Vehicle Technology Prospects and Challenges

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American Honda Motor Co.

USAEE
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3 Issues for the Future Automobile:

- Energy Supply & Demand Sustainability
- Climate Change
- Urban Air Quality
Transportation’s Social Issues

Key Issues

- Energy Sustainability
- Climate Change
- Air Pollution

Power train progress for CO2 reduction

- FCV Fleet test
- HEV expansion
- FCV development for future
- Clean diesel
- High efficient gasoline engine
- Base engine improvement
- Research for mass production

- V6
- VTEC
- i-DSI
- i-VTEC
- Diesel
- Gasoline
- Cylinder deactivation
- Accord
- Insight
- Civic
- MA
- I-MA
Clean & Fuel Efficient
I.C.E. Power Plants

Honda is Committed to Clean and Efficient Gasoline Vehicles

- Technically advanced F.E. leading models in the market
- Popular mass-market models with continual efficiency improvement
- Highest CAFE of major OEMs
**Wide FE Technology Application**

2003 Model Year Data from the 2003 FE Trends Report, US EPA

![Graph showing fuel efficiency (MPG) by vehicle type and model year.](image)

*Odyssey is larger and heavier than average mid-size van: 4500 ETW versus 4345*

**Honda VTEC Combustion:**

- HIGHER EFFICIENCY
- LOWER EMISSIONS
- GREATER PERFORMANCE

![Diagram of Honda VTEC combustion system.](image)
**i-VTEC Engine**

Intelligent Valve Timing Control

**Performance w/o Compromise**

- Increased Power: 160 hp
- Increased Fuel Efficiency (AT): 24/33 city/highway mpg
- Reduced Emissions: LEV II: LEV & SULEV

More Power, Lower Fuel Consumption, and Near Zero Emissions
New Generation of Engine Technologies

Engineering Concept

- Improvement of Volumetric Efficiency
- Combustion Efficiency & Combustion Control
- Reduction of Pumping Loss
- Reduction of Friction
- Lightweight & Compact

Lean Burn Technologies

VTEC Cylinder Idling

CR-V Full Model Change - 2002

<table>
<thead>
<tr>
<th>Attributes/Model</th>
<th>2001</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETW (lbs) AT 2WD</td>
<td>3375</td>
<td>3500</td>
</tr>
<tr>
<td>Range (MT, 4WD)</td>
<td>3375-3500</td>
<td>3500-3625</td>
</tr>
<tr>
<td>Length</td>
<td>178</td>
<td>179</td>
</tr>
<tr>
<td>Width</td>
<td>69</td>
<td>70</td>
</tr>
<tr>
<td>Height</td>
<td>66</td>
<td>66</td>
</tr>
<tr>
<td>Passenger vol</td>
<td>98</td>
<td>106</td>
</tr>
<tr>
<td>Cargo vol</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>Towing capacity</td>
<td>1000</td>
<td>1500</td>
</tr>
<tr>
<td>Engine size (L)</td>
<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Horsepower@rpm</td>
<td>146@6200</td>
<td>160@6000</td>
</tr>
<tr>
<td>Torque (ft-lb)@rpm</td>
<td>133@4500</td>
<td>162@3600</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>9.6:1</td>
<td>9.6:1</td>
</tr>
<tr>
<td>FE AT 2WD</td>
<td>22/25</td>
<td>23/28</td>
</tr>
<tr>
<td>AT 4WD</td>
<td>22/25</td>
<td>22/26</td>
</tr>
<tr>
<td>MT 2WD</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>MT 4WD</td>
<td>22/25</td>
<td>21/25</td>
</tr>
</tbody>
</table>

- Interior volume: + 9%
- Weight: +4%
- Displacement: +20%
- Horsepower: +10%
- Torque: +22%
- Towing capacity: +50%
- Fuel Economy: + 3-4%
VTEC VCM valve train

Variable Cylinder Management

Vehicle speed

Accel

Cruise

Decel

6 Cylinder operation

3 Cylinder operation
VCM Development Sequence

- 2003 Civic IMA (hybrid)
  - Used similar mechanism for cylinder deactivation on deceleration
- 2003 Inspire for Japanese market
- 2004 New mini van for Japanese market
- U.S. Honda light truck model for 2005 model year
- 2005 Accord IMA (hybrid)

Transmission Advances

- Computer controls are enabling a variety of improved transmission designs
  - Improved shift points and lock-up strategies
  - Lapillier 6-speed automatic
  - Dual-clutch automated manual
  - Continuously Variable Transmission (CVT)
- Not yet clear which is most cost effective, but efficiency improvements of at least 5 percent are likely
Incremental FE Technology

- **Engine technology**
  - High specific output (including 4 valve/cylinder)
  - Variable valve timing/lift
  - Cylinder deactivation
  - Direct injection
  - Precise air/fuel metering
- **Transmission efficiency**
  - 5/6 speed-AT/6-speed MT
  - CVT
  - Dual-clutch automated MT
- **Reduced losses**
  - Lightweight materials
  - Low drag coefficient
  - Low resistance tires
  - Lower accessory losses

**Cost and value issue**
- These technologies are continuously being incorporated into vehicles.
- However, consumers value other attributes more highly, such as performance, safety, utility, and luxury.
- Putting in technologies just to improve fuel economy may not be valued by customers.

