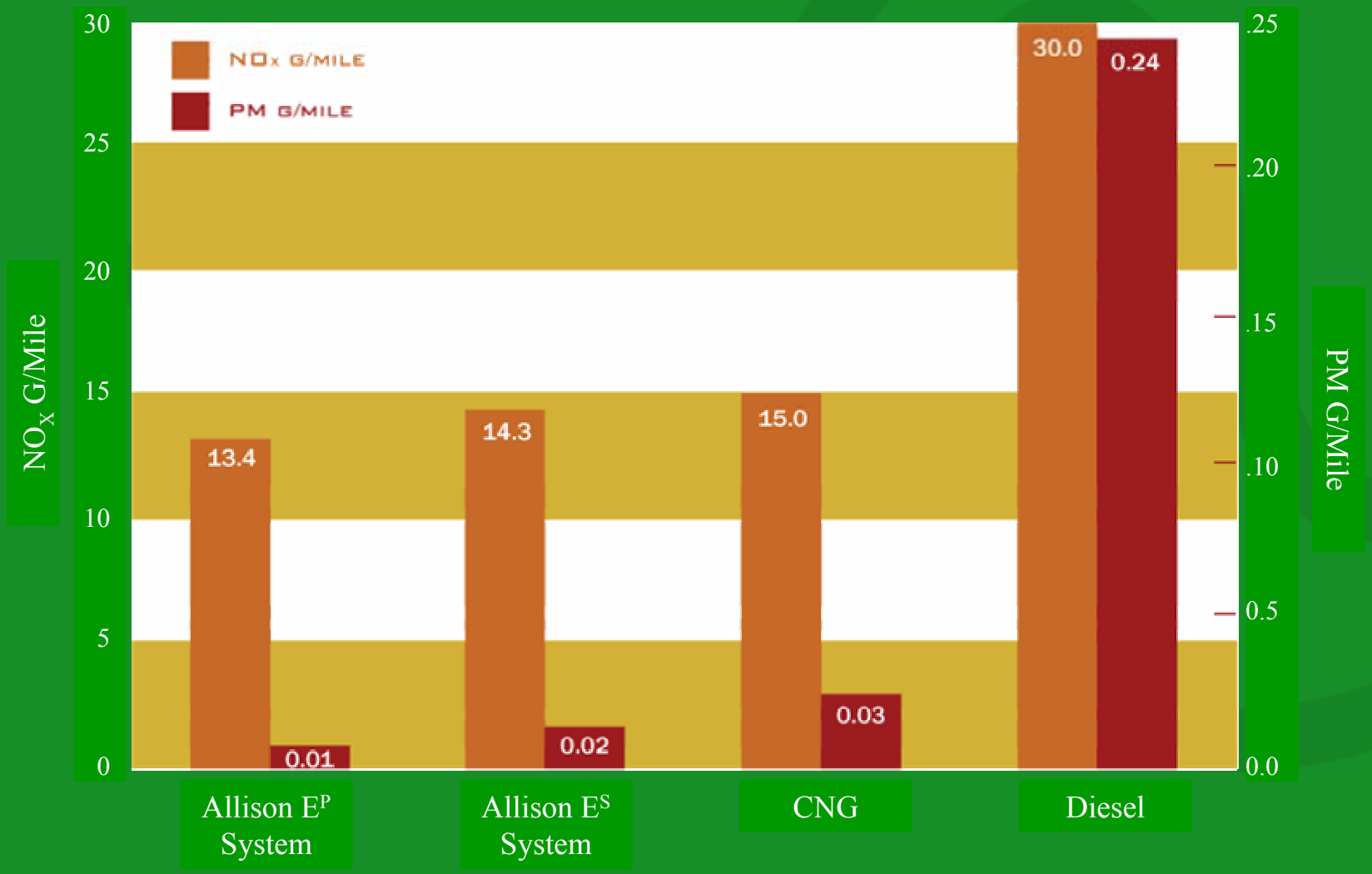
Hydrocarbons (HC) up to 90% less

% Reduction in Fuel = % Reduction in CO_2

**Demonstrated emissions operating a CBD-14 cycle at Southwest Research, Inc.*

Requires DPF

Urban Bus Emissions (on CBD-14)



