Sustainable Development of Urban Transport: Challenges and Opportunities

Environmental Performance of Motor Vehicles and Fuels

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Content of Presentation

In ~20 minutes elaborate:

- Short Introduction of AVL
- Background
- Fuels & New Vehicle Technology
- Scrapping Schemes
- Experiences
AVL Company

- AVL is the world’s largest private and independent company developing powertrain systems with internal combustion engines along with instrumentation and test systems.
- Founded 1948
- 4,500 employees worldwide
- Head office Graz, Austria
- Involved in more than 800 engine development projects
- More than 3,000 engine test bed installations
PEP – June 8, 2012, Moscow

Business Areas

- Passenger cars
- 2-wheelers
- Racing
- Construction
- Agriculture
- Commercial vehicle
- Locomotive
- Marine
- Power plants

AVL Advanced Simulation Technologies
AVL Instrumentation and Test Systems
AVL Powertrain Engineering
AVL Advanced Simulation Technologies
AVL Instrumentation and Test Systems
Transportation – Large Impact on Air Quality
(Mandated by Laws, Regulations, Directives)

Environmental Friendly Operation of Vehicles
(Regulated exhaust/evaporative emissions + GHG)

Driver Behavior – *Fuel Quality – Engine/Vehicle Technology*
(Eco-driving – Standards – Emission/Vehicle Regulations)
Basic Facts to Consider

- Manufacturer of engines/vehicles design their products to meet set standards (including in-service conformity)
- Introduction of ECU is needed to meet stringent requirements (Euro VI →), but difference between certification values and real life emission might increase

- Fuel consumption (i.e. operational costs) is high priority for vehicle owner/fleet operator, especially for HDVs
- Improvement of fuel quality must go hand-in-hand with development of engine technology
- Adulteration of fuel will jeopardize optimal emission performance

- Easiest/fastest way to improve ambient air quality is to improve fuel quality and to implement measures for existing vehicle fleet
- Introduction of new emission regulations will not reach the full effect before 15-20 years (renewal of vehicle fleet is very slow)
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NO\textsubscript{x} Emissions Pre Euro → Euro V

LDV Diesel: NEDC vs. ARTEMIS Driving Cycles
Example: Market Drivers for Light-Duty Vehicles

**USA - California 2017 – 2025** (Proposal September 28, 2011)
- More stringent HC + NO$_x$ tailpipe standards
- New PM standards
- More stringent evap. standard
- Standards for GHG (Proposal 130-99 g/km 2025)
- Modified reference fuel

**Europe**
- Euro 6 emission requirements (September 1, 2014)
- Development of WLTP (World Harmonized Test Procedure ~2020)
- CO$_2$-emissions:
  - LDV (130 g/km – 2012-2015; 95 g/km – prop. 2020; 70 g/km – disc. 2025)
  - LCV (175 g/km – 2014-2017; 147 g/km – 2020)

**Sweden**
- Environmental Classification (LDV´s, LCV´s)
  - LDV (“Super incentive” 4 000 €; (50 g/km – 2012 hybrids, electric)
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Development of Emission Limits/Technology (HDE)
Fuels for Transportation

**Conventional fuels on the market**
- Gasoline
- Diesel
- Methane-gas (fossil origin)
- “Low blends” (E5-E15, B7-B30)

**Alternative fuels**
- Biogas (replacing CNG, LNG)
- FAME (replacing diesel-mod engine)
- DME (replacing diesel)
- Ethanol (E85/ED95) rep. gasoline/diesel
- Methane-diesel (DDF-modified engine)
Fuels for Transportation

✓ All alternatives are needed, no fuel can be appointed as the “winner”

✓ Local considerations for the alternative is essential

✓ Some alternatives might increase regulated pollutants, especially $\text{NO}_x$, but in general reduce GHG

✓ Alternatives might require new/modified infrastructure

✓ Some alternatives will minimize risk for adulteration (methane gas)
Scenario for biofuels in Sweden 2020 (TWh)

- Sugar cane (import)
- Wheat (3 plants)
- Cellulosic (1 demo)
- Waste (Local)
- Gasification
- Black liquor
- HVO (Rapeseed Oil Etc.)

