Motor Vehicle Pollution Control
History, Status, Challenges & Opportunities

March 2005
M.P. Walsh

Outline
• Historical Overview: Evolution of the Clean Air Act
• Current Status
  – Health Effects
  – Regulatory Requirements
• Looking Ahead
  – Challenges
  – Opportunities

Key Messages
• Government Regulation Has & Will Continue To Drive The Global Motor Vehicle Pollution Control Market
• Health Impacts Are The Principle Drivers of Government Regulations
  – Environmental Damage Also Important (e.g. German Black Forest, Swedish Lakes)
  – Climate Issues Increasingly Important
• Vehicle and Fuels Technologies Have Consistently Risen To The Challenges Contained in the Regulations
• Great Progress Has Occurred and The Motor Vehicle Pollution Control Market is Large and Mature
• The Job is Far From Done, However, Especially In Developing Countries

Global Trends in Motor Vehicle (Cars, Trucks & Buses) Production

Key Messages

Global Trends in Motor Vehicle (Cars, Trucks & Buses) Production

Graph:
- Y-axis: Millions
- X-axis: Years (1950 to 2010)
- Trend line equation: y = -1.8e+009 + 9.28e+005x

R-square = 0.951   # pts = 53

Graph:
- Y-axis: Millions
- X-axis: Years (1950 to 2010)
- Trend line equation: y = -1.8e+009 + 9.28e+005x

R-square = 0.991   # pts = 53

y = -1.2e+009 + 3.28e+005x
The Global Market For New Motorcycles and Mopeds

<table>
<thead>
<tr>
<th>Region</th>
<th>Market Share</th>
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<tbody>
<tr>
<td>Asia</td>
<td>84.4%</td>
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<tr>
<td>Europe</td>
<td>7.9%</td>
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<tr>
<td>Latin America</td>
<td>3.5%</td>
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<tr>
<td>Middle East</td>
<td>0.4%</td>
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<tr>
<td>North America</td>
<td>6.0%</td>
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<tr>
<td>Africa</td>
<td>0.3%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
</tr>
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</table>

Source: Honda Facts & Figures

World Motor Vehicle Population

![Graph showing world motor vehicle population from 1930 to 2000.](image)

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
Los Angeles 1955: The Start of the Story
Air Not Breathable
and no solutions.

The 1950’s and 1960’s
• Initial Studies Carried Out
  – What is “Smog”?  
  – What Causes It? (Dr. Haagen Smit – HC, NOx, Sunlight)
  – What is the Role of Motor Vehicles? 
  – What Can Be Done About It?

The 1950’s and 1960’s (cont’d)
• 1959: California MVPCB adopted Vehicle Exhaust Standards  
  – Only When Two Devices Were Certified Were They To Be Required On New Vehicles – One Year After Certification  
• 1960: crankcase Emissions Standards Adopted By CA  
• Sept 1961: First Crankcase Device Certified (by GM) and GM Voluntarily installs on all 1961 CA Cars; other manufacturers followed  
• 1963 Crankcase Controls installed on all new cars Nationwide  
• June 1964: CA Approved 4 Exhaust Devices Meeting Standards (three catalysts and one direct flame afterburner) Triggering Mandatory Installation by 1966  
• August 1964, Auto Makers announced They Had Better “Engine Modifications” That Would Be Ready for 1966 Model Introduction  
• Other States – PA & New York – Began to Consider Vehicle Standards  
• 1965: Congress Passes Motor Vehicle Air Pollution Control Act  
• First Exhaust Standards Introduced in CA in 1966 and Nationally in 1968  
  – Engine Modifications Had Poor In Use Performance  
  – NOx Levels Increased

The 1950’s and 1960’s (cont’d)
• 1967: CARB Created  
• 1967: Federal Air Quality Act of 1967  
  – Amendment Submitted by Congressman Charles Dingle Deleting CA Authority Passed House Committee  
  – Deleted On House Floor  
  – Senator Muskie Emerges As Leader  
• 1969: Justice Department Investigation of Auto Industry Anti Trust Conspiracy Results in Consent Decree
1970 – The Watershed Year

