Der Beitrag der Automobilindustrie zum Weg in eine nachhaltige Mobilität

Dr. Stefan Keppeler
DaimlerChrysler AG, Group Research and Advanced Engineering

Vortragstagung SSM vom 20. September 2007
Verkehrshaus Luzern
Our Global Research And Development Network

- Group Research and Adv. Engineering: 2,000 Employees
- Mercedes Car Group Development: 8,400 Employees
Crude oil reserves worldwide in 2007: 165 bn tons

Average volume of Lake Geneva (Swiss): 89 bn m³

Confirmed crude oil resources would fit to an cube with an edge length of 5.8 km.

The annual consumption complies to an cube with a volume of 3.9 km³.

To Ensure Sustainable Mobility The Development Of Technologies To Reduce Fuel Consumption and Emissions Are Indispensable
Agenda

- Requirements on future propulsions - Emissions and Fuel Consumption
- Three steps to a sustainable mobility
  - Comparison conventional engines Otto/Diesel
  - DaimlerChrysler Diesel engines – a story of success
  - Technologies for emission reduction
  - Alternative Fuels: Characteristics and Potentials
- Conclusion and outlook – Technology Roadmap
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Global Challenges And Demand On Vehicles

Reduction of Emissions (incl. CO\textsubscript{2}-Emission) and Consumption
More economical Solution than the Competition, with higher Customer use

Global challenges

Demands on vehicle

- Customer
- Performance
- Price
- Current costs
- Reliability

- Regulations
- Safety
- Consumption
- Emissions
- Noise

Environment

- Clean Air
- Pollution
- Resources
- Recycling

Source: Downs 2002

Source: ASPO 2004

Source: Prognosis UNO
# NOx- And PM-Emissions

The major challenge is to fulfill the worldwide emission standards.

### Current Status

<table>
<thead>
<tr>
<th>Year</th>
<th>NOx (EU) [g/km]</th>
<th>PM (EU) [g/km]</th>
<th>NOx (EPA) [g/mi]</th>
<th>PM (EPA) [g/mi]</th>
<th>NOx (CARB) [g/mi]</th>
<th>PM (CARB) [g/mi]</th>
<th>NOx (Japan) [g/km]</th>
<th>PM (Japan) [g/km]</th>
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<tbody>
<tr>
<td>1998</td>
<td>0.9</td>
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<td>1.0</td>
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<td>1.0</td>
<td>0.08</td>
<td>0.55</td>
<td>0.14</td>
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<tr>
<td>1999</td>
<td>0.5</td>
<td>0.05</td>
<td>0.05</td>
<td>0.01</td>
<td>0.08</td>
<td>0.01</td>
<td>0.4</td>
<td>0.08</td>
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<tr>
<td>2000</td>
<td>0.25</td>
<td>0.025</td>
<td>0.60 (=Bin10)</td>
<td>0.08 (=Bin10)</td>
<td>0.2 (=LEV)</td>
<td>0.08 (=LEV)</td>
<td>0.28</td>
<td>0.052</td>
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<tr>
<td>2001</td>
<td>0.18</td>
<td>0.005</td>
<td>0.14 (=Bin8)</td>
<td>0.02 (=Bin8)</td>
<td>0.05 (LEV)</td>
<td>0.01 (LEV)</td>
<td>0.15</td>
<td>0.014</td>
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<tr>
<td>2002</td>
<td>0.08</td>
<td>0.005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>0.08</td>
<td>0.005</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2004</td>
<td>0.05</td>
<td>0.005</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>0.005</td>
<td>0.005</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>2006</td>
<td>0.005</td>
<td>0.005</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>0.005</td>
<td>0.005</td>
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<tr>
<td>2008</td>
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<td>0.005</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Tier 1**

- Tier 2 Phase-In
  - NOx: 0.2 (=LEV)
  - PM: 0.08 (=LEV)

**Tier 2**

- LEV2 Phase-In
  - NOx: 0.05 (LEV/ULEV)
  - PM: 0.01 (LEV/ULEV)