CARB Report

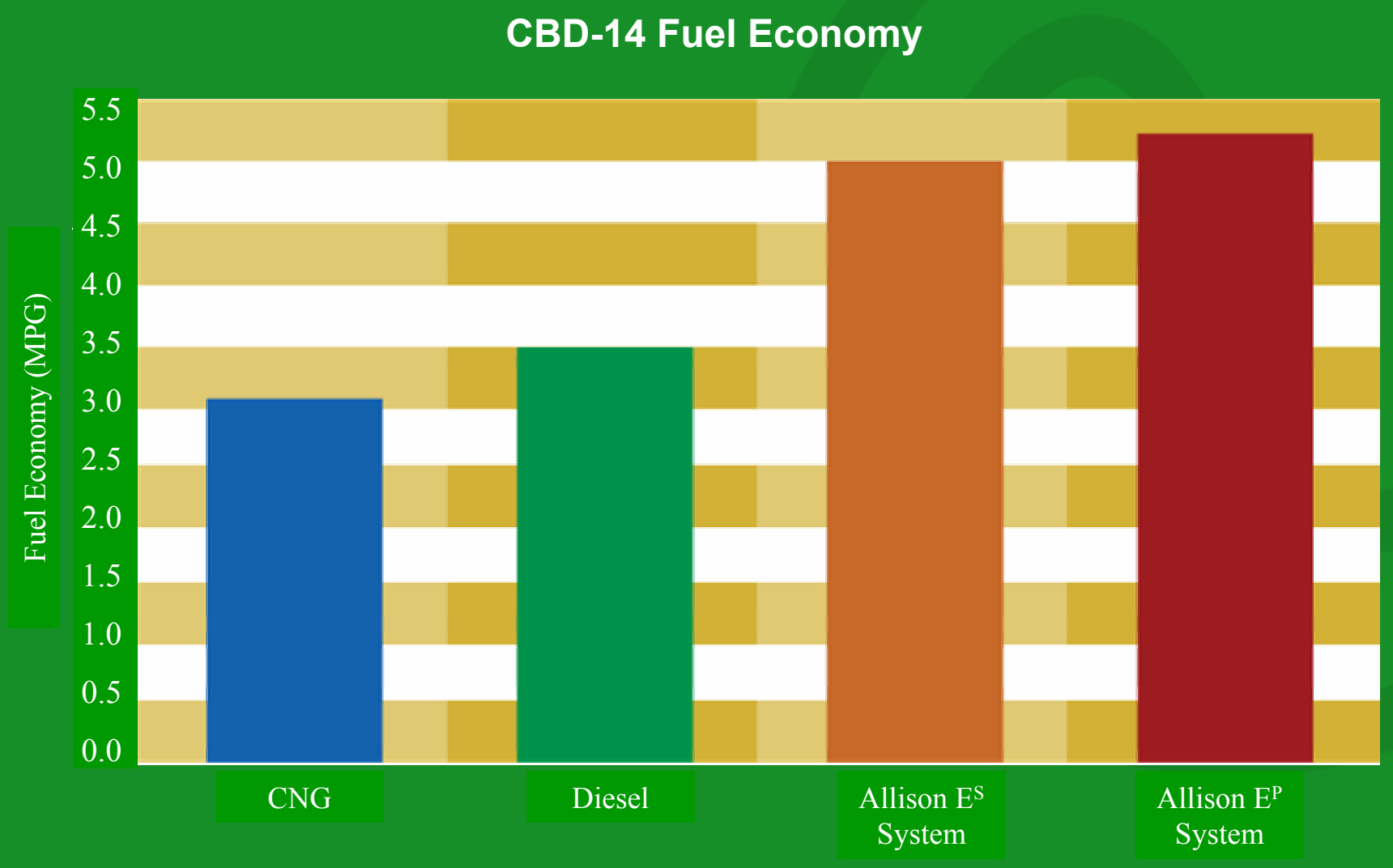
California Air Resources Board
Heavy-Duty Emissions Laboratory
Mobile Sources Control Division
Heavy-Duty Testing and Field Support Section
Test Engineers: Juan Osborn, Alvaro Gutierrez