• US EPA Created by President Nixon
• Major Air Pollution Episode Across Eastern US
• Collegiate Car Race Focused Attention on Alternatives to the ICE
• Landmark 1970 Amendments To Clean Air Act Adopted

1970 Clean Air Act Amendments Highlights

• Health Based Air Quality Standards
• Technology Forcing Emissions Standards
  – Effectively Required Catalytic Converters by 1975
  – Began Leaded Gasoline Phase Out – Linking Vehicles & Fuels
• Allowed Citizen Suits
• Gave EPA Broad Authority and Responsibility
• Clearly Defined Roles of National/State Governments
• Timelines Mandated for NAAQS Attainment with More Actions Required Of Those Needing Longer Time

Subsequent CAA Amendments

• 1977 Amendments
  – Added Section 177 Which Allows Other States To Adopt CA Standards
  – Added Focus on Heavy Duty Vehicles
  – More Focus on Fuels and Additives
  – Made I/M Programs Mandatory
• 1990 Amendments
  – Mandated Tier 1 and Provided For Tier 2 Requirements
  – Added Focus on Non Road Engines/Vehicles
  – Rejected Alternative Fuels or Engines Mandates
  – Required “Reformulated” Gasoline
  – Rejected Efforts (by Congressman John Dingle) To Remove CA Authority or eliminate Section 177

HEALTH & ENVIRONMENTAL EFFECTS
What pollutants are of concern?

- Carbon monoxide (CO)
- Ozone (ROG + NOx)
- Haze
- Particles (PM10/PM2.5) (NOx, SOx, ROG, ammonia)
- Toxics - Diesel particles - Benzene - Chromium - Asbestos

Health Impacts of Air Pollution

- Premature Deaths
- Cancer
- Developmental Effects
- Hospitalization
- Asthma Attacks and Bronchitis

Ozone Health Effects

- Causes inflammation in respiratory tract
- Reduces ability to breathe (lung function) for some people
- Increases hospitalization for asthma, other lung diseases
- Effects have been demonstrated for short term, long term effects have been less certain
- LA Children’s Health Study recently found structural lung damage with lifetime impairment

PM Health Effects

- High levels of PM (e.g. 500 µ/m³) known to cause premature death for many years – e.g. London 1952
- Recent studies in US, Europe, Asia, South America have found association of PM with premature death at much lower levels – no evidence of a “threshold” (safe level)
PM - The Epidemiology Studies

- A Number of Epidemiology Studies

Europe Studies  Harvard 6 Cities Study

PM10 Study in Europe
(Lancet Medical Journal – September 2, 2000)

- ~6% of all deaths from PM10
- ~40,000 deaths per year in Austria, France, Switzerland; 2 times traffic fatalities
- Motor Vehicles Responsible For ~50%
- People in Cities Die ~18 Months Earlier Than They Otherwise Would
- Over 300,000 cases of chronic bronchitis; 500,000 asthma attacks; 16 million lost person days of activity
- Health Costs From Traffic Pollution ~1.7% of total GDP

Increased Risk of Premature Mortality Due To 10µg/m³ PM2.5

Initial Results:
Asian Risk Estimates Similar to West

Journal of American Medical Association, March 2002
Dutch Study Links Proximity To Truck Traffic With Lung Function in Children

Truck Traffic Density

Lung Function in liter

Relative Cancer Risks in Los Angeles

Diesel PM
1,3-Butadiene
Benzene
Chrome VI
Formaldehyde
Para-Dichlorobenzene
Toluene
All Others

Cancer Studies in Railroad Workers HEI, 1995

Relative Risk (95% CI)
ARB In-Vehicle Study
Real-Time Fine Particle Counts
(L.A. Freeway, AM Rush Hour, Vent Open)

Time (120 minutes)
- Outside Vehicle 1
- Inside Vehicle 1

HDD Delivery Van
Diesel Charter Bus

Increasing Concerns About Ultrafine Particles

Comparison of Particle Emissions from SMPS.7: All Vehicles and Fuels - 50kph

United States

US and Canada New Vehicle Sales

A PM Solution Exists!

