Emission Control of Vehicles
A Road Map For Viet Nam

Outline

• Review Process
• Summarize The EU Standards
  – Vehicles
  – Fuels
• Review Technologies

What are the Air Quality Concerns?

Industrial Emissions
Energy Consumption
Vehicle Emissions
Agriculture

Human Health Concerns
Global Warming
Acid Rain
Ozone Depletion

Integrated Air Quality Management Framework

• Establish objectives, identify data gaps, strategy and plan
• Identify, analyze, and select management options
• Develop strategies and implementation plan
• Set baseline monitoring and enforcement
Integrating Science & Policy: How to Evaluate a Emissions Control Strategy?

Select Pollution Reduction Strategy

Model Changes in ambient air concentrations of pollutants

Model Changes in human exposure

Model Value of Health Benefits

Model Changes in Health Effects

How to Evaluate a Emissions Control Strategy?

Impact of Clean Vehicles and Fuels On Diesel Vehicle Emissions

Percent Reduction in Emissions

Source: Camarsa, BAQ 2003

Impact of Clean Vehicles and Fuels On Diesel Vehicle Emissions

Costs & Benefits of Clean Fuels and Vehicles

Total Cost: $11 billion

Total Benefits: $175 billion

Preparation of proposals in the EU

Source: European Commission

Costs & Benefits of Clean Fuels and Vehicles

Tier 2 Light-duty highway

Tier 4 nonroad

Heavy-duty highway

$ Billion Annually in 2030
European Process For Regulations

Commission proposal for a new Directive

COUNCIL co-decision procedure

ECONOMIC & SOCIAL COMMITTEES common position

Possible conciliation

DIRECTIVE OF THE EUROPEAN PARLIAMENT & COUNCIL

Implementation by Member States

Emmissions from gasoline cars

Economic & Social Committee

2nd reading

1st reading

Emission standard transition

International Best Practice
Meaningful Emission Control Reductions in New Vehicles Requires a Systems Approach

- Advanced Engine Designs
- Advanced Emission Controls
- Low Emissions
- High Quality Fuel and Lubricants
- Retrofit in the case of in-use vehicles

Gasoline Car Technology

- Euro 1: Closed loop three way catalyst; lambda sensor; canister (to control evaporative emissions)
- Euro II/III/IV: reduce engine out emissions

Best Practice Pollution Control System

- Improved Fuel System
- Improved Controls
- Internal Engine Improvements
- Preheated Catalyst (selected applications)
- Revised Catalyst Formulation
- Revised Exhaust System

European Emission Standards for Diesel Cars

- NOx & HC
- CO
- Particulates

State of the Art

- EU 1
- EU 2
- EU 3
- EU 4
- ECE R15/04
- Limits in [g/km]
- GVW < 3500kg
- Type Approval Values
- ECE R15/04
- 90%
- 97%
- 98%
Heavy-duty vehicles on ETC

Limits and technologies

Diesel Oxidation Catalyst

Diesel Particulate Filter
Catalytic particulate trap cell

Exhaust flow

Catalytic particulate trap cell

Catalytic particulate trap cell

Continuously regenerating particulate trap (CRT)

NOx to NOx Catalyst

Exhaust flow

Continuously regenerating particulate trap (CRT)

NO to NOx Catalyst

Exhaust flow

NOx Reduction

Engine control measures

Exhaust treatment measures

Fuel injection timing

Variable geometry turbo-charger

EGR

urea-SCR catalyst

NOx adsorber

Active & Passive HC-deNOx

NOx Reduction

Engine control measures

Exhaust treatment measures

Fuel injection timing

Variable geometry turbo-charger

EGR

urea-SCR catalyst

NOx adsorber

Active & Passive HC-deNOx

NOx Adsorber Catalyst

catalyst converts NO to NO2

NO stored (as nitrate) on adsorber catalyst

Rich (HC injection) Phase:

>90% efficiency

Injected fuel frees stored NOx

3-way catalyst clean up exhaust

NOx Adsorber Catalyst

Urea-Selective Catalytic Reduction

Oxidation Catalyst (NO)

Oxidation Catalyst (NO)

Urea-Selective Catalytic Reduction

Oxidation Catalyst (NO)

HC + O2 + NO → 2NO2

2NH3 + NO + NO2 → 2N2 + 3H2O

8NH3 + 6NO2 → 7N2 + 12H2O

Oxidation Catalyst (NO)

Urea-Selective Catalytic Reduction

Oxidation Catalyst (NO)

