ADVANCED PROPULSION TECHNOLOGY: DRIVING TO A SUSTAINABLE FUTURE

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PETROLEUM SUPPLIES ... 

35% OF WORLD’S ENERGY 

96% OF TRANSPORTATION ENERGY
FUTURE PETROLEUM DEMAND

Need 6 New Saudi Arabias by 2030!

Source: IEA World Energy Outlook, 2008
ENERGY OPTIONS

Energy Resource

- Oil (Conventional)
- Oil (Non-Conventional)
- Biomass
- Natural Gas
- Coal
- Renewables (Solar, Wind, Hydro)
- Nuclear
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Conversion
- Syngas

Energy Carrier
- Liquid Fuels & CNG
- Electricity
- Hydrogen

Propulsion System
- Conventional ICE: Gasoline/Diesel
- ICE Hybrid
- Plug-in Hybrid ICE
- Range-Extended EV
- Battery Electric
- Fuel Cell Electric

Electrification
Battery improvement expected, but still 100x lower density than liquid fuels

Hydrogen has significantly higher energy density than current batteries
Global Fuel Economy/CAFE/CO₂ Challenges

**Canada**
- Green Levy
- 6.6L/100km (35.5 mpg) in 2016
- Quebec; 34.7 mpg in 2016

**US-Federal**
- 35.5 mpg by 2016
- Gasoline $3/gallon

**California**
- 40% mpg 2009 → 2011
- 80% CO₂ reduction by 2050
- ZEV, PZEV rules

**European Union**
- 130g/km in 2015 (43 mpg)
- 95g/km in 2020 (58 mpg)
- Local CO₂ taxation
- Gasoline up to $6/gallon

**Japan**
- 23% CO₂ 1995 → 2010
- 29% CO₂ 2010 → 2015

**China**
- 6.9L/100km in 2015 (34 mpg)
- 5.0 L/100km in 2020 (47 mpg)

**Australia**
- 17% 2003 → 2010
ADVANCED PROPULSION TECHNOLOGY STRATEGY

Improve Vehicle Fuel Economy and Emissions

Displace Petroleum

Hydrogen Fuel Cell-Electric Vehicles

Battery-Electric Vehicles (including EVre)

Hybrid-Electric Vehicles (including Plug-in HEV)

IC Engine and Transmission Improvements

Energy Diversity

Petroleum (Conventional and Alternative Sources)

Alternative Fuels (Ethanol, Biodiesel, CNG, LPG)

Electricity (Conv. and Alternative Sources)

Hydrogen
MAXIMIZING FUEL EFFICIENCY

130% FOR CARS

80% FOR TRUCKS
IMPROVING GASOLINE ENGINES

- Modular and Flexible Architectures
- Reduced Mass
- Improved Combustion Technology
- Integration of Leading Edge Technologies

- Cam Phasing, Variable Valve Lift, Active Fuel Management
- Port Deactivation with EGR
- Spark Ignition Direct Injection
- Downsized SIDI Turbo Boosting
- HCCI – Homogeneous Charge Compression Ignition
GM E85 FLEX-FUEL VEHICLES

OVER 5.5M VEHICLES WORLDWIDE AND 17 MODELS IN NORTH AMERICA
SANDIA/GM STUDY:
BIOMASS FOR 90B GALLONS OF ETHANOL

2030 Land Use
- 44 M acres cropland as pasture and idle cropland
- 44 M acres non-grazed forest land
- No land use change for residues
- Equals 2006 corn ethanol acreage
FUTURE FLEX-FUEL VEHICLES ...
DIRECT-INJECTED AND TURBO ENGINES
FUEL ECONOMY POTENTIAL

% Gain in Cycle Average Fuel Economy

Upper Bound – Base Engine

Near Term
- 1-3%
- 2-4%
- 3-5%
- 6-8%
- 7-9%

Future
- 5-7%
- 8-12%
- 8-12%
- 12-15%

Upper Bound – Powertrain

Regenerative Braking
Stop-Start

Reduced Friction & Improved Thermal Management

Cam Phasing
PDA w/ High EGR
2-Step VVA w/ Phaser
Cylinder Deactivation (AFM)
Boosted, Downsized
Flexible VVA (Lift & Phasing)
Fully Flexible Valve Actuation
DI Stratified-Charged w/NOx Trap
Advanced DI/HCCI Concepts
GM VEHICLE ELECTRIFICATION STRATEGY
PORTFOLIO OF SOLUTIONS FOR FULL RANGE OF VEHICLES THAT PROVIDE CUSTOMER CHOICE

Petroleum and Biofuels (Conventional and Alternative Sources)

Electricity – ZEV Fuel

GM Hybrid 2-Mode 2-Mode PHEV Extended-Range EV Battery Electric Fuel Cell

Electrification
EXTENDED-RANGE ELECTRIC VEHICLE WITH FLEX-FUEL CAPABILITY

40 MILES GAS-FREE
Electricity: An important energy source with significant capacity to support transportation. 10 million Volts would add a load that is less than 1% of the current total grid load.
PROJECT DRIVEWAY

PRODUCTION-INTENT FUEL CELL SYSTEM

5,000 ORDINARY DRIVERS

1,400,000 MILES LOGGED
U.S. INFRASTRUCTURE DEVELOPMENT FOR FIRST MILLION FCEVs

- $10-15B investment would establish network of 11,700 stations
  - Top 100 urban areas
  - 130,000 miles of highway
SUMMARY

- Advanced propulsion technologies focused on both energy efficiency and energy diversity
- There is no single solution
- Our strategy is:
  - Continued improvement of conventional powertrains
  - More vehicles with biofuels capability
  - Increased electrification of the automobile