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
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, NO₂, Various Toxics Also Serious Health Concerns
Emissions Standards Trends For Gasoline Cars

Nitrogen Oxides

- US
- EU
- Japan

Emissions Standards Trends For Gasoline Cars

 Nitrogen Oxides

- 1967
- 1972
- 1977
- 1982
- 1987
- 1992
- 1997
- 2002
- 2007

0
0.5
1
1.5
2
2.5
3
3.5

g/km

United States

Europe

Japan

Gases

Cars

<table>
<thead>
<tr>
<th>Fuel economy</th>
<th>Emissions+</th>
<th>50% lower emission vehicles</th>
<th>75% lower emission vehicles</th>
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<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>
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</table>

+: compared to the new long-term standard in 2005
Comparison of Future Emission Standards on HD vehicles

Around 2005

Around 2009-10

(Challenge target)
About 1/3 of 0.7
Costs & Benefits of Clean Fuels and Vehicles

- Tier 4 nonroad highway:
  - Cost: $11 billion
  - Benefit: $175 billion

- Heavy-duty highway:
  - Cost: $11 billion
  - Benefit: $175 billion

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

$ Billion Annually in 2030
Worldwide Motorcycle Emission Regulations

**Europe**
- **EU II** (2003)
  - ECE40
  - Cold Start
  - HC: 1.0
  - NOx: 0.3
  - CO: 3.0
- **EU III** (2006)
  - HC: 0.8
  - NOx: 0.15
  - CO: 2.0
  - 30,000 km

**China**
- **III Stage** (2008)
  - ECE40
  - Cold Start
  - HC+NOx: 1.0~1.25
  - CO: 1.0~1.25
  - 10,000 km

**Japan**
- **IV Stage** (2004)
  - ECE40
  - Cold Start
  - HC+NOx: 2.0
  - CO: 7.0
  - 15,000 km
- **III Stage** (2008)
  - ECE40
  - Cold Start
  - HC+NOx: 1.0~1.25
  - CO: 1.0~1.25
- **II Stage** (2008)
  - ECE40
  - Cold Start
  - HC+NOx: 1.0~1.25
  - CO: 1.0~1.25
- **II Stage** (2004)
  - ECE40
  - Cold Start
  - HC: 1.2
  - NOx: 0.3
  - CO: 5.5
  - 10,000 km

**EU II**
- ECE40
- Cold Start
- HC: 1.0
- NOx: 0.3
- CO: 5.5
- 10,000 km

**India**
- **IV Stage** (2005)
  - IDC Cold Start
  - HC+NOx: 1.5
  - CO: 1.5
  - 30,000 km

**Taiwan**
- **IV Stage** (2004)
  - ECE40
  - Cold Start
  - HC+NOx: 2.0
  - CO: 7.0
  - 15,000 km

**China**
- **II Stage** (2004)
  - ECE40
  - Cold Start
  - HC: 1.2
  - NOx: 0.3
  - CO: 5.5
  - 10,000 km
- **II Stage** (2004)
  - ECE40
  - Cold Start
  - HC: 1.2
  - NOx: 0.3
  - CO: 5.5
  - 10,000 km

**Japan**
- **IV Stage** (2006/2007)
  - ECE40
  - Cold Start
  - HC: 0.3/0.5
  - NOx: 0.15
  - CO: 2.0
  - 12,000/24,000 km

**China**
- **II Stage** (2004)
  - ECE40
  - Cold Start
  - HC: 1.2
  - NOx: 0.3
  - CO: 5.5
  - 10,000 km

**Japan**
- **IV Stage** (2006/2007)
  - ECE40
  - Cold Start
  - HC: 0.3/0.5
  - NOx: 0.15
  - CO: 2.0
  - 12,000/24,000 km
Air Quality Trends in California
(1-hour Peak Indicator)

- Ozone
- Nitrogen Dioxide

ppm

California PM10 Air Quality Trend
( Maximum Annual Average of Quarters )

mg / m³

1989 1991 1993 1995 1997 1999 2001 2003
New Light Duty Vehicle Sales Forecast By Country/Region

Source: WBCSD
Global Trends in Vehicle Kilometers Traveled

Global Road Vehicle Kilometers Traveled
(10^12))