- Ethanol
- Biogas
- DME
- "Green Diesel"
- FAME

- Methanol gasification

- Blending in gasoline
- 200,000 FFV-cars
- 50,000-230,000 cars
- City buses
- Trucks
- 5000-10,000 Trucks
- Blending in diesel

12-18% of the total transportation energy can be substituted.
Example on New Vehicle Technology, LDV´s

✓ **Hybrid vehicles (HEV)**
  - 2012, 2 300 000 on the road in US (Toyota Prius 1.1 M)

✓ **Plug-in hybrid vehicles (PHEV – E-REV)**
  - 2015, 700 000; 2020, 4 90 000; 2030, 24 600 000

✓ **Electrical vehicles (EV)**
  - 2015, 300 000; 2020, 2 00 000; 2030, 8 700 000

✓ **Fuel cell vehicles (FCHV)**
  - 2015, public available

✓ **Hydrogen vehicles**
  - Mainly demonstration, ~ 200 LDV s in US

Source: IEA, Wikipedia
"BLUE MAP" = Scenario describing engine technology to achieve annual CO2 reduction by 50% from 2005 levels
Example of Actions for Existing Vehicle Fleet

✓ Scrapping Schemes

✓ Program for Inspection & Maintenance
  ✓ Including implementation & enforcement

✓ Incentives for renewable of vehicle fleet
  ✓ Reduction of taxes
  ✓ Introduction of Environmental Zone

✓ High quality retrofit of HDV (DPF – SCR)
  ✓ UNECE – informal working group REC
  ✓ Hong Kong buses (Euro II/III → Euro V)
  ✓ Buses for Env. zones (Euro II/III → Euro V)
Scraping Schemes for Vehicles

- A report published by IHS Global Insight
- Prepared for
  - European Commission
  - DG Enterprise and Industry
  - Automotive Industry
- Final Report, March 2010
- Annex – Country Profile (18 Countries)
Due to economical crises in 2008, 13 EU countries introduced 2009 scrapping schemes as a tool for market support.

Scrappage program were in operation in markets representing 85% of total vehicle sales in EU.

A typical scheme required scrapping of LDV minimum 10 years old

Average incentive 1 500 € for buying a new car

Total cost for EU Governments 8 billion Euro

**Bottom Line:** Scrapping schemes have been remarkably successful
A Scrapping Scheme might deliver the following:

- Economic stimulus
- Increase support to the vehicle industry
- Reduced vehicle emissions
  - Reduction of CO$_2$ emissions by 1.05 tones/year on EU level
- Improved vehicle safety
  - 700 000 additional vehicles with airbag
  - 930 000 with ABS
  - 890 000 with ESC
- Indirect effects may generate unwanted distortions to the automotive market structure and even to the wider economy
Observations from IHS Report

- Larger cars, premium and luxury brands and LCV have been only marginal beneficiaries of schemes, since financial conditions not are met (too expensive vehicles)

- Cars intended to be scrapped might instead be exported to newer Member States within EU

- Schemes are mostly directed to private owners (with older vehicles) but should also be designed to replace vehicles owned by small businesses

- Introduce variable incentives for “accelerated compliance” with future CO₂ standards (120g/km, 147 g/km etc.)

- Consider timing (no scheme when new regulation is approaching)
Retrofit of Heavy-Duty Vehicles

- **Exhaust Gas Recirculation, EGR**
  - Not feasible (recommended) due to high cost

- **Diesel particle filter, DPF (“fit and forget”)**
  - Suitable solution for Euro II →
  - Preferably low sulfur fuel (max 50 ppm)
    - Possible for sulfur content max 2 000 ppm
  - Maintenance of filter important
  - For Euro VI → Active regeneration recommended

- **Selective Regeneration Catalyst, SCR**
  - “Type Approval” for system for is recommended
  - System might not work outside regulated area of engine map
  - Exhaust temperature is essential for optimal performance
  - System need continuous monitoring (OBD, dual NO_x-sensors)
  - Dosing of UREA is crucial
    - Excessive emissions of ammonia (NH_3)
    - Crystallization might be a problem
On-road tests different modes of operation: 3 different engines/aftertreatment technologies

