Advanced Technologies at Toyota

Clean Air Act Advisory Committee

September 18, 2008

Tom Stricker
Toyota Motor North America
Topics

- Market Overview and Factors
- Deploying New Technology
- Hybrid
- Plug-In Hybrid
- Fuel Cell
- Conclusions
US Industry January-July Sales

'07/'08 Volume Decrease: 1,006,734 Units

2007: 9,554,500
2008: 8,547,700

Source: July Industry Report, (combined sales, include Hawaii)
# New Vehicle Segment Shifts

**July CYTD Sales versus Year Ago**

<table>
<thead>
<tr>
<th>Segment</th>
<th>% DSR Chg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>-11%</td>
</tr>
<tr>
<td>Total Lt Truck</td>
<td>-19.5%</td>
</tr>
<tr>
<td>Total Psgr Car</td>
<td>-2.2%</td>
</tr>
<tr>
<td>Entry</td>
<td>33.7%</td>
</tr>
<tr>
<td>Subcompact</td>
<td>5.1%</td>
</tr>
<tr>
<td>Standard Mid</td>
<td>-1.7%</td>
</tr>
<tr>
<td>Small SUV</td>
<td>-4%</td>
</tr>
<tr>
<td>Van</td>
<td>-17.7%</td>
</tr>
<tr>
<td>Small PU</td>
<td>-17.9%</td>
</tr>
<tr>
<td>Mid SUV</td>
<td>-24.6%</td>
</tr>
<tr>
<td>FSPU</td>
<td>-25.3%</td>
</tr>
<tr>
<td>Premium Mid</td>
<td>-27.2%</td>
</tr>
<tr>
<td>Large SUV</td>
<td>-30.7%</td>
</tr>
<tr>
<td>Sports Coupe</td>
<td>-25.7%</td>
</tr>
<tr>
<td>Near Luxury</td>
<td>-7.6%</td>
</tr>
<tr>
<td>Large SUV</td>
<td>-30.7%</td>
</tr>
</tbody>
</table>
Short-Term Factors

http://tonto.eia.doe.gov/dnav/pet/pet_pri_gnd_a_epmr_pte_cpgal_m.htm
Longer-Term Issues Driving Change in Business

1. Energy & Fuel Diversification
2. CO₂ Reduction
3. Air Quality
4. Urban Congestion

All affect Auto Industry

Global development of industry and technology in the 21st century
Accelerated consumption of fossil fuels
Population growth
Growing number of motor vehicles
The Automobile Challenge

1. Balance reduction of environmental impact with meeting consumer wants
   - *It doesn’t matter how “green” a product is if no one will buy it*

2. Mass market appeal
   - *Must sell millions to make real impact*

3. Life Cycle Assessment
   - *Must look beyond “tailpipe” for true environmental impact*
Toyota’s Multi-Path Approach

Issues

- CO₂ Reduction
- Energy Diversification
- Reduced Emissions
- Urban Congestion

Sustainable Products

Hybrid Technology

- Alternative fuel HV
- Diesel HV
- D-4
- Lean burn
- VVT-i

- Biofuels
- Synthetic fuels
- CNG
- Common rail DI

- FCHV
- Plug-in HV
- HSD

- DPNR

- Electrical energy
- Gasoline engines
- Diesel engines
- Alternative fuel engines

Reduced Emissions
Energy Diversification
Urban Congestion
CO₂ Reduction

Hybrid Technology

Toyota’s Multi-Path Approach

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Urban Congestion
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Hybrid Technology
Typical Cycle

Gen 1
Year 1

Base FE

Year 2
Minor mods.

Gen 2
Year 6

Gen 1 + \( \triangle \) %

4% CAFE Scenario

Gen 1
Year 1

Base FE

Year 2
Minor mods.

22% improvement at each generation requires major modifications in mid-cycle (substantially higher cost) and/or multiple technologies at each new redesign

Cost and product cycles cannot be separated. NAS costs (and others) assume normal product cycles.

Year 3
Major mods.?

