eAssist™ to EREV

Electrification Technologies for 2011

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PETROLEUM SUPPLIES...

35% OF WORLD'S ENERGY

96% OF TRANSPORTATION ENERGY
64 mb/d of gross capacity needs to be installed between 2007 & 2030 – Six times the current capacity of Saudi Arabia
Improve Vehicle Fuel Economy and Emissions

Displace Petroleum

Hydrogen Fuel Cell-Electric Vehicles

Battery-Electric Vehicles (including E-REV)

Hybrid-Electric Vehicles (including Plug-in HEV)

IC Engine and Transmission Improvements

Petroleum (Conventional and Alternative Sources)

Alternative Fuels (Ethanol, Biodiesel, CNG, LPG)

Electricity (Conv. and Alternative Sources)

Hydrogen

Energy Diversity

ADVANCED PROPULSION TECHNOLOGY STRATEGY
ENERGY CONSERVATION AND DISPLACEMENT
USING ELECTRIFICATION TECHNOLOGIES TO REDUCE CONSUMPTION AND DISPLACE PETROLEUM

Petroleum and Biofuels
(Conventional and Alternative Sources)

Increasingly Electrified Powertrains

Electricity and Hydrogen
(Zero Emissions Energy Sources)

eAssist™
Full Hybrid

Plug-in Hybrid
Extended Range Electric
Battery Electric
Fuel Cell Electric

CONSERVATION

DISPLACEMENT
HYBRIDIZATION

eAssist™ – Technology to Watch in 2011

Hybridization
• EV Operation
• Load Shifting
• Regeneration
• Stop/Start

Improvements in Conventional Powertrain

Technology Implementation

Conventional Upper Bound

Hybridization Upper Bound

Efficiency

Chevrolet Tahoe Hybrid
Chevrolet Silverado Hybrid
Toyota Prius IV
Ford Fusion
Buick LaCrosse eAssist™
Honda Insight
Opel Astra
Volkswagen Passat Bluemotion
LaCROSSE SEDAN WITH eASSIST™

EPA Estimated Label FE (MPG): 25 City/36 Highway
REGAL SEDAN WITH eASSIST™
Consumption reduction at the lowest cost

- Engine idle stop – and smooth starts
- Lower power regeneration (15kW)
- Grade based assist (10kW, 50Nm)
- Reduced engine and driveline losses
- Selected aero improvements
- Low rolling resistance tires

Base powertrain in the 2012 Buick LaCrosse

- Optional on Regal, Alpheon (Korea), LaCrosse (China)
Efficiency

Conventional Upper Bound

Hybridization Upper Bound

Hybridization
- EV Operation
- Load Shifting
- Regeneration
- Stop/Start

Improvements in Conventional Powertrain

Technology Implementation

Displace Petroleum
- Grid connection

- ELECTRIFICATION

- Buick LaCrosse eAssist™
- Toyota Prius IV
- Ford Fusion
- Chevrolet Volt

- Chevrolet Tahoe Hybrid
- Chevrolet Silverado Hybrid
- Honda Insight
- Opel Astra
- Volkswagen Passat Bluemotion

- BEV

REAL WORLD EV DRIVING RANGE

STRONG FUNCTION OF INTENSITY AND AMBIENT TEMPERATURE

FTP City
No HVAC, No Accessories
(Light Driving, Optimal HVAC Condition)

LA92
HVAC Set @ 22° C (Nominal Driving, Comfort HVAC Condition)

U.S. City Driving for MOST Customers

YOUR EV RANGE WILL VARY – A LOT !!
Typical Daily Commute - U.S.

Use Commuting Fuel

- 78% of customers commute 40 miles or less daily.

Bar chart showing the distribution of commuting miles:
- 29% commute 2-10 miles daily.
- 22% commute 12-20 miles daily.
- 17% commute 22-30 miles daily.
- 10% commute 32-40 miles daily.
- 7% commute 42-50 miles daily.
- 5% commute 52-60 miles daily.
- 3% commute 62-70 miles daily.
- 8% commute more than 70 miles daily.