**Step 2**

- NOx: 0.55
- PM: 0.14

**Step 3**

- NOx: 0.4
- PM: 0.08

**Step 4**

- NOx: 0.28
- PM: 0.052

**Step 5**

- NOx: 0.15
- PM: 0.014

**Step 6**

- NOx: 0.08
- PM: 0.005
History of the Emission Limits for Diesel Passenger Cars

**Europe (NEDC)**
- Euro 1: 1996
- Euro 2: 2000
- Euro 3: 2005
- Euro 4: 2009
- Euro 5: 2014
- Euro 6: 2017

**USA (FTP 75**)
- Tier 0: 1994
- Tier 1: 2000
- Tier 2: 2005

**Japan (10.15 M)**
- Step 1: 1992
- Step 2: 1995
- Step 3: 2000
- Step 4: 2005
- Step 5: 2010
- Step 6: 2015

**Emissions Limits**

<table>
<thead>
<tr>
<th>Step</th>
<th>HC (g/km)</th>
<th>NOx (g/km)</th>
<th>CO (g/km)</th>
<th>PM g/mi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>0.27</td>
<td>2.0</td>
<td>7.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Step 2</td>
<td>0.14</td>
<td>2.7</td>
<td>7.2</td>
<td>0.12</td>
</tr>
<tr>
<td>Step 3</td>
<td>0.08</td>
<td>1.0</td>
<td>4.0</td>
<td>0.05</td>
</tr>
<tr>
<td>Step 4</td>
<td>0.05</td>
<td>0.6</td>
<td>0.3</td>
<td>0.02</td>
</tr>
<tr>
<td>Step 5</td>
<td>0.025</td>
<td>0.25</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>Step 6</td>
<td>0.008</td>
<td>0.08</td>
<td>0.08</td>
<td>0.03</td>
</tr>
</tbody>
</table>

**PM Limits**

<table>
<thead>
<tr>
<th>PM Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1: 0.008</td>
</tr>
<tr>
<td>Step 2: 0.08</td>
</tr>
<tr>
<td>Step 3: 0.25</td>
</tr>
<tr>
<td>Step 4: 0.28</td>
</tr>
<tr>
<td>Step 5: 0.63</td>
</tr>
<tr>
<td>Step 6: 0.83</td>
</tr>
</tbody>
</table>
Increasing Worldwide Requirements For Reduction Of Emissions And Fuel Consumption

- Euro V+VI limits temporarily fixed.
- ACEA Self Commitment: 140 g CO2/km in 2008, respectively 130 g CO2/km in 2012.

- USA: CAFE (27.5 / 22.5 mpg MY08) will be increased after MJ 2010.
- California: AB 1493 Standard of 27.5 mpg in 2009 increasing to >40 mpg from MY 2016 on. Litigation pending.
- ZEV: Review scheduled for 2007 with focus on availability of fuel cell cars.


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Roadmap To Sustainable Mobility

**Today**

- Fuel Cell technology

**Future**

- Improved & alternative fuels

- Efficient cars
  - with efficient powertrains
  - with or without hybrid modules
Roadmap To Sustainable Mobility

today

future

Efficient cars

with efficient powertrains

with or without hybrid modules
Continuous Improvement: Potentials For Combustion Engines

**Diesel engine**

**Characteristics**
- J Consumption
- L Emissions

**Key Technologies:**
- Injection system
- Combustion process
- Homogenization
- Turbocharger
- Exhaust gas after treatment

**Gasoline engine**

**Characteristics**
- J Emissions
- L Consumption

**Key Technologies:**
- Dethrottling
- Direct Injection
- Charging
- Reduction of friction
- Engine cooling management

**Target:** Gasoline Cars As Efficient As Diesels
Diesel Cars As Clean As Gasoline Cars
Technology Options For Gasoline Engines

ACP: Advanced Cam Phaser
DI: Direct injection
DS: Direct Start
CAI: Controlled Auto Ignition
MDS: Multi Displacement System
PI: Port Injection
TC: Turbocharging
VLC: Valve Lift Control
VVT: Variable Valve Train
VCR: Variable Compression Ratio
Diesotto: Otto-Engine with Diesel genes
The Future of Mercedes-Benz Otto-Engines
Mercedes Gasoline Direct Injection (1954)
in-line six-cylinder engine with direct fuel injection in the 300 SL
CLS 350 CGI:
- Power: 215 kW / 292 PS (+8%)
- Torque: 365 Nm (+4%)