Year 4

Year 5

Gen 1 + 22%
Technology Takes Time to Penetrate

2007 EPA Automotive Fuel Economy Trends Report
Table 9 - Powertrain Characteristics of 1975 to 2007 Cars and Trucks (Percentage Basis)

% New Vehicle Fleet

Model Year

- FWD
- Lock-Up A/T
- CVT
- PFI
- Multi-Valve
- VVT
- Hybrid
Toyota Hybrid Development

80 Hybrid Designs
- Fuel Economy
- Emissions
- Technical Feasibility
- Cost

Hybrid Synergy Drive

Engine
Generator
Battery
Motor

1998 Prius
Toyota’s Line of Hybrids in America

**TOYOTA MODELS**

- **Prius**
  - Midsize 5 Door

- **Camry Hybrid**
  - Midsize 5 Door

- **Highlander Hybrid**
  - Midsize SUV

**LEXUS MODELS**

- **RX400h**
  - Luxury SUV

- **GS450h**
  - Premium Sport Sedan

- **LS600h**
  - Flagship

Combined US sales averaging over 23,000 / month in 2008
A Million & Half Hybrids Sold & Growing

Cumulative Hybrid Sales thru July 2008

Energy Benefits to Date*
- 660 Million gallons of gasoline saved
- 13.1 Billion lbs of CO2 emissions avoided

US Sales 900,000
Global Sales 1,500,000

*Toyota Estimate
Hybrid as a Foundation

- Toyota’s Hybrid Synergy Drive is the powertrain foundation for next generation technologies
  - Flexibility
  - Reduced development time & cost
  - Lower cost higher volume potential
## Toyota’s Current PHEV Prototype

<table>
<thead>
<tr>
<th>VEHICLE BENEFITS</th>
<th>PROTOTYPE OBJECTIVES</th>
<th>CHALLENGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fuel diversification (energy security)</td>
<td>• Study consumer behavior (US)</td>
<td>• Battery cost &amp; life – key for commercial introduction</td>
</tr>
<tr>
<td>• Potential greenhouse gas reduction</td>
<td>• Study public charging (Europe)</td>
<td>• Packaging</td>
</tr>
<tr>
<td>• Reduced fuel cost</td>
<td>• Demonstrate system, not battery capability</td>
<td>• Need for cleaner electricity</td>
</tr>
</tbody>
</table>

![Toyota’s Current PHEV Prototype Diagram](image)
Toyota PHEV Performance Specifications

- **EV Performance (Charge-depleting)**
  - Top speed in EV mode – 62 mph
  - Max EV power ~ 40 kW
  - EV range ~ 7 miles

- **Battery (2 x NiMH)**
  - 2 x 6.5 Ah (13Ah / 2.6kW-hr)
  - 202 V

- **Charging Time**
  - 1-1.5 hr on 220V
  - 3-4 hr on 120V

- **Max system power 100kW (20kw more than Prius)**
2010 – The Next Step

- Toyota has announced our next generation PHEV:
  - Significant numbers beginning in 2010 model year
  - Global program
  - Commercial fleets
  - Li-Ion batteries
    - Manufactured by Panasonic EV (Joint venture with Toyota)
    - Results to help determine suitability for consumer market

- Re-evaluate suitability of battery electric vehicles for consumer market
External Expert Cost Estimate per kWhr

Based on Estimates by M. Anderman

What is the right tradeoff for consumers?
# The Benefit of High Volume Sales

<table>
<thead>
<tr>
<th>Vehicle Number</th>
<th>Baseline</th>
<th>10% HV</th>
<th>20% HV</th>
<th>10% Adv Tech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional gas (25 mpg)</td>
<td>1000</td>
<td>900</td>
<td>800</td>
<td>900</td>
</tr>
<tr>
<td>HV (45 mpg)</td>
<td>100</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adv Tech (90 mpg)</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gallons Saved</td>
<td>N/A</td>
<td>26,667</td>
<td>53,333</td>
<td>43,333</td>
</tr>
</tbody>
</table>

Assumes all vehicles travel 15,000 mi/yr

![Graph showing fuel consumption comparison]

- **Adv Tech**
- **HV**
- **Gas**
Clean Power is Essential

The advantage is big in France where nuclear power generation is common. There is no advantage in China, which mainly uses coal-fired power plants.
### Toyota’s Current Fuel Cell Prototype

<table>
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<th>CHALLENGES</th>
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</thead>
<tbody>
<tr>
<td>Zero tailpipe emissions</td>
<td>Public education on hydrogen</td>
<td>Fuel cell system cost</td>
</tr>
<tr>
<td>Potential non-petroleum, diversified fuel sources</td>
<td>Demonstrate technology</td>
<td>Fuel cell stack life</td>
</tr>
<tr>
<td>Low / zero carbon fuel</td>
<td>Identify infrastructure issues</td>
<td>Lack of infrastructure</td>
</tr>
</tbody>
</table>
Key System Components

Power control unit (PCU)
Controls precisely the distribution of electric power of the fuel cell and secondary battery.

