A Comparative Assessment of Vehicle Technologies and Fuels: Diesel, CNG or Hybrid

CAI Latin America
Lima, Peru
May, 2003

Summary
- Why We Are Interested
- Diesel Pro & Con
- CNG Pro & Con
- Hybrid Pro & Con
- Conclusions

What pollutants are of concern?
- Greenhouse gases (CO2, methane)
- Ozone (ROG + NOx)
- Particles (PM10/PM2.5) (NOx, SOx, ROG, ammonia)
- Carbon monoxide (CO)
- Toxics - Diesel particles - Benzene - Chromium - Asbestos

Health Impacts of Air Pollution
- Premature Deaths
- Cancer
- Developmental Effects
- Hospitalization
- Asthma Attacks and Bronchitis
Health Effects

- Different Pollutants have Different Effects
  - Carbon Monoxide - circulatory system, heart
  - Ozone - respiratory system, lung
  - Nitrogen Dioxide – respiratory system
  - PM - lung, potential effects on heart
  - Diesel, Air Toxics - cancer, respiratory effects
- There are potential effects of the Mixture
- Some Populations more sensitive than others
  - elderly
  - people with heart and lung disease

Greenhouse Gas Effect

- Some of the infrared radiation passes through the atmosphere.
- Some infrared radiation is absorbed and re-emitted in all directions by GHG.
- The effect is to warm Earth.
- Most radiation is absorbed by the Earth and makes it warm.
- Earth and atmosphere reflect 30% radiation.

Global Warming Concerns

- IPCC - 1995
  - "the balance of evidence suggests a discernible human influence"
- IPCC - 2000
  - "there has been a discernible human influence on global climate"

Share of worldwide CO2 emissions from the combustion of fuel, by sector -- 1998

- Production of Energy 45%
- Commercial and other 4%
- Residential 8%
- Manufacturing and Construction 19%
- Transport 36%

Source: IEA 2000a.
Elements of a comprehensive vehicle pollution control strategy

- Clean vehicle technology
- Traffic and demand management
- Appropriate maintenance
- Clean fuels

To reduce individual vehicle emissions
To influence vehicle use

Fuel Consumption: Diesel Vs. Gasoline
Mercedes E320

![Graph showing fuel consumption comparison between gasoline and diesel](image)

- Fuel Economy
- Fuel Consumption Over 100,000 Miles

Gasoline: 25.7 MPG, 35 Gallons
Diesel: 30.3 MPG, 30.9 Gallons
Saves 1000 Gallons

Source: Dr. Rudolf W. Thom
January 2003, SIAT 2003

However...

Diesel Particulate Matter

- Solid sea salt (0.01-0.02 µm)
- Soot from carbonaceous materials (0.005-0.1 µm)
- Sulfuric acid (H2SO4)
- Organic compounds
- Sulfate and elemental sulfur

Hear no diesel. See no diesel. Smell no diesel.
**Increased Risk of Premature Mortality Due To 10μg/m³ PM₂.₅**

- All Causes
- Pulmonary
- Lung Cancer

**Cancer Studies in Railroad Workers HEI, 1995**

**Health Impacts of Diesel in California**

<table>
<thead>
<tr>
<th>Impacts Of Diesel PM₂.₅</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaths</td>
<td>2,900</td>
</tr>
<tr>
<td>Chronic Bronchitis</td>
<td>2,590</td>
</tr>
<tr>
<td>Hospital Admissions</td>
<td>2,790</td>
</tr>
<tr>
<td>Lower Lung Symptoms</td>
<td>95,400</td>
</tr>
<tr>
<td>Loss of Days Work</td>
<td>621,000</td>
</tr>
</tbody>
</table>

**Comparison of PM10, PM2.5, and Ultrafine PM**

- PM10 (10 μm)
- PM2.5 (2.5 μm)
- Ultrafine PM (0.1 μm)

**Relative size of particles**

- Human Hair (60 μm diameter)
Typical engine exhaust mass and number weighted size distributions shown with alveolar deposition.

Vehicles Are A Major Source of Ultrafine Particles

Comparison of Particle Emissions from SMPS: All Vehicles and Fuels - 50kph

A PM Solution Exists!

PSA’s DPF System for Diesel Passenger Cars
Comparison of the Cancerogenous Potential of Otto- and Diesel Passenger Cars in Urban Traffic

Comparison of NOx Emission Type Approval Data from Current Passenger Car Types

In Germany, Diesels Actually 7 times More NOx Than Otto

Emission Performance Light-duty Diesels

<table>
<thead>
<tr>
<th>Model</th>
<th>NOx</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA VW 1.9 / Jetta</td>
<td>0.7</td>
<td>0.053</td>
</tr>
<tr>
<td>US Mercedes 3.0 / E300</td>
<td>0.8</td>
<td>0.08</td>
</tr>
<tr>
<td>EU Peugeot 607¹</td>
<td>0.6</td>
<td>0.0005</td>
</tr>
<tr>
<td>Toyota Avensis Prototype</td>
<td>0.05</td>
<td>0.006</td>
</tr>
</tbody>
</table>

