A View from Ford

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Ford in 2006

A year of transition

• Lost $12.7B
• US market share fell to 16.4%
• Reducing salaried workforce up to 30%
• 35,000 union employees took buyouts
• Secured $18B loan collateralized using plants and intellectual property

• Hired Alan Mulally from Boeing as CEO
• Fusion/Milan/Zephyr received Consumer Reports highest predicted reliability score, over Toyota Camry and Honda Accord
• Fusion, Mustang atop JD Power APEAL ratings
• Launched the Ford Edge
The US and Global Auto Industry

**Business Factors**

- Globalization
- Manufacturing overcapacity
- Pressure on margins
- Commodity costs
- ‘Legacy’ costs
- Supplier instability and consolidation
The US and Global Auto Industry

Technical Challenges

• Energy Security/Fuel Efficiency
• Climate Change/CO₂
• Emissions
• Safety
• Performance
• Market Segmentation
• Cost!

Response to these challenges takes many forms

Clean Diesels
Gas-Electric Hybrids
Fuel Cell Vehicles
Challenges

Impact of Energy Security

- Crude oil and fuel price has been generally high and volatile since 2002.

- US consumers have responded to fuel prices by beginning to shift from SUVs and trucks to smaller, more fuel-efficient cars.
Challenges

**Hybrid-electric vehicle sales**

- Shift to fuel-efficient vehicles is not uniform and homogeneous
- Hybrids: early adopters


PJ Lamberson, University of Michigan
**Challenges**

**CO2 Emissions**

- Light-duty vehicles contribute 20% of US CO2 emissions, 17% in EU
- US transportation associated with ~ 6% of world CO2
- Many sectors play a role
- New car share is small initially -- time is required for improvements to accumulate
CO2 and Climate Change

- Growing recognition of reality and significance of climate change
- In our own industry, scenario planning reflects the magnitude of the challenge
  - A TTW CO2 of 75 g/km corresponds to a fuel economy of 72 mpg
- Achieving significant fossil CO2 reductions in the transport sector is benefited by combinations of vehicle efficiency and fuel substitution actions
Future Transportation Energy

Fuel and Powertrain Diversity

Powertrains

- Internal combustion engine
- (Hybrid) electric
- Fuel cell

Fuels

- Gasoline
- Diesel
- Natural Gas
- Ethanol, Biodiesel
- Electricity
- Advanced Biofuels
- Hydrogen
All Fuels Are Not Created Equal

- Significant factor in vehicle range, package space, and cost
- One of the major obstacles to H2 as a transportation fuel
- Perhaps the major technological hurdle for battery electric vehicles
Future Transportation Energy

Hydrogen Internal Combustion Engine

Potential
• ‘Bridging’ technology could help pave the way for adoption of fuel cells
• Engine modifications enable H2 fueling
• Near zero emissions

Issues
• Range

Airport Shuttle Bus
• 6.8L V-10 Hydrogen Supercharged Engine
• 12 passengers
Future Transportation Energy

Hydrogen Fuel Cell

Potential
• Zero emissions (H2O)
• High efficiency

Issues
• Temperature extremes
• Durability
• Cost

Ford Focus Fuel Cell Fleet
Sacramento, CA – 8
SE Michigan – 8
Vancouver, BC – 5
Orlando, FL – 5
Berlin, Germany – 3
Aachen, Germany – 1
Plug-In Hybrid

Potential
- Extends vehicle range and indicated fuel economy
- Benefits from limited range of typical daily commute
- Shifts some CO2 emissions to power sector

Issues
- Battery weight, cost
- Shifts some CO2 emissions to power sector

HySeries hydrogen fuel cell plug-in hybrid
Future Transportation Energy

Supply Tradeoffs

- **Biomass**: use as fuel feedstock or energy source at power plant?
- **Renewable electricity**: make hydrogen or grid electricity?
- How do emerging technologies (e.g., sequestration) and potential policies (e.g., cap-and-trade, carbon tax) change the outcomes?
Overall Findings

• We are entering an era of **powertrain and fuel diversity**

• **Biofuels** are appealing from both CO2 and energy security perspectives
  
  • How much will be available – and when?

• **Hydrogen** offers very low emissions
  
  • Storage, production, and distribution are significant challenges

• **Electric vehicles** can provide good performance and low WTW emissions
  
  • Hindered by battery technology and charging physics

• There is a real **opportunity** to:
  
  • Help us **understand the risks** and hedges associated with these diverse choices
  
  • Identify how **cross-sector tradeoffs and interactions** may affect the fuel landscape
  
  • Understand how most efficiently to realize **energy security and CO2 goals**
A View From Ford

Questions
Ford Research and Advanced Engineering

People

Competency
• 1,300 people
• 1/3 each PhD, Masters, Bachelors

Stability
• R&A average 15 years in position

Diversity
Extremely diverse as measured by nationality, education, culture, and geography
• Projected per-vehicle CO₂ emission reductions starting in 2000 to meet different CO₂ stabilization levels

**Substantial** CO₂ reductions required, e.g., 60% for 550 ppm

⇒ *Fuel substitution, efficiency improvements, other actions*
Gasoline and diesel HEVs using renewable fuels can achieve well-to-wheels CO₂ comparable to fossil-fuel based H₂ FCEVs, but at slightly higher tailpipe emissions.

Emissions/CO₂ tradeoffs differentiate various options.

New infrastructures are required to reach zero CO₂.
Energy Sources: CO$_2$/Cost Tradeoffs

The reference case is gasoline + diesel in the expected demand ratio in 2010.