Source: WBCSD
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

Cars, Trucks & Buses
- China: 9.4%
- ROW: 90.6%

Motorcycles & Scooters
- China: 43.0%
- ROW: 57.0%
Chinese Vehicle Population Has Been Exploding (million)

Total Vehicle
- Annual Growth Rate 11.6%

Private Vehicle
- Annual Growth Rate 23.0%

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

Source: He Kebin
# Emission Standards For New Vehicles

## Control Measures on Motor Vehicle Pollution

Beijing, Shanghai already Introduced Euro 2 in 2003

<table>
<thead>
<tr>
<th>Time Category</th>
<th>Before 2000</th>
<th>2000</th>
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<td>EURO I</td>
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<td>jû</td>
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<td>jû</td>
<td>EURO I</td>
<td>jû</td>
<td>jû</td>
<td>jû</td>
<td>EURO II</td>
</tr>
</tbody>
</table>
China Fuel Consumption Standards – MT Cars

Phase I will be effective in July 2005
Phase II will be effective in July 2008
What’s In Play in China

Nationally-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 New Vehicle Sales

- Cars, Trucks & Buses:
  - India: 2.2%
  - ROW: 97.8%

- Motorcycles & Scooters:
  - India: 16.9%
  - ROW: 83.1%
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 Reliance refinery at 10 PPM
Brazil New Vehicle Sales

Brazil 3.4%
ROW 96.6%
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 50 in 2009; on rural areas from 3500 to 2000 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)

- **2000**
  - No Controls: 3.4%
  - Euro4/LEV: 2.2%
  - Euro3/Tier 1: 70.8%
  - Engine Modifications: 3.5%
  - TWC: 20.1%

- **2005**
  - No Controls: 3.5%
  - Euro5/LEV2: 1.8%
  - Euro4/LEV: 59.0%
  - Engine Modifications: 3.8%
  - TWC: 24.1%
  - Euro3/Tier 1: 7.8%

- **2010**
  - Engine Modifications: 1.0%
  - No Controls: 2.7%
  - Euro5/LEV2: 62.1%
  - Euro4/LEV: 18.9%

- **2015**
  - Engine Modifications: 0.6%
  - No Controls: 3.1%
  - Euro5/LEV2: 78.1%
  - Euro3/Tier 1: 8.7%
  - Euro4/LEV: 8.9%

- **2020**
  - TWC: 0.6%
  - Euro3/Tier 1: 1.9%
  - Euro4/LEV: 8.3%
  - Euro5/LEV2: 84.8%
Global Distribution of Emissions Controls
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
(Business As Usual Scenario)

Normalized to 2000

THC  NOx  N2O  HFC
CO  PM  CH4  OC

Vehicle Emissions Trends
(Business As Usual Scenario)
Vehicle Emissions Trends
(Aggressive Scenario)
Ultra Low Sulfur Diesel Fuel Is Spreading
SO$_x$ Emissions From Road Vehicles (000)

- Business as Usual
- Aggressive Scenario

SO$_x$

Tons/Year

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<thead>
<tr>
<th>Year</th>
<th>Business as Usual</th>
<th>Aggressive Scenario</th>
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<tr>
<td>2000</td>
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## Approaches To Global Warming Potential

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<td>296</td>
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<td>CH₄</td>
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<td>HFC</td>
<td>1,300/120</td>
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<tr>
<td>SOₓ</td>
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<td>-45</td>
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CO₂ Equivalent Non-CO₂ Greenhouse Gases From Road Vehicles

- Business as Usual
- Aggressive
GWP Using the CEF Non-CO$_2$ Approach

Thousands

Business as Usual

Aggressive Strategy

Using the CEF Non-CO$_2$ Approach
Comparison of fleet average GHG emission standards standardized by gCO$_2$/km for new light-duty vehicles

Source: Feng An, Sauer
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

l/100km


LDGV Base LDGV FE Case LDDV Base Case LDDV FE Case

Light Duty Vehicle Fuel Consumption
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, CO$_2$
  - (90 % Reduction Possible)
- Variable displacement compressors reduce system energy requirements, leading to lower CO$_2$ 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
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