Secondary battery
Stores the regenerative electric power and assists output of the fuel cell at acceleration.

Toyota FC Stack
Unit (fuel cell) that generates electric power from the hydrogen and oxygen in the air.

High-pressure hydrogen tank
Stores the hydrogen supplied to the Toyota FC Stack.

Motor
Generates the driving force of the vehicle.
Steady Improvement

**Compactness / High Power Density**
- Double
- Triple

**Stack Durability**
- ‘05 Model
- Goal

**Cost**
- 1/10 by design / materials
- × 1/10 by mass production

**High & Low Temperature**
- Operating Temperature
  - 105°C
  - -30°C

**Driving Range**
- Double

Next targets

Over 500 miles demonstrated
Conclusions

• Toyota recognizes we must adapt to multiple energy and environmental issues and regulations
• Deploying technology takes time
• Hybrid is the foundation for future vehicle technologies at Toyota - PHEVs & FCs are evolutions
• PHEVs & FCs show environmental & energy security promise, but only if produced in large volumes
• Durability, cost and infrastructure challenges remain for PHEVs and FCs
• Without “green” fuels, the environmental benefit (GHG reduction) of these technologies will be modest at best
Thank You!

Questions?
Corporate Average Fuel Economy (CAFE)
Historical CAFE Standards

- CAR
- TRUCK
Car CAFE Performance

- **Toyota**
- **Industry Average**

<table>
<thead>
<tr>
<th>Year</th>
<th>Toyota MPG</th>
<th>Industry Average MPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>27.0</td>
<td>27.0</td>
</tr>
<tr>
<td>2000</td>
<td>29.0</td>
<td>29.0</td>
</tr>
<tr>
<td>2001</td>
<td>31.0</td>
<td>31.0</td>
</tr>
<tr>
<td>2002</td>
<td>33.0</td>
<td>33.0</td>
</tr>
<tr>
<td>2003</td>
<td>35.0</td>
<td>35.0</td>
</tr>
<tr>
<td>2004</td>
<td>37.0</td>
<td>35.0</td>
</tr>
<tr>
<td>2005</td>
<td>37.0</td>
<td>35.0</td>
</tr>
<tr>
<td>2006</td>
<td>37.0</td>
<td>35.0</td>
</tr>
<tr>
<td>2007</td>
<td>37.0</td>
<td>35.0</td>
</tr>
<tr>
<td>2008</td>
<td>37.0</td>
<td>35.0</td>
</tr>
</tbody>
</table>
Truck CAFE Performance

- Toyota
- Industry Average
Energy Bill (EISA) Requirement

35 mpg (min) combined fleet by 2020

Current Car Std

Current Truck Std

EISA Trajectory

Old CAFE System

- Smaller vehicles provided a benefit
- Concern about small vehicle safety
- Concern about manufacturers with greater number of larger vehicles
Old CAFE System
- Smaller vehicles provided a benefit
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New CAFE System
- Target based on size of vehicle
- Head-to-head fuel economy within each class is more important
- Particular challenge for light trucks
- Technology needed on all size classes
**New CAFE System (2011 model year)**

<table>
<thead>
<tr>
<th>Fuel Economy</th>
<th>Smaller/Lighter</th>
<th>Bigger/Heavier</th>
</tr>
</thead>
<tbody>
<tr>
<td>(+)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(-)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Proposed Size-Based CAFE Targets

MPG Target for Vehicle

WB x TW (tire center @ ground)
Energy Bill (EISA) and NHTSA Proposal

NPRM Combined Standard
Nominal EISA Rate (3.3%)

4.5% / yr
3.3% / yr

MPG


MY
Flex Fuel Vehicle Credit

FFV Credit Phase-Down

Max. MPG Credit

Model Year