LONG-TERM TRENDS in PERSONAL MOBILITY

Ian Sutherland
Energy Systems Research, GM Global R&D Laboratories
- Light-duty vehicle stock projected to grow 140% to 2 billion vehicles by 2050
- Significant potential for further growth as global population reaches 9 billion in 2050
GLOBAL PRIMARY ENERGY CONSUMPTION

Transportation: 19.1%
Industry: 12.9%
Residential/Commercial: 30.1%
Electric Utility: 37.9%

Data Source: IEA World Energy Outlook 2009
Petroleum proved reserves growing – currently 54 years’ consumption – OK for now

Not distributed equally on geographic basis, but easily transported barring conflict

Increasing prices, security of supply, GHG emissions, and urban air quality concerns driving

Vehicle efficiency improvements – use less fuel per mile traveled

Gradual shift away from oil – diversify with biofuels, natural gas, grid electricity, hydrogen

Source: BP Statistical Review of World Energy June 2012
FULL RANGE OF TECHNOLOGY DRIVERS

- Regulatory Demands
- Energy Security
- Climate Change
- Customer Requirements
- Fuel Prices
- Technology Innovation

AUTOMOBILE INDUSTRY
GM ADVANCED PROPULSION TECHNOLOGY STRATEGY

- **Energy Diversity**
  - Petroleum (Conventional and Alternative Sources)
  - Alternative Fuels (Ethanol, Biodiesel, CNG, LPG)
  - Electricity (Conv. and Alternative Sources)
  - Hydrogen

- **IC Engine and Transmission Improvements**
- **Hybrid-Electric Vehicles (including Plug-in HEV)**
- **Battery-Electric Vehicles (including EREV)**
- **Hydrogen Fuel Cell-Electric Vehicles**

- **Improve Vehicle Fuel Economy and Emissions**
- **Displace Petroleum**

**Time**
ENERGY DIVERSITY
ETHANOL

>9 MILLION
GM FlexFuel Vehicles
Worldwide
ENERGY DIVERSITY
CNG AND LPG
- 10 CNG and 18 LPG global applications
- Domestic fuel source
- 15-25% CO₂ reduction
Lightweight materials can provide 35-60% weight reduction compared to steel.
DIE CAST MAGNESIUM ENGINE CRADLE

- One piece; first in industry
- 10.4 kg; 35% weight reduction compared to aluminum

AE44 Alloy

Aluminum Isolation Washers for Cradle-to-Body Attachment

2006 International Magnesium Association Application Award
MULTI-MATERIAL BODY – THE FUTURE

Mg-Intensive Front-end

Steel: 79 Parts; 84 kg
Mg: 35 Parts; 46 kg
(Eliminate 44 Parts and Save 38 kg - 45%)

Castings (15): 31 kg
Extrusions (3): 9 kg
Sheet Parts (17): 6 kg

AHSS Passenger Compartment

Composite Floor Pan
GM WELDING PROCESS MAY HELP IMPROVE FUEL ECONOMY
GM AL RSW TECHNOLOGY

- GM patented process to provide ridge texture breaks thru oxide
  - Both electrode/sheet interfaces have consistent, low contact resistance
- Production compatible dressing process
  - Macro-featured electrode – ridges, grooves, terraces

![Ridges on electrode](image1)
![Ridge impression in sheet](image2)
![Ridge close-up](image3)

![Ideal Aluminum RSW](image4)
IMPROVING GASOLINE ENGINES
INCREASING FUEL ECONOMY WHILE REDUCING EMISSIONS

Base Engine Technologies

- Modular & Flexible Architectures
- Reduced Mass
- Improved Combustion Technology
- Integration of Leading-edge Technologies

Spark Ignition Direct Injection
Cam Phasing, Variable Valve Lift, Active Fuel Management
Downsized SIDI Turbo Boosting
Advanced Combustion
eASSIST™

Standard on LaCrosse

25 City/36 Hwy MPG
38 Miles Battery Electric Driving

+ 342 Miles Extended Range Driving
VOLTEC PROPULSION SYSTEM

- 288-Cell, 16-kWh Battery
- DC Cables
- 1.4L Engine
- Fuel Tank
- AC Cables
- Half Shafts
- Power Inverter
- 111-kW (149-hp) 2-Motor Electric Drive Unit
Coaxial Drive Unit features a GM-designed, oil-cooled, permanent magnet motor
WHAT IF BATTERY IMPROVEMENTS DON’T GO FAR ENOUGH?

PRODUCTION-INTENT FUEL CELL SYSTEM

6,000 ORDINARY DRIVERS

>2,500,000 MILES LOGGED
CARS THAT DON’T CRASH

VEHICLES THAT DRIVE THEMSELVES
### SAFETY AND CRASH AVOIDANCE TECHNOLOGIES

<table>
<thead>
<tr>
<th><strong>Lane Departure Warning (LDW)</strong></th>
<th><strong>Side Blind-Zone Alert</strong></th>
<th><strong>Dual Feature Front Camera:</strong> Lane Departure Warning and Forward Collision Alert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadillac DTS</td>
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<td>Chevrolet Equinox</td>
</tr>
<tr>
<td>Cadillac STS</td>
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<td>GMC Terrain</td>
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<tr>
<td>Buick Lucerne</td>
<td>Cadillac Escalade</td>
<td>Opel Zafira</td>
</tr>
</tbody>
</table>

**LDW w/Traffic Sign Recognition**

- **Opel Eye**
  - Opel Insignia
  - Opel Astra
  - *Opel*: Logo

**Speed/Curve Advisor**

- Cadillac STS
- Cadillac DTS
- Cadillac SRX
- *Chevrolet*: Logo
- *GMC*: Logo

**Rear Vision Camera**

- Many Models
- *Chevrolet*: Logo
- *GMC*: Logo

**Electronic Stability Control**

- Many Models
- *Chevrolet*: Logo
- *GMC*: Logo

**Adaptive Cruise Control w/Forward Collision Alert**

- Cadillac DTS
- Cadillac STS
- *Chevrolet*: Logo
- *GMC*: Logo

**Adaptive Cruise Control and Auto Collision Mitigation Braking**

- Opel Zafira

**Side Blind-Zone Spotter Mirror**

- Chevrolet Traverse
- *Chevrolet*: Logo
- *GMC*: Logo

**Other Technologies**

- **Rear Vision Camera**
- **Electronic Stability Control**
- **Lane Departure Warning (LDW)**
- **LDW w/Traffic Sign Recognition**
- **Speed/Curve Advisor**
- **Adaptive Cruise Control w/Forward Collision Alert**
- **Adaptive Cruise Control and Auto Collision Mitigation Braking**
- **Side Blind-Zone Alert**
- **Side Blind-Zone Spotter Mirror**

The image provides a comprehensive overview of various safety and crash avoidance technologies offered in different models of vehicles.
WHAT WE NEED

- Energy security
- Clean environment (CO$_2$)
- Economic prosperity