United States

US & Canada
54.8%
Key Motor Vehicle Regulations
In California

- Catalytic Converters and Unleaded Fuel
- Required use of TWC and computer-based emission control
- On-Board Diagnostics II
- Low Emission Vehicle I + Phase I Gasoline
- Roadside Truck Inspections
- Phase II Gasoline
- Gasoline Trucks
- Diesel Trucks
  - Low Emission Vehicle II
  - On-Road Motorcycles
  - Urban Transit Buses
  - Diesel Trucks


New Car Emissions Standards in the US

Air Quality Trends in California
(1-hour Peak Indicator)

- Ozone
- Nitrogen Dioxide

California PM10 Air Quality Trend
(Maximum Annual Average of Quarters)
Over 90% of Californians Breathe Unhealthy Air at Times
Days Over Applicable State Standard, 1999 Monitoring Data

Serious Air Quality Problems Persist Nationally

California’s Goal: “Zero” Emissions

US Tier 2 Standards Also Approaching Zero
EPA Clean Fuel & Vehicle Programs

- **1999 Tier 2 Standards**
  - Gasoline sulfur control (30 ppm average)
  - Stringent light-duty vehicle standards
  - Same standards for light trucks and cars
  - Same standards for gasoline and diesel (PM filters for diesels)

- **2000 Heavy-Duty 2007 Standards**
  - Diesel sulfur control (15 ppm maximum)
  - Stringent heavy-duty gasoline & diesel vehicle standards
  - PM filter forcing standards, NOx catalysts based standards

- **2004 Nonroad Tier 4 Standards**
  - Diesel sulfur control (2 steps - 500 ppm in 2008, 15 ppm in 2011)
  - Stringent emission standards, based on on-highway standards

- **Ongoing – Diesel Retrofit**
  - Ultra-low sulfur diesel fuel enables diesel PM retrofits
  - Realize substantial Air Quality and Health Benefits earlier

- **In Process – Locomotive and Marine Diesel Standards**
  - Marine diesel sulfur control (15 ppm maximum) already done in Nonroad
  - Benefit from same technologies as on-highway and nonroad
  - Proposed rulemaking in 2005

Clean Fuel and Vehicle Programs

**Clean Fuel and Vehicle Programs Diesel PM Reductions**

Clean Fuel and Vehicle Programs NOx Reductions

Costs & Benefits of Clean Fuels and Vehicles

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

$ Billion Annually in 2030
Current Issues & Future Challenges in CA

Reducing greenhouse gas emissions

- Phase-in 2009-16 -- 30% less CO$_{2}$eq
- For cars -- equal to EU voluntary standards
- Compliance using existing technologies
  - Combustion, transmission
  - Hybrid models expanding, significant demand
  - Diesel: Could meet LEV II by ~2008
- Legal challenge
- Opposition from US EPA possible - waiver
- NAS study -- challenge to CA authority to regulate

Hotter Days Lead to Higher Emissions and More Smog

- 10 warmest years of the last century all occurred within the last 15 years.

Source: California Environmental Protection Agency
Emissions From Gasoline Cars In Europe

<table>
<thead>
<tr>
<th>Year</th>
<th>CO</th>
<th>NOx</th>
<th>HC+NOx</th>
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<tr>
<td>1990</td>
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<td>2010</td>
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</table>