Increasing fuel efficiency about 10% (Requires Ultra-Low-Sulfur Fuel)
Diesel History And Success

the evolution of the diesel is closely linked to innovative Mercedes-Benz developments


First Diesel engine (1893)
Prechamber Principle, Injection Pump by Prosper L’Orange (1908-1921)
1. Diesel Passenger Car Mercedes-Benz Type 260 D (1936)
4-Valve-Diesel, electr. Diesel Control (1993)
Common Rail Injection (1997)

Selke ignition engine by Rudolf Diesel (Patent 1892)
1. Diesel Truck Benz 5-Tons (1923)
Exhaust Turbo Charger (1976)
Noise Encapsulation (1983)
Particular Trap without additive, Maintenance free as standard in all MB Diesel Passenger Cars (2005)
First cleanest BLUETEC Diesel (2006)
Technology Options For Diesel Engines

EGR: Exhaust Gas Recirculation
CR: Common Rail
DPF: Diesel Particulate Filter
DOC: Diesel Oxidation Catalyst
NSC: NOx-Storage Catalyst
SCR: Selective Catalytic Reduction
TC: Turbocharger
In Three Steps – Towards The Cleanest Diesel Of The World

1. Internal Measures, Clean Fuels
2. Oxidising Catalytic Converter, Particulate Filter
3. BLUETEC Technology

- Efficient and clean combustion process
- Lower emissions incl. particulate emissions
- Reduce emissions of nitrogen oxides by 80 percent.
Diesel Engines

“... as clean as Gasoline engines ....“

Vehicle segment

The optimal system for every segment

BLUETEC I

Oxi catalyst
Particulate filter
SCR catalyst
DeNox catalyst

BLUETEC II

Oxi catalyst
Particulate filter
AdBlue tank
AdBlue metering valve
SCR catalyst

BLUETEC technology enables us to produce the cleanest Diesel vehicles of each class
Hybrid – Functionality and FE-Potential

Functionalities

- E-Drive
- Boost
- Power split transm.
- Recuperation
- Start/Stop

Classification

<table>
<thead>
<tr>
<th>Functionality</th>
<th>FE improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro-Hybrid</td>
<td>5%</td>
</tr>
<tr>
<td>Mild-Hybrid</td>
<td>15%</td>
</tr>
<tr>
<td>Full-Hybrid</td>
<td>25%</td>
</tr>
</tbody>
</table>

Cost

- Micro
- Mild
- Full (parallel)
- Full (power split)

FE improvement:
- 5%
- 15%
- 25%
- 30%
Experiences with DaimlerChrysler Fuel Cell Vehicles

<table>
<thead>
<tr>
<th>60 F-Cell vehicles in customer hands (end 2004)</th>
<th>36 Buses (Citaro) Europe, Australia, China</th>
<th>3 Light Duty vehicles at UPS Europe, USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>~1.280.000 km, 37.880 h</td>
<td>~1.801.000 km, 120.700 h</td>
<td>~180.000 km, 5.530 h</td>
</tr>
</tbody>
</table>

- DaimlerChrysler is pioneer of Fuel Cell Vehicle.
- Daily operation of more than 100 FCV’s all over the world.
- Long experience with FCV’s (first FCV in 1994).
- Big variety of FCV’s: Passenger cars, buses, vans.
Future Engine Concepts Require Adapted Fuels

**Today**
- Gasoline and Diesel Engines
  - Clean Conventional Fuels
    (Required for Particulate- and NOx-Aftertreatment Systems)

**Tomorrow**
- Advanced Gasoline and Diesel Engines
  - Blends With Synthetic Fuels
    (Allow cost effective in-cylinder emission reduction)

**Future**
- New Engine Concepts
  - New Synthetic Fuels
    (Potential enabler for new engine concepts)
Alternative Propulsion Technologies
DC is working on various propulsion systems

