Towards Zero Emission Vehicles

ITF Workshop 1:
Advances in Energy-efficient Transport Technologies
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Environmental Affairs Group
Toyota Motor Europe
CO$_2$ emissions by sector

Breakdown of worldwide CO$_2$ emissions sources

Transport accounts for 23% of all man made CO$_2$ emissions. Comprehensive CO$_2$ constraints are needed in each sector.

Source: IEA
Three Major Issues

1. Energy
2. CO$_2$ (global warming measures)
3. Air quality

- Global development of industry & technology in the 21st century
- Accelerated consumption of fossil fuels

- Population growth (in USA, Asia, etc.)
- Growing number of motor vehicles
Global increase in vehicles

1.2 billion by 2020!

Source: Handbook of automotive industry 1999
Toyota’s approach
Automotive fuel diversification scenario

1. Improve gasoline & diesel vehicle technology (reduce oil consumption to cut CO₂)

2. Promote adaptation of alternative fuels

**Oil remains mainstream**

- Gasification & synthetic technology
- CO₂ sequestration
- Gas storage technology
- Build infrastructure
- Hydrogen production
- CO₂ sequestration
- Electrical storage technology
- Ultra high density electrical storage technology

**Efforts toward using alternative fuels**

- Synthetic fuels (FT synthetic diesel, etc.)
- Biofuels
- Gaseous fuels (CNG, LPG)
- Hydrogen
- Electricity

Drilling & storage technology

Each alternative fuel poses many challenges. There is no strong mainstream candidate.
Multiple pathways
toward the Ultimate Eco-Car

Hybrid technology boosts performance for all powertrain systems
**History of Toyota’s HV Development**

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>'96</td>
<td>Prius (THS)</td>
</tr>
<tr>
<td>'97</td>
<td>THS with good fuel economy and lowest emissions</td>
</tr>
<tr>
<td>'98</td>
<td>World’s first massproduced Hybrid passenger car</td>
</tr>
<tr>
<td>'99</td>
<td>THS-II: enhanced environmental &amp; driving performance</td>
</tr>
<tr>
<td>'00</td>
<td>THS-II system application for several models</td>
</tr>
<tr>
<td>'01</td>
<td>Series hybrid developed for small bus driving in city</td>
</tr>
<tr>
<td>'02</td>
<td>Coaster HV</td>
</tr>
<tr>
<td>'03</td>
<td>Estima HV</td>
</tr>
<tr>
<td>'04</td>
<td>Crown mild HV</td>
</tr>
<tr>
<td>'05</td>
<td>Stop &amp; Start Vitz(Yaris)</td>
</tr>
<tr>
<td>'06</td>
<td>RX400h</td>
</tr>
<tr>
<td>'07</td>
<td>Highlander HV</td>
</tr>
<tr>
<td></td>
<td>Camry HV</td>
</tr>
<tr>
<td></td>
<td>GS450h</td>
</tr>
<tr>
<td></td>
<td>LS600h</td>
</tr>
<tr>
<td></td>
<td>THS-II system application for several models</td>
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</tbody>
</table>

**Key Models**
- Prius (THS)
- Camry HV
- GS450h
- LS600h
- RX400h
- Highlander HV
- Coaster HV
- Estima HV
- Crown mild HV
- Vitz(Yaris)
- Stop & Start
- Mild hybrid
- Parallel hybrid with diesel engine
- Parallel hybrid with CVT

**Toyota Dyna HV**

**Vitz(Yaris)**

**THS-ll system**

**THS-II: enhanced environmental & driving performance**

**Series hybrid developed for small bus driving in city**
What is hybrid?

- **Engine stop**
- **Regenerative braking**

**Mild hybrid**
- **Motor-assist**
- **Regenerative braking**
- **Engine stop**

**Strong hybrid**
- **EV Drive**
- **Motor-assist**
- **Regenerative braking**
- **Engine stop**
## Prius - Well to Wheel total efficiency

<table>
<thead>
<tr>
<th></th>
<th>W to T (%)</th>
<th>T to W (%)</th>
<th>Total Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conventional Gasoline</strong></td>
<td>88</td>
<td>16</td>
<td>14%</td>
</tr>
<tr>
<td><strong>'98 Prius</strong></td>
<td>88</td>
<td>28</td>
<td>25%</td>
</tr>
<tr>
<td><strong>New Prius</strong></td>
<td>88</td>
<td>37</td>
<td>32%</td>
</tr>
<tr>
<td><strong>03 FCHV</strong></td>
<td>58</td>
<td>50</td>
<td>29%</td>
</tr>
<tr>
<td><strong>FCHV future</strong></td>
<td>70</td>
<td>60</td>
<td>42%</td>
</tr>
</tbody>
</table>