Source: EUCAR/JRC/CONCAWE WTW Study, 2003
Vehicle Efficiency: Tracking the Energy

- **Fuel - 100**
- **Engine**: 62
  - Combustion Eff.
  - Parasitic Losses
  - Dynamic Range
- **Idle**: 16
  - Engine Control
  - Engine Shutoff
  - Hybridization
- **Accessories**: 2
  - A/C Cycle
  - High-Eff Alt.
  - Electrical Acc.
- **Drivetrain**: 6
  - Parasitic Losses
  - Dynamic Range
- **Inertia**: 8
  - Hybridization
  - Weight Reduction
- **Braking**: 8
  - Low-Rolling Tires
  - Weight Reduction
- **Rolling**: 3
  - Aero Drag
  - Frontal Area
After Diana Brehob, Lorelei Muñiz, Tom Kenney, Ford Motor Company

⇒ Incremental improvements to existing technology still effective and important!
Fuel and Powertrain Diversity

- Gasoline
  - Ethanol blends up to 10%
- Diesel
  - Biodiesel blends up to 5%
- Ethanol (E85)
- Second-Generation Biofuels
  - Lignocellulosic
  - Higher alcohols
- Electricity
  - Plug-in hybrids
  - Battery electrics
- Hydrogen
  - Internal combustion engines
  - Fuel cells
### Our Competitor’s Positions

<table>
<thead>
<tr>
<th>OEM</th>
<th>Sustainability</th>
<th>Climate Change</th>
<th>Fuel Economy</th>
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</table>
| **Toyota** | • Global Vision 2010: ideal stance to be adopted for the benefit of people, society, and the global environment.  
• Toyota will continue efforts to contribute to realizing a sustainable society through “making things.”  
• 2010 Vision for Honda - to be recognized as "a company that society wants to exist."  
• Honda believes there is no single solution to America’s future energy needs. Advanced technologies and alternative fuels (biofuels [ethanol, biodiesel from cellulosics], natural gas, and fuel-cells) will both play a role.  
• 3 Pillars of Sustainability (Ghosn): Corporate Governance, Corporate Citizenship, and Environment.  
• Society urgently demands environmental progress  
• "GM expanding and accelerating commitment to develop electrically driven vehicles, beyond fuel cell and hybrid programs. Remains committed to fuel cell development and continue to make significant progress in this area. Continues to see fuel cells as the best long-term solution for reducing dependence on oil. (2006)  | • "While it is unclear how closely one [earth surface temperature rise] correlates to the other [atmospheric CO2], it would be a mistake not to pay attention."  
• "Honda recognizes global climate change and energy sustainability as the critical environmental challenges of the day …and believes it has a responsibility to reduce greenhouse gas (GHG) emissions…“  
• "CO2 reduction is included as one of the key management performance indicators (along with quality, cost, timing)  
• "We recognize that the concentration of greenhouse gases in the atmosphere is increasing, and we believe there is a constructive way for all stakeholders to move forward together on this issue. The basic challenge is best addressed through voluntary initiatives and market-oriented measures, not government mandates.  
• "GM is committed to increasing fuel economy and reducing emissions, and is an industry leader in applying fuel-saving advanced technologies to high-volume production vehicles. “  | • Second Toyota North American Environmental Action Plan, Goal #1 "achieve best-in-class fuel efficiency performance."  
• 2010 Target - Improve CAFE in US by 5% from 2005 levels  
• "Internal combustion engines will remain the primary power source for mobility at least until around 2020 and we think it critically important to improve their efficiency and fuel economy."  
• "Nissan Green Program 2010" will increase fuel economy starting from 2010; internal aim to reduce CO2 emissions by 40% over 10 years.  |
Sustainability

Meanings and Implications for Our Business

- Economic
- Social
- Environmental
  - Beginning of Life
    - Energy
    - Emissions
  - End of Life
    - Energy
    - Emissions
- In Use
  - Energy
  - Emissions
    - Criteria Pollutants
    - CO2
Sustainability Drivers

**Life-Cycle CO2**

• In-use phase dominates life-cycle CO2 emissions of vehicles

<table>
<thead>
<tr>
<th>Life cycle CO₂ Impact (tonnes) for mid-size car</th>
<th>Tonnes</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material production (steel, aluminum, plastics, …)</td>
<td>3.5</td>
<td>5.7%</td>
</tr>
<tr>
<td>Ford manufacturing/assembly</td>
<td>2.5</td>
<td>4.0%</td>
</tr>
<tr>
<td>Manufacturing logistics (inbound/outbound)</td>
<td>0.1</td>
<td>0.2%</td>
</tr>
<tr>
<td>Fuel (120,000 miles at 22.9 mpg) WTW</td>
<td>55.1</td>
<td>88.9%</td>
</tr>
<tr>
<td>Maintenance and repair</td>
<td>0.6</td>
<td>1.0%</td>
</tr>
<tr>
<td>End of life/recycling</td>
<td>0.1</td>
<td>0.2%</td>
</tr>
<tr>
<td>Total Lifecycle</td>
<td>61.9</td>
<td>100%</td>
</tr>
</tbody>
</table>
Sustainability Drivers

CO2 and Climate Change
LDV Fleet WTW CO$_2$ Emissions for 550-ppm Stabilization
LDV Fleet WTW CO₂ Emissions for 450-ppm Stabilization

- Africa
- Latin America
- Middle East
- India
- Other Asia
- China
- Eastern Europe
- FSU
- OECD Pacific
- OECD Europe
- OECD North America
Emissions, concentrations, and temperature changes corresponding to different stabilization levels for CO₂ concentrations.
550 may not be sufficient to keep temp increase to