<table>
<thead>
<tr>
<th>Bus</th>
<th>Speed (km/h)</th>
<th>CO (g/kWh)</th>
<th>HC (g/kWh)</th>
<th>NO\textsubscript{x} (g/kWh)</th>
<th>CO\textsubscript{2} (g/kWh)</th>
<th>Average exh temp °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (EGR/Ox.cat)</td>
<td>59.3</td>
<td>0.2</td>
<td>0.00</td>
<td>4.1</td>
<td>717</td>
<td>339</td>
</tr>
<tr>
<td>Euro IV</td>
<td>23.2</td>
<td>0.4</td>
<td>0.08</td>
<td>4.4</td>
<td>700</td>
<td>318</td>
</tr>
<tr>
<td>B (SCR/DPF I)</td>
<td>56.3</td>
<td>0.8</td>
<td>0.00</td>
<td>1.7</td>
<td>561</td>
<td>246</td>
</tr>
<tr>
<td>Euro IV</td>
<td>18.7</td>
<td>0.7</td>
<td>0.03</td>
<td>5.4</td>
<td>560</td>
<td>198</td>
</tr>
<tr>
<td>C (SCR/DPF II)</td>
<td>59.2</td>
<td>0.8</td>
<td>0.02</td>
<td>1.4</td>
<td>593</td>
<td>241</td>
</tr>
<tr>
<td>Euro V/EEV</td>
<td>23.5</td>
<td>2.3</td>
<td>0.02</td>
<td>1.8</td>
<td>640</td>
<td>231</td>
</tr>
</tbody>
</table>

All results are averages of 3 tests
Test of EEV (Euro V) Buses Fuelled by Diesel vs. RME: Emissions (g/km) and fuel consumption (l/100 km)

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Swedish Experience (II)
PEP – June 8, 2012, Moscow  
Swedish Experience (III)

Euro V Truck – DPF + SCR, different load and mode of operation

<table>
<thead>
<tr>
<th>Trip</th>
<th>Test weight</th>
<th>Duration (min)</th>
<th>Speed (km/h)</th>
<th>Distance (km)</th>
<th>CO (g/kWh)</th>
<th>HC (g/kWh)</th>
<th>NOx (g/kWh)</th>
<th>Fc. (l/100km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total trip</td>
<td>---</td>
<td>6.5 hours</td>
<td>32</td>
<td>199</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>ST-1</td>
<td>41 800</td>
<td>193</td>
<td>30</td>
<td>97</td>
<td>1.3</td>
<td>0.02</td>
<td>1.5</td>
<td>51.6 (564 g/kWh)</td>
</tr>
<tr>
<td>ST-2</td>
<td>26 100</td>
<td>41</td>
<td>8</td>
<td>6</td>
<td>2.2</td>
<td>0.02</td>
<td>5.1</td>
<td>70.6 (565)</td>
</tr>
<tr>
<td>ST-3</td>
<td>18 550</td>
<td>54</td>
<td>13</td>
<td>11</td>
<td>2.5</td>
<td>0.04</td>
<td>4.4</td>
<td>49.0 (553)</td>
</tr>
<tr>
<td>ST-4</td>
<td>16 050</td>
<td>34</td>
<td>34</td>
<td>19</td>
<td>2.8</td>
<td>0.03</td>
<td>2.9</td>
<td>29.9 (546)</td>
</tr>
<tr>
<td>ST-5</td>
<td>12 200</td>
<td>17</td>
<td>49</td>
<td>19</td>
<td>2.3</td>
<td>0.01</td>
<td>2.7</td>
<td>26.4 (540)</td>
</tr>
<tr>
<td>ST-6</td>
<td>19 750</td>
<td>48</td>
<td>60</td>
<td>47</td>
<td>1.3</td>
<td>0.01</td>
<td>1.5</td>
<td>34.5 (560)</td>
</tr>
</tbody>
</table>
Swedish Experience (IV)

Euro VI Truck with EGR System, tested at different temperatures

<table>
<thead>
<tr>
<th>Ambient temperature:</th>
<th>CO (g/km)</th>
<th>HC (g/km)</th>
<th>NO\textsubscript{x} (g/km)</th>
<th>CO\textsubscript{2} (g/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1; +22°C, start with hot (80°C) engine, 75 minutes</td>
<td>0.8</td>
<td>0.2</td>
<td>4.2</td>
<td>820</td>
</tr>
<tr>
<td>Test 2; -5°C, start with hot (60°C) engine, 75 minutes</td>
<td>1.1</td>
<td>0.2</td>
<td>6.6</td>
<td>910</td>
</tr>
<tr>
<td>Test 3; -5°C, start with cold (-5°C) engine, 75 minutes</td>
<td>1.0</td>
<td>0.2</td>
<td>9.9</td>
<td>1000</td>
</tr>
<tr>
<td>Test 4; -5°C, start with cold (-5°C) engine, first 20 min</td>
<td>4.4</td>
<td>0.5</td>
<td>38</td>
<td>1650</td>
</tr>
</tbody>
</table>
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