Report No. 01-01

Test Dates: 7/10/01-7/13/01

Executive Summary
July 30, 2001

Hybrid Benefits
Improved Fuel Economy



EP40 System™ Drives Up Hyde Street in San Francisco

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20 Preview Units in 2003

- 20 Preview units (Pilot Productions) will be sold June - September 2003
- Preview units to be sold to key fleets that will champion the technology
- Selection to be strategic and result in significant orders

Preview Program

- Deployments
  - 2 OCTA (January 2001)
  - 2 Portland Tri-Met (April 2002)
  - 2 SEPTA (August 2002)
  - 1 St. Paul (September 2002)
  - 1 Seattle (Oct 2002 Articulated Bus)
  - 1 NJT (Nov 2002 Suburban Coach)
  - 3 Salt Lake (March 2003)
  - 1 Seattle (May 2003 40')
  - 2 Hartford (May 2003)
  - 4 Houston (June 2003)
  - 10 SEPTA (August 2003)

Hybrid Electric Buses

- Today: They're here and they work.
- Tomorrow: We need to get more on the road. Not waiting for the fuel cell.

Start of Production

- October 2003
- Vocations are
  - 40’ Transit Bus
  - 60’ Articulated Bus
  - 40 & 45’ Suburban Coach
- Current Releases:
  - New Flyer: both 40’ & 60’ Artic Low Floor (ISL)
  - Gillig: both 40’ Standard Floor & Low Floor (ISB)
  - MCI: 40/45’ D-Series Suburban Coach (ISL)

How can the government help?

- Direct Vehicle Purchases/Government Funding
  - Funding Municipal Bus Programs
  - Government Fleet purchases
  - U.S. Military Applications
- Manufacturer Incentives
  - Accelerated Depreciation on Investment (incentive to move to next generation design)
  - R&D tax credit for engineering
- Consumer Incentives
  - Incentives/Tax Benefits for Fuel Consumption Savings
    - Incentivize fuel savings, not fuel efficiency

Transit Bus Procurement Funding

- **TEA-21 Reauthorization Initiative:**
  - Secure funding to advance hybrid electric propulsion technologies in qualifying 40-foot transit buses, articulated transit buses and suburban coaches
  - Heavy Hybrid Industry: Allison Transmission General Motors Corporation, BAE SYSTEMS Controls, Eaton Corporation
  - Differential Cost Proposal "Clean Bus Deployment Program"

Differential Cost Proposal "Clean Bus Deployment Program"

Sec. 5309- Bus Capital Procurement:

FUNDING: $100M per year for 6 years

- ***PURPOSE:*** Recognize the importance of advancing electric propulsion technologies for the successful transition to fuel cell buses; Only clean buses that advance the pathway to fuel cell buses are eligible.
- ***MINIMUM of $50M*** each year for electric propulsion bus technologies
- Eligible Purchases:
  - Covers the differential cost of clean bus purchases over comparable transit buses
  - Transit agencies/public bodies in nonattainment or maintenance areas
  - Clean Bus Cost: No more than twice the cost of a comparable transit bus
  - Minimum Purchase: 5 clean buses
  - Limitation: No single transit agency may receive funds in one year in excess of 10% of the funding available in that year