*(Toyota Data: 10-15 mode)*
Evolution of Hybrid Units

Continuous improvements (KAIZEN) and the challenge to achieve higher performance with smaller and lighter units in other words, improved output density, is a key objective for hybrid development.
## Motor

### Technology
- Permanent magnet motor
- High voltage motor
- High speed motor
- 2 stage motor speed reduction device

### Output density ratio

<table>
<thead>
<tr>
<th>Year</th>
<th>Model</th>
<th>Output Density Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>'97 Prius</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>'03 Prius</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>'05 RX400h</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>'06 GS450h</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>'07 LS600h</td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

**Note:** Output density ratio is shown to increase by +250%.
Inverter / Power Control Unit

Output density ratio *

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* Volumetric base
Inverter / Power Control Unit

GS450h vs RX400h:

- Weight reduction: -43%
- Volume reduction: -63%
Battery

- '97 Prius
  - Smaller
  - Lighter
  - (Cylindrical)

- '00 Prius
  - +35%
  - (Prismatic resin case)

- '03 Prius
  - RX400h
  - +30%
  - (Prismatic metal case)

- '97 Prius
  - (Cylindrical)

Graph shows the comparison of output density (W/kg) and (W/L) for different models of Toyota batteries, indicating improvements in weight and size.
HV Market: Cumulative sales (global)

Aiming to reach 1 million annual sales sometime during the 2010s

Cumulative number of hybrid sales (Thousand)

- PRIUS (US, Europe, …)
- PRIUS (Japan)
- TOYOTA / LEXUS HVs (Total)
- All HVs including other company's HVs (Total)

TOYOTA MOTOR EUROPE
Plug-in Hybrid
Plug-in Hybrid Vehicle

Mainly EV in city driving

Mainly HV in long distance and high speed driving

Engine
Motor

Battery

Recharging circuit

120 / 240 VAC single phase

Recharged mainly at night

Household electrical energy

Plug-in hybrids : A new style of electricity utilization

TOYOTA MOTOR EUROPE
## Plug-in Hybrid: CO₂ reduction potential

### Electric generation in each country

<table>
<thead>
<tr>
<th>Country</th>
<th>Thermal</th>
<th>Water</th>
<th>Nuclear</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Japan</td>
<td>80%</td>
<td>20%</td>
<td>0%</td>
</tr>
<tr>
<td>France</td>
<td>50%</td>
<td>50%</td>
<td>0%</td>
</tr>
</tbody>
</table>

### Well-to-wheel CO₂ emissions

<table>
<thead>
<tr>
<th>Country</th>
<th>Prius</th>
<th>Plug-in hybrid vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Japan</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>France</td>
<td>1.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

25km drive range (13km EV range)  
**Toyota estimation**

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**Further CO₂ reduction well-to-wheel**
Plug-in Hybrid: Environmental performance

Plug-in technology can further enhance the environmental performance of hybrids both in CO₂ & pollutant emissions.
Plug-in Hybrid Vehicle in Europe

- Road testing in Europe since September 2007 in partnership with EDF
- Lithium-ion PHVs in Europe by 2010
Toyota Fuel Cell Hybrid
Fuel Cell Hybrid Vehicle (FCHV)

- Travelled 560 km between Osaka and Tokyo without refuelling
- Seeking improvements toward future commercialisation
Downsizing and Weight Reduction

New Technologies: Toyota iQ = *860 kg*

Less than 100 g/km CO₂

The six space-saving engineering innovations:
1. Differential
2. Flat under-floor fuel tank
3. Smaller heater/air conditioning unit
4. Asymmetric dashboard
5. Centre take-off steering gear
6. Slim seat design
Downsizing and Weight Reduction
Future Technologies:
Toyota 1/X = 420 kg
Future Traffic Society
Personal Mobility for a New Traffic Environment: i-REAL
TOYOTA GLOBAL VISION 2020

Open the Frontiers of Tomorrow
through the energy of people and technology