¹ Low mileage

Low Sulfur Diesel Fuel Is Also Necessary
TEST BUS
(CWstprt CNG w/OxiCat)

<table>
<thead>
<tr>
<th>CWstprt</th>
<th>2001 Cummins Westport C Gas Plus</th>
</tr>
</thead>
<tbody>
<tr>
<td>engine</td>
<td>C Gas Plus</td>
</tr>
<tr>
<td>chassis</td>
<td>New Flyer 40 passenger</td>
</tr>
<tr>
<td>after-treatment</td>
<td>OEM Catalyst</td>
</tr>
<tr>
<td>fuel</td>
<td>pipeline fuel meeting CARB spec's</td>
</tr>
</tbody>
</table>

Average NO\textsubscript{x} and PM Emissions - CBD

Average Carbonyl Emissions (CBD Driving Cycle)

Average Benzene Emissions by Driving Cycle

1,3 Butadiene Emission by Driving Cycle
(Envelopes represent 2 std. dev. of replicate measurements)
Hybrid Vehicle Commercialization

### Toyota Prius
- Small car
- 2000

### Honda Civic
- Small car
- 2002

### Ford Escape
- Small SUV
- 2003

### Dodge Durango
- Large SUV
- 2003

### GM Sierra
- Large Pickup
- 2004

### GM
- Medium SUV
- 2004

### Toyota
- Minivan
- ?

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**Source:** JEVA, 2002

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#### Hybrid Vehicles Developed and Sold in Japan

<table>
<thead>
<tr>
<th>Type</th>
<th>Size</th>
<th>Name</th>
<th>Maker</th>
<th>Range</th>
<th>Battery</th>
<th>Motor/System</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>Compact</td>
<td>Prius</td>
<td>Toyota</td>
<td>31 km/l</td>
<td>Ni-MH</td>
<td>AC Synch/ P/S</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Insight (MT)</td>
<td>Honda</td>
<td>35</td>
<td>Ni-MH</td>
<td>AC Synch/ P</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CIVIC-H</td>
<td>Honda</td>
<td>32</td>
<td>Ni-MH</td>
<td>AC Synch/ P</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Insight (AT)</td>
<td>Honda</td>
<td>29.5</td>
<td>Ni-MH</td>
<td>AC Synch/ P</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>Estima-H</td>
<td>Nissan</td>
<td>20</td>
<td>Li-Ion</td>
<td>AC Synch/ P/S</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>Crown-Wagon</td>
<td>Toyota</td>
<td>18</td>
<td>Ni-MH</td>
<td>AC Synch/ P/S</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>Estima-H</td>
<td>Toyota</td>
<td>15</td>
<td>Lead</td>
<td>AC Synch/ P/S</td>
</tr>
<tr>
<td>Truck</td>
<td>3.5 t</td>
<td>Ranger</td>
<td>Hino</td>
<td>8 (60km/h)</td>
<td>Lead</td>
<td>AC Induct/ P</td>
</tr>
<tr>
<td>Bus</td>
<td>Micro</td>
<td>Coaster</td>
<td>Toyota</td>
<td>4.3</td>
<td>Lead</td>
<td>AC Induct/ S</td>
</tr>
<tr>
<td></td>
<td>Transit</td>
<td>Blue Ribbon city</td>
<td>Hino</td>
<td>30%↑</td>
<td>Ni-MH</td>
<td>AC Induct/ P</td>
</tr>
</tbody>
</table>

Note: Micro hybrid PCs and HD hybrid trucks are being developed by Japanese automakers.

Vehicle | Energy source | Avg. mpg | CO₂ (g-C/mile) | CO₂ (g-C/km) trap+filter
--- | --- | --- | --- | ---

Automatic Transmission
- Honda Insight: Gas/electric 84.5 23.2 39.7
- Honda Civic: Gas/electric 48.5 35.0 39.7
- VW Golf, Jetta: Diesel 45.5 37.8 39.7
- Toyota Echo: Gas 39 38.0

Manual Transmission
- Honda Insight: Gas/electric 64.5 26.2
- Toyota Prius: Gas/electric 48.5 30.6
- Honda Civic: Gas/electric 39.5 37.5

Gasoline/electric hybrids emit less CO₂ than the best diesel vehicles in U.S.

Mark Jacobson, Haagen Smit 2003

Comparison of Fuel Economy for Diesel and Hybrid Passenger Cars

Comparison of Various EFVs

Economic Challenges: LDD vs Gasoline HEV

- **Fuel economy improvement**
  - Strong gasoline HEV: 40-50%
  - Diesel: 35-40%

- **Cost**
  - Short Term | Long Term
  - Strong HEV: $2500 | $1500
  - Diesel: $2350 | $1900

1. Compact car 2. Includes after-treatment
Conclusions

- Diesel, CNG & Hybrids Each Have High Potential
- Stringent Performance Standards Necessary To Obtain Full Potential
- Major Challenges
  - Diesel – PM, NOx
  - CNG – Aldehydes, Infrastructure
  - Hybrids - Cost