Urea-Selective Catalytic Reduction

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Urea-Selective Catalytic Reduction

Oxidation Catalyst (NO)

Urea-Selective Catalytic Reduction

Oxidation Catalyst (NO)
Different Fuels = Different Emissions

Blending with 5 - 12 different components

Sulfur + Additives
Blending with 5 - 12 different components

Sulfur + Additives

Different Crude Oils and Refineries

Sulfur + Additives

~200 HC

+ Air

~500 HC

Different Combustion

Selective EU Fuel Quality Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>1996 (Euro 2)</th>
<th>2000 (Euro 3)</th>
<th>2005 (Euro 4)</th>
<th>2009 (Euro 5)</th>
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<tbody>
<tr>
<td>Gasoline</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Vapour Pressure</td>
<td>60</td>
<td>60</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Sulfur max ppm</td>
<td>500</td>
<td>150</td>
<td>50/10</td>
<td>10</td>
</tr>
<tr>
<td>Diesel</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Cetane Number</td>
<td>48</td>
<td>51</td>
<td>51</td>
<td>?</td>
</tr>
<tr>
<td>Density max kg/m³</td>
<td>845</td>
<td>845</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Poly-Aromatic max vol %</td>
<td>11</td>
<td>11</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Sulphur max ppm</td>
<td>500</td>
<td>350</td>
<td>50/10</td>
<td>10</td>
</tr>
</tbody>
</table>

Gasoline Effects on Emissions

<table>
<thead>
<tr>
<th>Fuel-change</th>
<th>Emissions</th>
<th>Regulated</th>
<th>Unregulated</th>
<th>Improvement or Deteriorates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO</td>
<td>HC</td>
<td>NOx</td>
<td>Benzene</td>
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<tr>
<td>Reduction of :</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bencene</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+/++</td>
</tr>
<tr>
<td>Aromatics</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++/++</td>
</tr>
<tr>
<td>Olefins</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++/++</td>
</tr>
<tr>
<td>Sulphur</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+/++</td>
</tr>
<tr>
<td>Vapor pressure</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-/++</td>
</tr>
<tr>
<td>Adjustment</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-/++</td>
</tr>
<tr>
<td>Volatility</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-/++</td>
</tr>
<tr>
<td>Addition Oxygenates</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-/++</td>
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Diesel-Fuel Effects on Emissions

<table>
<thead>
<tr>
<th>Diesel fuel-change</th>
<th>Vehicle - Emissions LDV / HDV</th>
<th>CO</th>
<th>HC</th>
<th>NOx</th>
<th>Particulates</th>
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<tr>
<td>Reduction of:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphur</td>
<td>o</td>
<td>o</td>
<td>?/o</td>
<td>+/++</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>++/-</td>
<td>++/++/++</td>
<td>o/+</td>
<td>++/++/++</td>
<td></td>
</tr>
<tr>
<td>Poly-Aromatic</td>
<td>-/+</td>
<td>-/+</td>
<td>+/o</td>
<td>+/o</td>
<td></td>
</tr>
<tr>
<td>Back End Distillation (T95)</td>
<td>o/-</td>
<td>o/-</td>
<td>-/o</td>
<td>+/o</td>
<td></td>
</tr>
<tr>
<td>Increase of ...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cetane Number</td>
<td>++++/++</td>
<td>++++/++</td>
<td>o</td>
<td>-/+</td>
<td></td>
</tr>
</tbody>
</table>
Increase in In-Use Vehicle Emissions in Bangkok Due To Sulfur in Fuel (Gasoline)

Increase in In-Use Vehicle Emissions in Bangkok Due To Sulfur in Fuel (Diesel)

**Fuel Sulfur Negatively Affects All Catalyst-Based Emission Control Technology**

- Impacts of Sulfur
  - $\text{SO}_2$ Sticks to Catalyst Sites (Chemisorption)
  - Inhibits Gaseous Catalytic Reactions
  - Catalytic Oxidation of $\text{SO}_2$ to $\text{SO}_3$
    - $\text{SO}_2$ Adds to Tailpipe PM Emissions – Up to 40 to 50% of $\text{SO}_2$ Can Be Oxidized to $\text{SO}_3$
    - $\text{SO}_3$ Reacts with Catalyst Base Metal Oxides to Form Metal Sulfate which reduces catalytic activity
  - For Catalyst-Based Diesel Particulate Filters, Sulfur Adversely Effects the Regeneration of the Filter
  - For NOx Adsorbers, Sulfate Clogs Up and Shuts Down the NOx Storage Mechanism