Gasoline Car and Fuel Regulations Converging Worldwide

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<thead>
<tr>
<th>Regulation</th>
<th>Limits</th>
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<td>Euro I</td>
<td>900 ppm</td>
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<tr>
<td>Euro II</td>
<td>500 ppm</td>
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<tr>
<td>Euro III</td>
<td>150 ppm</td>
</tr>
<tr>
<td>Euro IV</td>
<td>50 ppm</td>
</tr>
<tr>
<td>Euro IV/V</td>
<td>10 ppm</td>
</tr>
<tr>
<td>Japan '00</td>
<td>100 ppm</td>
</tr>
<tr>
<td>Japan '05/07</td>
<td>10 ppm</td>
</tr>
<tr>
<td>CA SULEV/Tier 2</td>
<td>30 ppm</td>
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</table>

Production of Diesel Passenger Cars

- Western Europe
- Exceeded 50% in Oct '04
- Diesel share in overall passenger car production in %

Emissions From Diesel Cars In Europe

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<tr>
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CAFÉ (Clean Air For Europe) Programme

- Thematic Strategy on Air Pollution to be presented in May 2005
- Expected to include:
  - Review of air quality standards, focus PM and Ozone
  - EU 5 emission standards for light duty vehicles and Euro 6 for HDV (expected alongside strategy and late 2005 respectively) focus on diesel emissions, standards which will require full PM traps, NOx controls
- Fiscal support for "pseudo Euro 5" (0.005 g/km) in many EU Member States starting January 2005 – Clean Diesels already hitting the market

NO\textsubscript{x} emissions projected for 2010 compared to NEC emission ceilings

"With climate measures" scenario, EU-25

- Off-road
- On-road heavy duty
- On-road light duty
- Stationary
- Industrial processes
- Non-energy use
- Marine generation
Premature deaths attributable to ozone [cases/year]

Contribution to primary PM2.5 emissions “With climate measures” scenario, EU-15

Loss in life expectancy attributable to anthropogenic PM2.5 [months]

“Political” Orientation

• Last Decade – Commission Proposes, Parliament Tightens
• Current Environment Commissioner Seems Less Knowledgeable/Committed Than Wallstrom
• Enterprise Commissioner Pushing Competitiveness Agenda
• In Parliament, Absence of MEP Lange a big loss
Conclusions for EU

- LD Euro 5 proposal due mid-2005, HD Euro 6 in autumn 2005;
- The priority issues are further NOx and particulate mass reductions and controls on ultra-fine particles;
- Euro 5 likely to focus on PM; less on NOx;
- Review of fuel quality also being addressed (except sulphur).

Asia

Asia New Vehicle Sales

Asia Could Surpass Europe by 2010

Japan

Japan New Vehicle Sales

New Standards For Japanese Vehicles (October 2005)

Japan Adopted The “Muskie Standards” After A Visit by the Senator in early 1970’s
Desulfurizing Fuels in Japan

1953 76 92 97 2003’ 05’ 07

Gasoline

Proposed Limit Value of Diesel-powered Vehicles
(2009 ~ ) (Draft)

<table>
<thead>
<tr>
<th></th>
<th>PM</th>
<th>NOx</th>
<th>NMHC</th>
<th>CO</th>
<th>Achievement periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger car</td>
<td>0.005</td>
<td>0.08</td>
<td>0.024</td>
<td>0.065</td>
<td>0.00 %</td>
</tr>
<tr>
<td>Light-weight</td>
<td>0.005</td>
<td>0.08</td>
<td>0.024</td>
<td>0.065</td>
<td>0.00 %</td>
</tr>
<tr>
<td>(GVW 1.7t or less)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Middle-weight</td>
<td>0.007</td>
<td>0.15</td>
<td>0.024</td>
<td>0.063</td>
<td>1.7 = 2.5</td>
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<tr>
<td>(GVW over 1.7t – 3.5t or less)</td>
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<td></td>
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</tr>
<tr>
<td>Heavy-weight</td>
<td>0.01</td>
<td>0.7</td>
<td>0.17</td>
<td>2.22</td>
<td>3.5 – 12</td>
</tr>
<tr>
<td>(GVW over 3.5t or less)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