Fuel Economy Improvement - ???
Depends on how much is already incorporated into fleet and synergies (or lack of synergy) between technologies.

Hybrid Vehicles

- Electric Motor
- Efficient hybrid engine
- CVT
- Intelligent Power Unit (IPU)
Integrated Motor Assist Hybrid
(Honda Civic Hybrid)

Parallel - Type

- Relatively Simple, Lightweight & Compact
- Efficient in City and Highway driving

Engine and Motor Output Characteristics

CIVIC HYBRID

High Efficiency, High Torque Electric Motor

116 lb-ft (Engine + Motor Assist)
87 lb-ft (1.3L Engine only)
93 HP
Hybrids: Who is the buyer?

Customer Profile

Innovator

Early Adopter

Early Majority

Majority

Hanger-On

Insight-Prius-Civic

Attractive Hybrid Features

Integrated Electric Motor

Best “Idle” Quality: Beats any Luxury Car!

Superior Driving Range: Fewer Trips to the Station!

Low Operating Cost: Fuel Savings!

Pride of Ownership: Social Benefits!
Future Hybrid Cost Reduction?

Barriers to Achieving Potential Fuel Economy Increases

- Tradeoff with other attributes
- Declining fuel cost
- Consumers versus society
Since 1987:

- Car CAFE up 0.9 mpg, light truck CAFE down 0.8 mpg
- LDT market share increased from 28% to 48%
- Combined CAFE decreased by 1.5 mpg

Effect of Attribute Tradeoffs - Cars

Fuel efficiency has increased by about 1.5% per year since 1987
However, this has all been used to increase other attributes more highly valued by the customer, such as performance, comfort, utility, and safety
Effect of Attribute Tradeoffs - LDT

Light Truck Data from EPA’s 2003 FE Trends Report

Fuel efficiency has increased by about 1.9% per year since 1987. However, this has all been used to increase other attributes more highly valued by the customer, such as performance, comfort, utility, and safety.

Real Gasoline Price

Motor Gasoline Regular Retail Prices, U.S. City Average, adjusted using CPI-U
Fleet Fuel Economy

Real Gasoline Prices and In-Use Fleet MPG
(2004 $ per gallon)

Gasoline Cost per Mile

Real Gasoline Cost for Cars - Cents per Mile
(2004 $ per gallon)
Real Fuel Cost - % of Disposable Income

Per Capita Disposable Income from BEA, Table 2.1, Personal Income and Its Disposition

Willingness to Pay for FE

J.D. Power Hybrid Vehicle Acceptance Study
March 6, 2002 Press Release

- Consumer interest in hybrid vehicles increases as gasoline prices rise
- 30% of buyers would “definitely” consider - another 30% indicate a strong consideration
- Of these, 1/3 would buy even if fuel cost savings during their ownership period would be less than the extra cost of the hybrid option

2/3 would not pay more than fuel savings during ownership period
Customer Value of Hybrid Fuel Savings
(Savings for the first 50,000 miles @ U.S.$1.80/gallon)

<table>
<thead>
<tr>
<th>Hybrid fuel economy increase</th>
<th>Small car</th>
<th>Midsize car</th>
<th>Large truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 20%</td>
<td>$441</td>
<td>$652</td>
<td>$1,071</td>
</tr>
<tr>
<td>+ 40%</td>
<td>$756</td>
<td>$1,118</td>
<td>$1,837</td>
</tr>
<tr>
<td>+ 80%</td>
<td>$1,176</td>
<td>$1,739</td>
<td>$2,857</td>
</tr>
</tbody>
</table>

J.D. Power survey on hybrids found that “Consumers indicate a willingness to pay more – $1,000 to $1,500 – for a hybrid powertrain…”

Technology Conclusions

- Technology is available to improve fuel economy
- Challenge is customer’s low value of fuel economy
  - Real cost of driving very low
  - Other attributes (performance, utility, comfort, safety) valued more highly
  - Most customers only consider fuel savings during their period of ownership
- Hybrid technology is being widely promoted and is progressing rapidly
  - J.D. Power predicts over 20 hybrid vehicle models and sales of about 350,000 per year in 2008 (Oct 2003)
  - Cost is the key issue to be solved in order to sell to the mainstream mass market