- Sources of Funding: Highway Trust Fund, Transit Account

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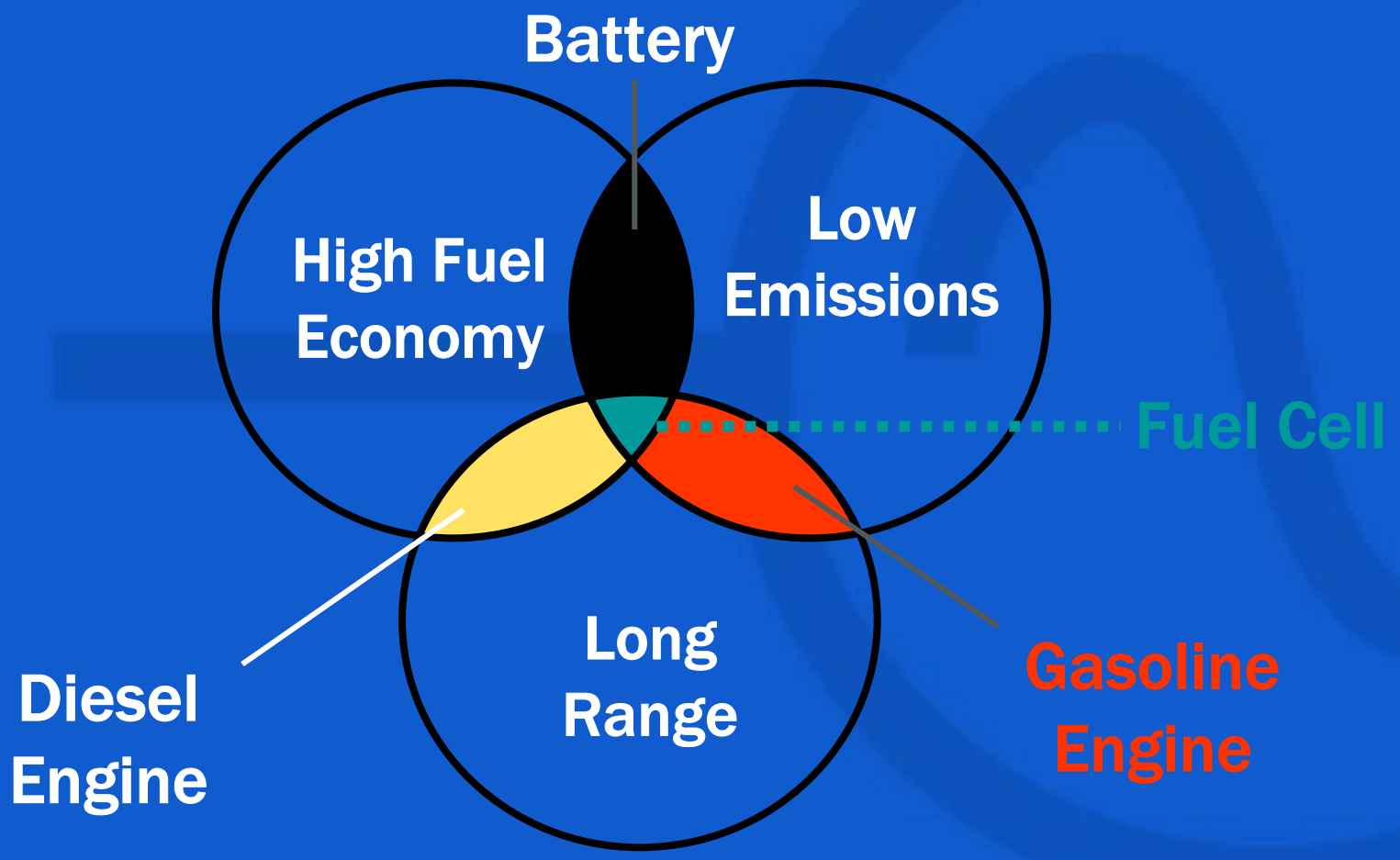
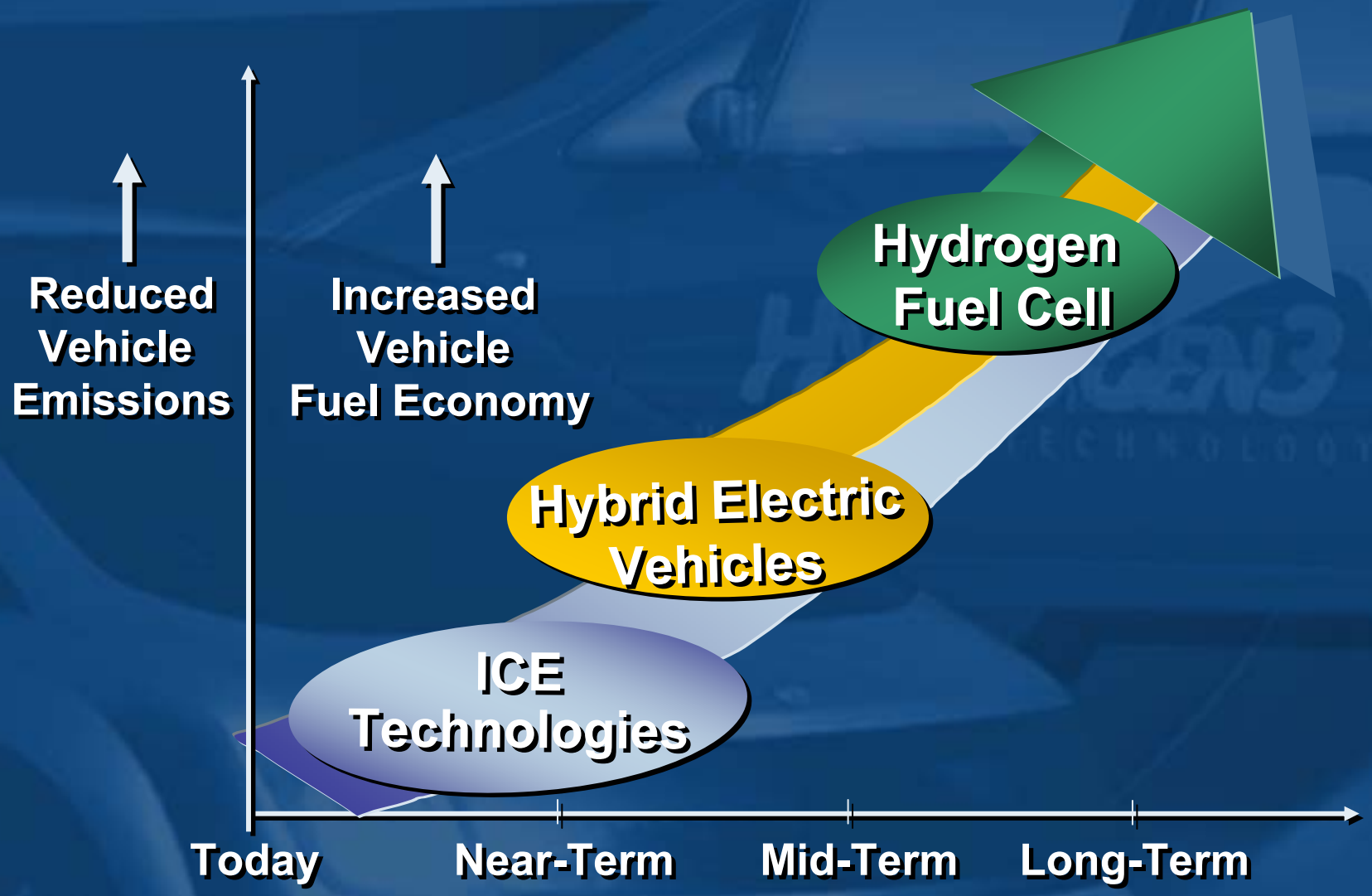