1. Unit: Heavy-weight: g/kWh
2. Lower column means ratio of reduction from the new long-term standard (enforce by 2005).
3. (GVW) Gross weight Vehicle, NMHC: Non-methane hydrocarbons


<table>
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<tr>
<td>Passenger car</td>
<td>0.005</td>
<td>N.C.</td>
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<tr>
<td>Light-weight</td>
<td>0.005</td>
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</tr>
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1. Unit: Heavy-weight: g/kWh
2. Except Heavy-weight: g/km
3. (GVW) Gross weight Vehicle, NMHC: Non-methane hydrocarbons

note) Target values of particulate matter are applied only to lean-burn, direct-injection vehicles mounted with storing-type NOx reduction catalyst.
Anticipated Diesel Emission Reduction Technologies in Japan

<table>
<thead>
<tr>
<th>Technology</th>
<th>2003-04</th>
<th>2005</th>
<th>2009-10</th>
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</thead>
<tbody>
<tr>
<td>Improvement of combustion chamber and air-intake system</td>
<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>Improvement of fuel injection system</td>
<td>○</td>
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<td>○</td>
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<tr>
<td>Cooled EGR</td>
<td>×</td>
<td>×</td>
<td>○</td>
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<tr>
<td>Turbo Charger</td>
<td>△</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>HCCI (Homogeneous Charge Compression Ignition)</td>
<td>×</td>
<td>×</td>
<td>△</td>
</tr>
<tr>
<td>NOx sensor</td>
<td>×</td>
<td>×</td>
<td>○</td>
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<tr>
<td>Urea sensor</td>
<td>×</td>
<td>×</td>
<td>△ or ○</td>
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<td>Oxidation Catalyst</td>
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<td>○</td>
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<td>Passive type Diesel Particulate Filters (DPF)</td>
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<tr>
<td>Selective Catalytic Reduction (SCR)</td>
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<td>△</td>
<td>○</td>
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<tr>
<td>NOx Adsorber</td>
<td>×</td>
<td>×</td>
<td>○</td>
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</tbody>
</table>

Note: ○: Prevailed  △: Limited use  ×: Not Possible

Comparison of Future Emission Standards on HD vehicles

<table>
<thead>
<tr>
<th>Category</th>
<th>NOx (g/kWh)</th>
<th>CO (g/kWh)</th>
<th>PM (g/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US (2010~)</td>
<td>0.13</td>
<td>6.0</td>
<td>5.0</td>
</tr>
<tr>
<td>EU (2008~)</td>
<td>0.00</td>
<td>0.627</td>
<td>0.00</td>
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<tr>
<td>JAPAN (Draft)</td>
<td>0.03</td>
<td>3.5</td>
<td>0.13</td>
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Around 2005

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<td>6.0</td>
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</table>

Around 2008-10

Next exhaust emission standards* for special vehicles recommended in the 6th report

<table>
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<tr>
<th>Category</th>
<th>NOx (g/kWh)</th>
<th>HC (g/kWh)</th>
<th>CO (g/kWh)</th>
<th>PM (g/kWh)</th>
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<tbody>
<tr>
<td>Diesel</td>
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<tr>
<td>19kW – 37kW</td>
<td>6.0 (6.0)</td>
<td>1.0 (1.5)</td>
<td>5.0 (5.0)</td>
<td>0.4 (0.8)</td>
</tr>
<tr>
<td>37kW – 56kW</td>
<td>4.0 (4.0)</td>
<td>0.7 (1.0)</td>
<td>5.0 (5.0)</td>
<td>0.3 (0.6)</td>
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<tr>
<td>56kW – 75kW</td>
<td>3.6 (3.6)</td>
<td>0.4 (1.0)</td>
<td>5.0 (5.0)</td>
<td>0.2 (0.4)</td>
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<tr>
<td>75kW – 130kW</td>
<td>3.6 (3.6)</td>
<td>0.4 (1.0)</td>
<td>3.5 (3.5)</td>
<td>0.17 (0.3)</td>
</tr>
<tr>
<td>130kW – 560kW</td>
<td>3.6 (3.6)</td>
<td>0.4 (1.0)</td>
<td>3.5 (3.5)</td>
<td>0.17 (0.3)</td>
</tr>
<tr>
<td>Gasoline</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19kW – 560kW</td>
<td>0.6 (0.6)</td>
<td>0.6 (0.6)</td>
<td>20 (20)</td>
<td>—</td>
</tr>
</tbody>
</table>

* Parenthetic numbers are current standards applied from 2003.

