Global Trends In Motor Vehicle Pollution Control

May 2005
Michael P. Walsh

Outline

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

Key Messages

• Government Regulation Has & Will Continue To Drive Global Motor Vehicle Pollution Control
• 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 In Reducing Vehicle Pollution in Spite of Continued Vehicle Population Growth
• The Job is Far From Done, However
  – Urban Air Pollution in Developing Countries
  – Climate Change

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

\[ y = -1.8 \times 10^9 + 9.28 \times 10^5x \]

\( R^2 = 0.951 \)  \( # \text{pts} = 53 \)
The Global Market For New Motorcycles and Mopeds

World Motor Vehicle Population

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?
    - National Crankcase Controls (1963)
    - CA Tailpipe Standards (1966)
    - National Tailpipe Standards (1968)

1970 – The Watershed Year
- US EPA Created by President Nixon
- Landmark 1970 Amendments To Clean Air Act Adopted
  - 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 – New York Was First
  - 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 To Remove CA Authority or eliminate Section 177
HEALTH & ENVIRONMENTAL EFFECTS

What pollutants are of concern?

- Carbon monoxide (CO)
- Ozone (ROG \text{ + NOx})
- Haze
- Particles (PM10/PM2.5)
  \(\text{(NOx, SOx, ROG, ammonia)}\)
- Toxics
  - Diesel particles
  - Benzene
  - Chromium
  - Asbestos
- Greenhouse Gases
  - CO2, methane

PM\textsubscript{10} Study in Europe

(Lancet Medical Journal – September 2, 2000)

- \textasciitilde6\% of all deaths from PM\textsubscript{10}
- \textasciitilde40,000\ deaths per year in Austria, France, Switzerland: 2 times traffic fatalities
- Motor Vehicles Responsible For \textasciitilde50\%
- People in Cities Die \textasciitilde18\ 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 \textasciitilde1.7\% of total GDP
Increased Risk of Premature Mortality Due To 10μg/m³ PM$_{2.5}$

Dutch Study Links Proximity To Truck Traffic With Lung Function in Children

Relative Cancer Risks in Los Angeles

Based on ARB monitoring data 1995 - 1997
**Key Motor Vehicle Regulations In California**

- 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

**Air Quality Trends in California**

- Ozone
- Nitrogen Dioxide


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

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

### Diesel PM Reductions

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>PM (tons)</th>
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<tr>
<td>2000</td>
<td>40,000</td>
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<td>2015</td>
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<tr>
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<td>20,000</td>
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<tr>
<td>2025</td>
<td>15,000</td>
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<td>2030</td>
<td>10,000</td>
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### NOx Reductions

<table>
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<th>NOx Tons (millions)</th>
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<tr>
<td>1990</td>
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<td>2025</td>
<td>0</td>
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<tr>
<td>2030</td>
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</table>

Costs & Benefits of Clean Fuels and Vehicles

- **Tier 2 Light-duty highway**
  - Cost: $1 billion
  - Benefit: $175 billion
  - Total Cost: $11 billion
  - Total Benefits: $175 billion

- **Heavy-duty highway**
  - Cost: $1 billion
  - Benefit: $175 billion

- **Tier 4 nonroad**
  - Cost: $1 billion
  - Benefit: $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
**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
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


<table>
<thead>
<tr>
<th>Emissions standard</th>
<th>Fuel economy</th>
<th>Vehicles: achieving standard in 2010</th>
<th>Tax Incentives</th>
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<tr>
<td>Emissions</td>
<td>Fuel economy</td>
<td>Vehicles: achieving standard in 2010</td>
<td>Tax Incentives</td>
</tr>
</tbody>
</table>
| Emissions: 50% lower emission vehicles | 5% higher fuel economy than standard in 2010 | 25% annual tax reduction *200,000 yen purchase tax deduction | *
| Emissions: 75% lower emission vehicles | 5% higher fuel economy than standard in 2010 | 50% annual tax reduction *300,000 yen purchase tax deduction | *


<table>
<thead>
<tr>
<th>PM</th>
<th>NOx</th>
<th>NMHC</th>
<th>CO</th>
<th>Achievement period</th>
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<td>0.005</td>
<td>N.C.</td>
<td>2009</td>
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- Light-weight (GVW 1.7t or less): 0.005
- Middle-weight (GVW over 1.7t - 3.5t or less): 0.007
- Heavy-weight (GVW over 3.5t): 0.01

Unit: Heavy-weight :g/kWh

*Note: Target values of particulate matter are applied only to lean-burn, direct-injection vehicles mounted with storing-type NOx reduction catalyst.
Comparison of Future Emission Standards on HD vehicles

- **Japan (Draft)**
- **US (2010~)**
- **EU (2008~)**

### NOx (g/kWh)
- **US (2007~)**
- **US (2010~)**
- **CHALLENGE target**

### PM (g/kWh)
- **US**
- **JAPAN**
- **EU**

### Table

<table>
<thead>
<tr>
<th>Region</th>
<th>NOx (g/kWh)</th>
<th>PM (g/kWh)</th>
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<tbody>
<tr>
<td><strong>US (2007~)</strong></td>
<td>0.27</td>
<td>0.84</td>
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<tr>
<td><strong>US (2010~)</strong></td>
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<td>0.84</td>
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<tr>
<td><strong>CHALLENGE target</strong></td>
<td>0.17</td>
<td>0.72</td>
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### Graph

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

- **Personal transport activity by region**

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

- **China New Vehicle Sales**

- **China**

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

- **Source**: Sustainable Mobility Report calculations
Chinese Vehicle Population Has Been Exploding

- Total Vehicle: Annual Growth Rate 11.6%
- Private Vehicle: Annual Growth Rate 23.9%

Plus Approximately 50 Million Motorcycles and Over 20 Million Agricultural Vehicles

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

- Total: Annual Growth Rate 16.7%
- Cars: Annual Growth Rate 31.8%

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

Vehicle Growth in Beijing is Exploding

- 1st 1M for 48 years
- 2nd 1M for 6 years
- 3rd 1M for only 3 years?
Pollution Shifting From Coal Based To Vehicle Based

Shanghai November 2004

Control Measures on Motor Vehicle Pollution
Emission Standards For New Vehicles

<table>
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<tr>
<th>Time Category</th>
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Beijing, Shanghai already introduced Euro 2 in 2003

China Fuel Consumption Standards

MT Cars

India New Vehicle Sales

India
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.

Brazil New Vehicle Sales
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

Mexico New Vehicle Sales

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 2004
**Africa**

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

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**Gasoline Car and Fuel Regulations Converging Worldwide**

<table>
<thead>
<tr>
<th>Region</th>
<th>Sulfur Limit</th>
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<tbody>
<tr>
<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>
</tr>
</tbody>
</table>

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**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

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**Ultra Low Sulfur Diesel Fuel Is Spreading**

- Various regions and cities have different sulfur limits for diesel fuel.
Emission Standards For HD vehicles Also Converging

Around 2005

Around 2009-10

Two GHG Scenarios For Non CO2 Gases

• Business As Usual
  – Currently Adopted or Soon To Be adopted Emissions Standards
  – Industrialized Countries HFC Control
    • 50% by 2015
    • 90% by 2020
• More Aggressive Standards
  – RICs on par with industrialized by 2015
  – Developing on par by 2020

Vehicle Emissions Trends (Business As Usual Scenario)

Vehicle Emissions Trends (Aggressive Scenario)
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
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