**Sulfur Effects**

- Sulfate make
- Sulfate Poisoning
- Sulfur inhibition
- Precious Metal
- Transition Metal
- Zeolite or refractory oxide support
International Best Practice
Ultra Low Sulfur Diesel Fuel Is Spreading

MMT is An Emerging Fuels Problem
- Fuel octane under pressure due to elimination of lead
- Organo-metallic additives are a cheap way to increase octane
- Experience with these additives shows that they can cause
  - Health problems
  - Technical problems

Implications of Recent Study
“The finding that manganese transport out of the brain occurs via the slow process of diffusion, rather than via carrier-mediated transport, is important. It suggests that no mechanism exists to protect the brain from accumulating manganese. This finding has important implications for neurotoxicity resulting from chronic manganese exposure.”

Experience with MMT
China: Blocked catalytic converter
- After 33,000 km
- Red Deposits of Manganese-Oxide
- Source: Schindler, VW
ICCT Conclusions Regarding MMT

Considering the available information, the International Council on Clean Transportation (ICCT) is unable to conclude that the use of MMT will not result in direct adverse health impacts nor that emissions of CO, HC and NOx from catalyst equipped cars will not increase. Based upon the precautionary principle, the California Air Resources Board banned the use of MMT in unleaded gasoline in 1976. In 1996, the Administrator of the EPA stated, “the American public should not be used as a laboratory to test the safety of MMT” (Browner 1996). The ICCT believes this statement to be true for the citizens of every country. Consistent with the precautionary principle, the ICCT recommends that countries delay any use of MMT in gasoline at this time, pending the outcome of ongoing health-based studies and further review of the vehicle impacts.

Copies of the ICCT Report Available at http://www.cleantransportcouncil.org/index.php

Type Approval

- EC Directives/UN ECE Regulations require third party approval
- Testing, certification and production of conformity assessment by an independent body
- Each Member State (MS) required to appoint:
  - Approval Authority: to issue approvals
  - Technical Service: to carry out testing
- Approval issued by one Approval Authority will be accepted by all MS

Dynamometer test cycle

Light Duty: Certification/ R&D Test System
Conformity of Production

- Witnessed certification testing, issuing of Separate Directive Approvals by the Member State authority, and issue of the WVTA.
- Audits of COP data/facilities/test facility quality processes on a regular basis (i.e. every 1 - 2 years).
- Mandatory COP checks and testing by the manufacturer / holder of the Approval.
- New for Stage III Light Duty Emission Directive:
  - In-service conformity, potential authority surveillance testing and provision for mandatory recall.

Conformity In-Service

- In-Service Testing
- For 10 years, Sweden conducted formal (A-60) in-service surveillance testing to identify models/Engine Families not meeting their 5 year / 80,000km emission durability requirement for passenger cars.
- Early testing in Sweden identified concerns for many manufacturers, but later in-service tests have shown a high level of compliance.

Conformity In-Service

- In-Service Testing
- Stage III emission Directive 98/69/EC introduces specific in-service test criteria/recall provisions:
  - from Jan. 2000/2001 Stage III limits for 5 years / 80,000km,
  - from January 2005, Stage IV limits for 5 years / 100,000km,
- In-use compliance testing is a two stage process carried out by the original type-approval authority:
  - audit of manufacturer supplied information;
  - selection and possible testing of in-use vehicles.
In-use Compliance audit

As a requirement of type-approval, manufacturer submits in-use compliance testing report to TAA for audit.

TAA reviews manufacturer's in-use compliance report.

Manufacturer provides additional information or test data.

Does TAA agree manufacturer's in-use report confirms acceptability of vehicle(s)?

YES

Process complete
No further actions

NO

Does TAA decide that the information is insufficient to reach a decision?

YES

TAA begins formal in-use compliance survey programme on suspect vehicle type(s)

NO

In use Compliance: Testing

Test a minimum three vehicles of the type

Outlying emitters?

YES

SAME cause?

YES

Max. sample size?

Yes

PASS?

Apply test statistic

Yes

SAMPLE has FAILED

No

MORE than one?

Yes

ONE test

Increase sample by one vehicle

NO

FAIL?

Apply test statistic

Yes

SAMPLE has PASSED

No

MORE than one?

Yes

ONE test

Increase sample by one vehicle

NO

More than one?

Yes

ONE test

Increase sample by one vehicle

No

More than one?

Yes

ONE test

Increase sample by one vehicle

No

More than one?

Yes

ONE test

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