Outline of new legislation framework (on the table)

<table>
<thead>
<tr>
<th>Category</th>
<th>Statutory</th>
<th>Other Mobile Source</th>
<th>Non-road vehicles</th>
<th>On-road vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car, bus, truck, etc.</td>
<td></td>
<td>Air pollution control law &amp; Road vehicle act</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car, bus, truck, etc.</td>
<td></td>
<td>Air pollution control law</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scope: Non-road special vehicles Act (under discussion at National Diet)

Emission standards: The same as On-road Special Vehicles

Enforcement: 2006
6th report of CEC recommended about future prospect of non-road emission standards after 2006.

- Regulation for special diesel motor vehicles will be greatly strengthened in about 2010, premised on the use of after-treatment devices such as DPF.
- Regulatory details will be the subject of future studies.
- Studies must also be conducted on the introduction of new exhaust emission testing methods that are designed to evaluate after-treatment device.

**Discussions will start within the next year.**

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

- **Population**
  - Not Adopted: 35.0%
  - Adopted: 65.0%
- **Vehicle Population**
  - Not Adopted: 35.0%
  - Adopted: 65.0%

**Four Challenges:**
- Eliminate the Yellow Colored Areas
- Narrow the Technology/Fuel Quality Gap in Blue Areas
- Continue to Push the Technology Envelope by Tighter Standards
- No Backsliding!

**Problem Could Get Worse Due To High Growth Especially In Asia**

- Personal transport activity by region
  - Total: 2.4% /year
  - Africa: 1.9% /year
  - Latin America: 2.0% /year
  - Middle East: 1.9% /year
  - India: 2.5% /year
  - Other Asia: 1.7% /year
  - China: 5.0% /year
  - Eastern Europe: 1.5% /year
  - Former Soviet Union: 2.3% /year
  - OECD Pacific: 0.7% /year
  - OECD Europe: 0.5% /year
  - OECD North America: 1.2% /year

- And even more significant freight transport growth: 2.5% /year

**China New Vehicle Sales**

- Cars, Trucks & Buses
- Motorcycles & Motorbikes
Chinese Vehicle Population Has Been Exploding (million)

- Total Vehicle
- Private Vehicle

Annual Growth Rate 11.6%
Annual Growth Rate 23.9%

By the end of 2003, China has become the 4th largest producer in the world.

Growth in Annual Vehicle Production Has Been Even Faster (million)

- Total
- Cars

Annual Growth Rate 16.7%
Annual Growth Rate 31.8%

Most Vehicles Are in Cities
Vehicle Growth in Beijing is Exploding

- 1st 1M for 48 years
- 2nd 1M for 6 years
- 3rd 1M for only 3 years?

Source: He Kebin

Beijing November 2004

Pollution Shifting From Coal Based To Vehicle Based

Shanghai November 2004

Control Measures on Motor Vehicle Pollution

Emission Standards For New Vehicles

<table>
<thead>
<tr>
<th>Time Category</th>
<th>Before 2000</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>ECE 1503</td>
<td>EURO I</td>
<td>←</td>
<td>←</td>
<td>←</td>
<td>←</td>
<td>←</td>
</tr>
<tr>
<td>LDV &amp; LDY</td>
<td>ECE 1503</td>
<td>←</td>
<td>←</td>
<td>←</td>
<td>←</td>
<td>←</td>
<td>←</td>
</tr>
<tr>
<td>HDDV</td>
<td>None</td>
<td>←</td>
<td>←</td>
<td>←</td>
<td>←</td>
<td>←</td>
<td>←</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>ECE R 40</td>
<td>←</td>
<td>←</td>
<td>←</td>
<td>←</td>
<td>←</td>
<td>←</td>
</tr>
</tbody>
</table>