Based on OmniStats Data posted by the U.S. Bureau of Transportation.
## Creating a New Propulsion Category

<table>
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<tr>
<th>HEV</th>
<th>Electric Vehicle</th>
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<tr>
<td>Hybrid Electric Vehicle</td>
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<td>Petroleum</td>
<td>Electricity + Petroleum</td>
<td>Electricity: Limited Range</td>
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EXTENDED-RANGE Electric Vehicle

VOLT

25–50 miles BATTERY Electric Driving + HUNDREDS of miles EXTENDED RANGE Driving
EV driving characteristics

- 111 kW EV power
- 100 mph top speed
- EV responsiveness

Acceleration

- 0–60 mph in about 9 seconds

Extended range

- >300 ER miles eliminates “range anxiety”
- Smooth transitions
- EV feel preserved even in ER driving
ELECTRIFICATION EFFECTIVENESS

“100 MILE” BEV VEHICLE UTILITY FOR 90% OF ALL U.S. DRIVING DAYS

323 days
EV Driving
Without Stress

12 days
EV Driving
With Stress

30 days
Use a Second Car or...
Get Stranded

2010 Internal GM dataset
• >100k daily drives
• 4 seasons
• 50% percentile driver
• U.S. “real world”
• Charging available at home
ELECTRIFICATION EFFECTIVENESS

“40 MILE” EREV VEHICLE UTILITY FOR 100% OF ALL U.S. DRIVING DAYS

- 315 days EV Driving Without Stress
- 50 days EV Driving Followed by Petroleum Without Stress

2010 Internal GM dataset
- >100k daily drives
- 4 seasons
- 50% percentile driver
- U.S. “real world”
- Charging available at home
“40 MILE” EREV ACTUALLY DISPLACES MORE PETROLEUM THAN “100 MILE” BEV IN THE U.S.

Economics of Electrification Effectiveness:

- Batteries need to be highly utilized
- EREV's more fully utilize a smaller battery
  - Full EV capability for most commuting
  - Full utility for the unexpected…

2010 Internal GM dataset
- >100k daily drives
- 4 seasons
- 50% percentile driver
- U.S. “real world”
- Charging available at home
TECHNOLOGY in TRANSITION

A PERIOD OF TRANSITION WITH COMBINED ELECTRICITY AND LIQUID FUELS
HAPPENING NOW – IN 2011

Petroleum and Biofuels
(Conventional and Alternative Sources)

Electricity
(Zero Emissions Energy Sources)

Era of Liquid Fuels

Era of Transition

Era of Electricity

eAssist™ coming in 2011

EREV – In Production Now
Electrification technologies for 2011

- eAssist™
  - Lower cost, practical efficiency extension of base powertrains
  - 2012 Buick LaCrosse — 37MPG Highway

- EREV
  - Practical petroleum displacement
  - 2011 Chevrolet Volt — 25–50 miles EV range

Factors for EREV and BEVs in path to energy diversity

- Customer expectations for vehicle utility
  - No compromise of vehicle utility with eAssist™, HEVs, EREV
  - EREV can practically displace more petroleum than BEVs

- Economics of durable energy storage in petroleum/electricity
Electrification Has Changed GM

“Beginning in 2011, General Motors will add 1,000 engineers and researchers...

...over the next two years to significantly expand its vehicle electrification expertise to lead in the development of electric vehicles from hybrids to electric vehicles with extended-range capability, like the 2011 Chevrolet Volt.”

– Dan Akerson, GM Chairman and CEO

- New skill sets
- New academic curricula
- New ENTHUSIAM for one of the biggest global growth industries
INVESTING IN MICHIGAN’S GREEN ECONOMY

- Detroit–Hamtramck: $336M – Volt Assembly Plant
- Flint Engine South: $286M – Engines
- Brownstown Township: $43M – Battery Assembly Facility
- Bay City: $62M – Cam Shafts and Connecting Rods
- Grand Blanc: $30M – Tooling
- Warren: $27M – Battery Systems Lab
- Flint Tool & Die: $23M – Stamping
- Flint Metal: $2M – Stamping

$809 MILLION
THANK YOU!