Motor Vehicles: Overview, Alternatives, Issues

Air Pollution as Climate Forcing: Alternative Scenarios – Their Benefits and Costs
M.P. Walsh
With Advice & Assistance from B. Croes, A. Ayala, R. Corey and M. DeLucchi
May 2005

One Result: Serious Health Concerns
- WHO Concludes ~ 800,000 Premature Deaths Each Year From Urban PM; Most in Asia
- Numerous Studies in Europe & US Consistently Link PM With Premature Deaths, Hospital Admissions, Asthma Attacks, Etc.
- No Evidence of a Threshold
- PAPA Project Indicates Similar Effects in Asia
- Ozone, NOx, Various Toxics Also Serious Health Concerns

Emissions Standards Trends For Gasoline Cars

World Motor Vehicle Population

- 0 200 400 600 800 1000 1200 Millions
- 0 0.5 1 1.5 2 2.5 3 3.5 g/km Nitrogen Oxides
- US EU Japan

<table>
<thead>
<tr>
<th>Emissions+</th>
<th>Fuel economy</th>
<th>☆☆☆: 50% lower emission vehicles</th>
<th>☆☆☆☆: 75% lower emission vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicles: achieving fuel economy standard in 2010</td>
<td>No incentives</td>
<td>*25% annual tax reduction *200,000 yen purchase tax deduction</td>
<td></td>
</tr>
<tr>
<td>Vehicles: 5% higher fuel economy than the standard in 2010</td>
<td>*25% annual tax reduction *200,000 yen purchase tax deduction</td>
<td>*50% annual tax reduction *300,000 yen purchase tax deduction</td>
<td></td>
</tr>
</tbody>
</table>

+: compared to the new long-term standard in 2005

Comparison of Future Emission Standards on HD vehicles

Costs & Benefits of Clean Fuels and Vehicles

- Tier 2 Light-duty highway
- Tier 3 Heavy-duty highway
- Tier 4 nonroad

Total Cost: $11 billion
Total Benefits: $175 billion

$ Billion Annually in 2030
Adopted 65.0%  
Not Adopted 35.0%  

Population  
Adopted 71.0%  
Not Adopted 29.0%  

Developing Countries Which Have Adopted US Or EU Standards For New Vehicles

The Challenges:
- Eliminate The Yellow Colored Areas
- Narrow the Technology/Fuel Quality Gap in Blue Areas

China

China New Vehicle Sales

Chinese Vehicle Population Has Been Exploding (million)

Plus Approximately 50 Million Motorcycles And Over 20 Million Agricultural Vehicles
Growth in Annual Vehicle Production Has Been Even Faster (million)

By The End of 2003, China Has Become The 4th Largest Producer In The World

Vehicle Growth in Beijing is Exploding

Emission Standards For New Vehicles

Control Measures on Motor Vehicle Pollution

Beijing, Shanghai already Introduced Euro 2 in 2003
**China Fuel Consumption Standards – MT Cars**

- **Phase I**
  - Effective in July 2005
  - Existing Models

- **Phase II**
  - Effective in July 2008

**What’s In Play in China**

- **Nationwide SEPA**
- **Mobile Sources**
  - Developing 11th Five Year Plan Document
  - Putting Strong Environmental Case Together For Euro 4 Stds & Fuels
- **Euro 3 in 2007, Euro 4 in 2010 likely – April?**
- **Trying to Get Sulfur Issue to State Council Soon**
- **Fuels Workshop in July with US EPA**

**Beijing EPB**

- **Likely Euro 3 Gasoline, Euro 4 Diesel in 2005/6**
- **Cleaner Fuels Adopted For July 1, 2005**
- **Interested in Accelerating Euro 4 before Olympics**
- **Retrofit Demonstration with US EPA**
- **Shanghai, Guangzhou EPB**
  - Also Interested in Leapfrogging

**India**

**India New Vehicle Sales**

- **Cars, Trucks & Buses**
  - India 97.8%
  - ROW 2.2%
- **Motorcycles & Scooters**
  - India 59.9%
  - ROW 40.1%

**New Vehicle Standards in India**

- **Entire Country**
  - Euro 2 – April 2005
  - Euro 3 – April 2010
- **Major Cities**
  - Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad & Ahmedabad, Pune Surat, Kanpur & Agra Already Euro 2
  - Tighter emission norms for all private vehicles, city public service vehicles and city commercial vehicles
    - Euro 3 From April 2005
    - Euro 4 From April 2010
    - Entire country at 500 PPM Sulfur this year
    - Largest Balance refinery at 10 PPM
Brazil New Vehicle Sales

<table>
<thead>
<tr>
<th>Year</th>
<th>Engine Modifications</th>
<th>TWC</th>
<th>EU4/LEV</th>
<th>Euro3/Tier 1</th>
<th>No Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Brazil**