Phase I will be effective in July 2005
Phase II will be effective in July 2008

China Fuel Consumption Standards – MT Cars

Beijing, Shanghai already introduced Euro 2 in 2003
What’s In Play in China

- Nationally-SEPA
  - Mobile Sources
    - Developing 11th Five Year Plan Document
    - Will Put Strongest Environmental Case Together For Euro4 Stds & Fuels
    - Euro 3 in 2007, Euro 4 in 2010 likely – April?
    - Trying to Get Sulfur Issue to State Council Soon
    - Possible Fuels Workshop in July?
- Beijing EPB
  - Pushing For Euro 3 Gasoline, Euro 4 Diesel in 2005/6
  - Cleaner Fuels Adopted For July 1, 2005
  - Interested in Accelerating Euro 4
  - MMT Concern
- Shanghai EPB
  - Also Interested in Leapfrogging to Euro 4

Stationary NOx Control

- Very Weak Standards At Present
- Growing Awareness At SEPA & Some Local EPB’s
  - Ozone
  - Acid Rain
  - PM
- Professor Hao Preparing A Report
  - Need
  - Cost & Feasibility
  - Bring Report To Gov’t Officials

India

India New Vehicle Sales

- Cars, Trucks & Buses
  - India 2.2%
- Motorcycles & Scooters
  - India 97.8%

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
- Through CSE (and ARAI), pushing to accelerate Time Schedule
India Diesel Fuels Road Map

Some parts of Country will not meet 2005 schedule; Largest Reliance Refinery Now Making 10 PPM

Exhaust Emission Standards in Korea

- Gasoline Passenger Car
  - LEV of LEV-1 standard was applied in Jan. 2003.
  - ULEV of LEV-2 standard (of CARB) will be applied from 2006.1 with a phase-in of 25/50/75/100%.
- Diesel HDV
  - EURO-3 standard was applied in 2002.7/2003.7.
  - EURO-4 standard will be applied from 2006.10/2008.1.
  - ESC/ETC test mode will be adopted.
- Diesel Passenger Car
  - EURO-3 will be applied from 2005.1, but half of the cars will have to install DPF.
  - EURO-4 will start from 2006.
- Diesel LDT
  - EURO-3 was applied in 2002.7/2003.7.
  - EURO-4 will be applied from 2006.1/2007.1.

DPF Promotion Program in Korea

- 3 step program is progressing for the 2nd stage DPF retrofit promotion
- 1st step: “DPF evaluation program” was being performed from Dec. of 2003.
  - Examine the level of DPF technology and evaluate the applicable potential to Korean vehicles.
  - 6 systems were evaluated, which using Catalyst, Fuel additive, Electric heater, and Plasma technology.
  - Evaluate the real operation condition of DPF and DOC by the fleet operation of several hundred vehicles (520 DPFs and 1098 DOCs).
  - The demonstration DPF systems selected by the results of DPF evaluation program and certification test.
- 3rd step: “Main retrofit program” will start from 2005
  - 428,000 of DPFs and 579,000 of DOCs are expected to be retrofitted during main retrofit program. In this year (2005) 15,861 DPFs and 13,541 DOCs are scheduled to be retrofitted.
- Management system after retrofit is important consideration.