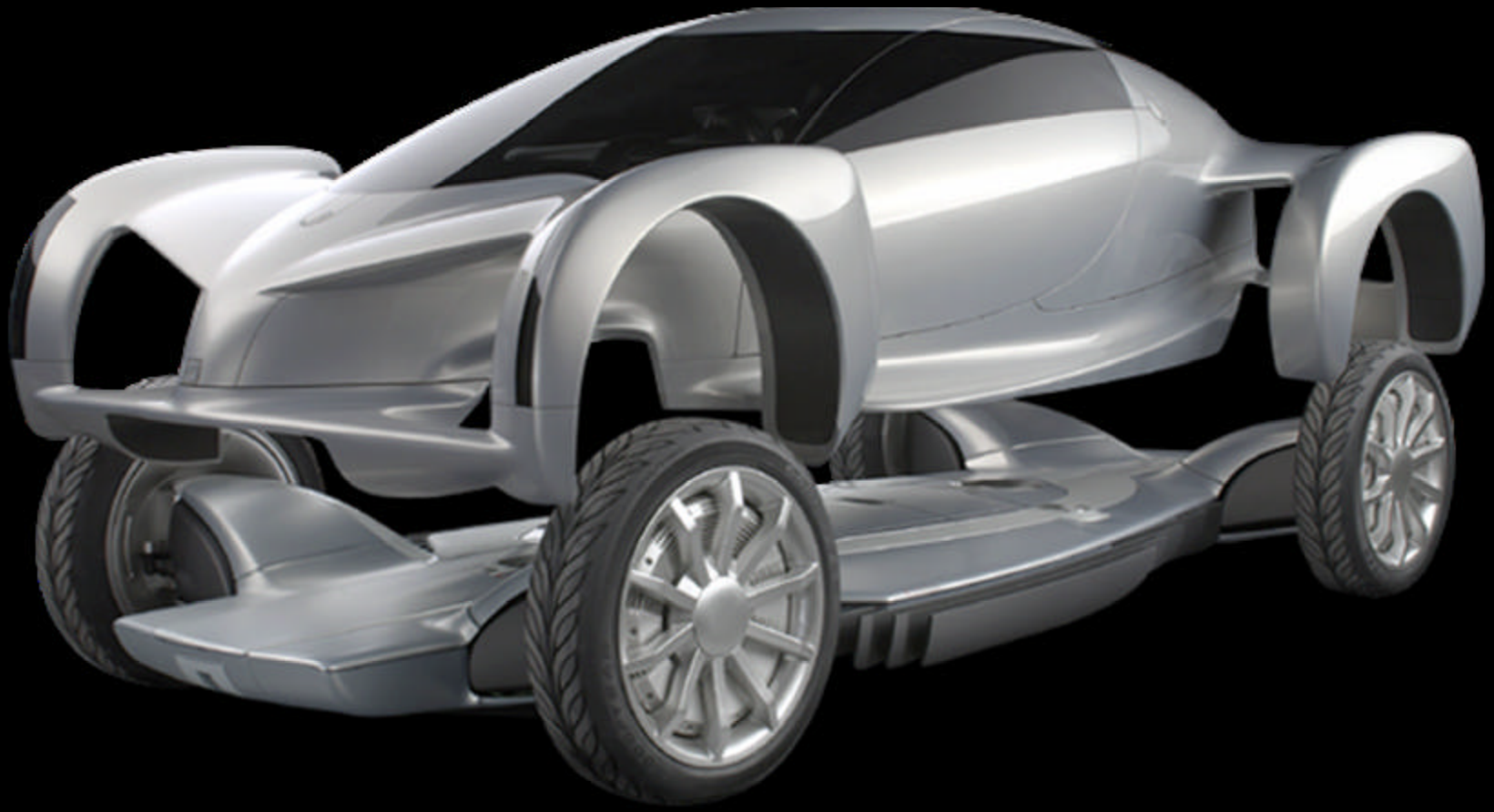
Why Fuel Cells?




Reduced Vehicle Emissions
Increased Vehicle Fuel Economy
Hydrogen Fuel Cell
Hybrid Electric Vehicles
ICE Technologies
Today
Near-Term
Mid-Term
Long-Term

AUTONOMY



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GM

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