- Passenger Cars & Light Commercial Vehicles
  - Tier 1 Phased in 2005-2007 (40/70/100%)
  - FedLev in 2009
  - No Diesel Cars Allowed
- Heavy Duty Trucks & Buses
  - Euro 3 Phased in 2004-2006
  - Euro 4 in 2009
- Fuels
  - Diesel Fuel S in City from 2000 to 500 in 2005 & to 500 in 2009
  - Diesel Fuel S in Rural areas from 2000 to 500 in 2005 & to 500 in 2009
  - Gasoline S from 1000 to 400 in 2004 & to 80 in 2008
- State of Sao Paulo Gearing Up To Push Sulfur Issue

**Global Distribution of Emissions Controls**

- New Gasoline Cars (000)
- Heavy Duty Diesel Trucks (000)
Forecasting Emissions

- WBCSD Vehicle Growth Forecasts
- Aggregate Countries into Three Categories
  - Industrialized (OECD)
  - Rapidly Developing (Most of Asia)
  - Developing (The Remainder)
- US EPA Emissions Factors by Technology Category
- GWP's from CARB and Mark DeLucchi

Two Scenarios

- Business As Usual
  - Currently Adopted or Soon To Be adopted Emissions Standards
  - Industrialized Countries HFC Control (see Richard Corey presentation)
    - 50% by 2015
    - 90% by 2020
  - More Aggressive Standards
    - RICs on par with industrialized by 2015
    - Developing on par by 2020
  - VMT Held Constant in Both (WBCSD) No TCMs

Vehicle Emissions Trends
(Condensed View)

Normalized to 2000

Vehicle Emissions Trends
(Aggressive Scenario)

Normalized to 2000
Ultra Low Sulfur Diesel Fuel Is Spreading

SOx Emissions From Road Vehicles (000)

Approaches To Global Warming Potential

<table>
<thead>
<tr>
<th></th>
<th>CARB</th>
<th>CEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>CO</td>
<td>1.2</td>
<td>9.1</td>
</tr>
<tr>
<td>NOx</td>
<td>0</td>
<td>4.4</td>
</tr>
<tr>
<td>N₂O</td>
<td>296</td>
<td>280</td>
</tr>
<tr>
<td>CH₄</td>
<td>23</td>
<td>15</td>
</tr>
<tr>
<td>HFC</td>
<td>1,300/120</td>
<td>1,250/115</td>
</tr>
<tr>
<td>BC</td>
<td>0</td>
<td>2420</td>
</tr>
<tr>
<td>NMHC</td>
<td>3</td>
<td>3.3</td>
</tr>
<tr>
<td>OC</td>
<td>0</td>
<td>-230</td>
</tr>
<tr>
<td>SOx</td>
<td>0</td>
<td>-45</td>
</tr>
</tbody>
</table>
Carbon Dioxide Scenarios

- WBCSD Base Case
- Aggressive Case
  - ROW On A Par with Europe by 2025
  - Europe Continues Steady Progress to 2050
  - No Prescription for Diesels, Hybrids, Fuel Cells, Alt Fuels Etc

Light Duty Vehicle Fuel Consumption

Comparison of fleet average GHG emission standards standardized by gCO₂/km for new light-duty vehicles

Source: Feng An, Sauer
Engine Technologies with Potential to Reduce GHGs

- 5, 4 or 3 valves per cylinder
- variable valve timing
- idle stop/start
- cylinder deactivation
- variable compression ratio
- variable displacement
- advanced IC engines (diesel, DI gas)

Other Technologies which Could Reduce Vehicle GHGs

- Transmissions
  - lockup 6/5/4 speed
  - automatically shifted manuals
  - CVTs
- Advanced Powertrains
  - integrated starter alternatives
  - hybrids
  - fuel cells

Technologies That Reduce Methane or Nitrous Oxide

- Relatively high global warming potential compared to carbon dioxide
- Catalyst modifications have been demonstrated that reduce methane emissions
- Nitrous oxide emissions may also be reduced through catalyst modifications

Technologies That Reduce HFC Emissions

- Better materials and fittings can reduce leakage
  - (50% Reduction Possible)
- Alternative refrigerants with lower global warming potential
  - R152a, CO₂
  - (90% Reduction Possible)
- Variable displacement compressors reduce system energy requirements, leading to lower CO₂ emissions
### Contrasting Approaches To Reducing Emissions

- **Conventional Pollutants**
  - 1970 CAA – mandatory technology forcing standards for Light Duty Vehicles
  - Now Underway for Trucks
  - Vehicles improved more than order of magnitude in one generation

- **Greenhouse Gases or Fuel Economy**
  - Standards only based on what is on the shelf until recently
  - Many technology advances Used for Power or Performance
  - Only Now Are We starting To Push the Technology Envelope

### Issues/Conclusions

#### Action Agenda

- Aircraft & Marine Need To Be Addressed
- Technical Solutions to Conventional Pollution & Non CO2 Greenhouse Gases Are Available and Just Need To Be Applied & Accelerated in Developing World
- Carbon Dioxide Remains Difficult Issue But Not Because Technical or Policy Options Are Not Available
- GHG Standards Should Be Mandated For All Vehicle Categories
  - Pushing The Technology Envelope
  - Providing Sufficient Lead Time
  - Fuels Technologies May Have Important Role
- Transportation Controls, BRT systems, etc Also Need To Be Part of the Solution