Taiwan New Vehicle Emissions Standards

<table>
<thead>
<tr>
<th>Vehicles</th>
<th>Standards</th>
<th>Effective date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline cars</td>
<td>STAGE_{III}</td>
<td>1/1/1999</td>
</tr>
<tr>
<td></td>
<td>STAGE_{IV}</td>
<td>1/1/2008</td>
</tr>
<tr>
<td>Diesel cars</td>
<td>STAGE_{III}</td>
<td>1/7/1999</td>
</tr>
<tr>
<td></td>
<td>STAGE_{IV}</td>
<td>1/1/2007</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>STAGE_{IV}</td>
<td>1/7/2007</td>
</tr>
</tbody>
</table>

1. The emission standards of gasoline cars and diesel cars: present-USA standard, STAGE_{IV}, EURO IV.
2. After enter the WTO, the emission standard of motorcycle will take the EURO standard or USA standard.
The composition and performance standards in fuel


(2) Gradually lower the sulfur content in diesel from 5,000 ppmw in 1989 to 50 ppmw in 2005.

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Benzene (vol%), max</th>
<th>Sulfur (ppmw), max</th>
<th>RVP (psi), max</th>
<th>Oxygen (wt%), max</th>
<th>VOCs+NOx (mg/km), max</th>
<th>TOXICs (mg/km), max</th>
<th>Aromatics (vol%), max</th>
<th>Alkene (vol%), max</th>
</tr>
</thead>
<tbody>
<tr>
<td>gasoline</td>
<td>0.5</td>
<td>1.0</td>
<td>8.9</td>
<td>8.7</td>
<td>2.0</td>
<td>2.7</td>
<td>1.0</td>
<td>18</td>
</tr>
<tr>
<td>diesel</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- Benzene (vol%), max: 0.5 in 2002, 1.0 in 2005, 1.0 in 2007
- RVP (psi), max: 8.9 in 2002, 8.7 in 2005, 8.7 in 2007
- Oxygen (wt%), max: 2.0 in 2002, 2.7 in 2005, 2.7 in 2007
- VOCs+NOx (mg/km), max: 1.0 in 2002, 1.0 in 2005, 1.0 in 2007
- TOXICs (mg/km), max: 18 in 2002, 18 in 2005, 18 in 2007

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 2009 & 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

Mexico

- 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 2009 & 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
Mobile Sources Program In Mexico

- Tighten emission limits for new gasoline and diesel vehicles.
  - Gasoline:
    - Tier I first introduced in 1999 (US-EPA-94).
    - Tier II to be introduced in 2006, under discussion.
  - Diesel:
    - EPA-98 currently in place.
    - Standards for new diesel vehicles under discussion.
  - Key Issue Is Fuel Quality – Sulfur
  - EPA Retrofit Initiative

Positive Actions Are Spreading Around The World

Lead Free Gasoline Worldwide

- 50% of Gasoline Now Lead Free
- Most Countries Committed by 2005/6
- Sulfur Discussion Beginning
- MMT Substitute?

Gasoline Car and Fuel Regulations Converging Worldwide

- Euro I 500 ppm
- Euro II 150 ppm
- Euro III 50 ppm
- Euro IV 10 ppm
- Japan '00 100 ppm
- Japan '05/07 10 ppm
- CA SULEV/Tier 2 30 ppm
The Three-way Catalytic Converter Is Going On Over 90% Of All New Gasoline Cars Produced This Year Worldwide

- Layered washcoat architectures and support materials with high thermal stability
- Integrated HC adsorption functions
- Mounting materials with improved durability
- High cell density ceramic or metallic substrates
- Insulation schemes for heat management

Ultra Low Sulfur Diesel Fuel Is Spreading

Emission Standards For HD vehicles Also Converging

Global Distribution of Emissions Controls
Gasoline Cars (000)
Conclusions

- Vehicle Standards Increasingly Linked To Fuel Quality
- Standards in US/EU/Japan Converging but Differing Technology Options May Emerge
  - EU Diesel Standards Will Still Likely Lag After Euro 5 and Euro 6
- Major Challenges in Developing Countries
  - Narrowing Gap For Industrializing Countries
  - Getting Progress With The Laggards
- Fuel Economy/Climate Issues Getting Greater Attention in Europe & Japan Than in US (Except for CA) But Much More Needs To Be Done