Current and future requirements concerning energy, environmental issues, sustainable mobility and business environment demand a versatile propulsion portfolio.
Roadmap To Sustainable Mobility

Improved & alternative fuels
DC Fuel Roadmap

Limited Energy Resources and Impact of Fuels on Fuel Economy and Emissions demand for an Energy Strategy

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>High in Sulfur, high aromatics</td>
</tr>
<tr>
<td>Gas to Liquids</td>
<td></td>
</tr>
<tr>
<td>Biomass to Liquids</td>
<td></td>
</tr>
<tr>
<td>Compressed Natural Gas</td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Emission-free, almost CO₂-free</td>
</tr>
<tr>
<td>Synthetic (GTL) Fuels</td>
<td>Low emissions</td>
</tr>
<tr>
<td>Clean Conventional Fuels</td>
<td>Sulfur-free, low in aromatics</td>
</tr>
<tr>
<td>1st Generation Biofuels</td>
<td>(FAME, Bio-Ethanol, …)</td>
</tr>
<tr>
<td>2nd Gen. Biofuels (BTL)</td>
<td>Low emissions and almost CO₂-free</td>
</tr>
<tr>
<td>Based on Biomass</td>
<td></td>
</tr>
<tr>
<td>Based on Natural Gas</td>
<td></td>
</tr>
<tr>
<td>Based on Crude Oil</td>
<td></td>
</tr>
<tr>
<td>Based on Renew. Energy</td>
<td></td>
</tr>
</tbody>
</table>

Diversification
Synthetic fuels (CTL, GTL, BTL and BTH) are produced using similar technologies. These synthetic fuels can be tailored to a certain extend to the needs of the IC engines.

1. **Coal** → Transformation into Synthesis Gas → CTL Diesel (clean)
2. **Natural Gas** → Transformation into Synthesis Gas → GTL Diesel (clean)
3. **Biomass** → Transformation into Synthesis Gas → BTL Diesel (clean, CO$_2$-neutral)

Alternative: Direct use of hydrogen from gasification e.g. in fuel cells → BTH (clean, C-free)

<table>
<thead>
<tr>
<th>Property</th>
<th>Range worldwide</th>
<th>Regulation Needs/Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water [mg/kg]</td>
<td>1</td>
<td>Cap / prevention of phase separation</td>
</tr>
<tr>
<td></td>
<td>10 - 200</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 - 10,000</td>
<td></td>
</tr>
<tr>
<td>Lubricity [nm]</td>
<td>230</td>
<td>Cap / lubrication high pressure pump</td>
</tr>
<tr>
<td></td>
<td>400 - 460</td>
<td></td>
</tr>
<tr>
<td></td>
<td>690</td>
<td></td>
</tr>
<tr>
<td>T 95 [°C]</td>
<td>275</td>
<td>Cap and range / spray formation, combustion of inj. fuel</td>
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<tr>
<td></td>
<td>340 - 360</td>
<td></td>
</tr>
<tr>
<td></td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Density [kg/l]</td>
<td>0.805</td>
<td>Range / fuel economy acc. to engine calibration range</td>
</tr>
<tr>
<td></td>
<td>0.82 - 0.845</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.875</td>
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<tr>
<td>Cetane [-]</td>
<td>38</td>
<td>Cap and range / combustion timing acc. to engine calibration</td>
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<td>51 - 55</td>
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<td></td>
<td>61</td>
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<tr>
<td>Sulfur [mg/kg]</td>
<td>1</td>
<td>Cap / durability exhaust after-treatment, environm. benefit</td>
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<td>10 - 50</td>
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</tr>
<tr>
<td></td>
<td>1,000</td>
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</tr>
</tbody>
</table>

Quality of real world fuels often reveal great discrepancies in comparison to WWFC (World Wide Fuel Charter) recommendations.
**SunDiesel**

**Vehicle/Engine:**
E320 CDI (Series-Production-Vehicle)
Displacement: 3 l
Power: 165 kW
Torque: 540 Nm
Injection System: Common Rail
Gearbox: 7-Speed-Automatic transmission 7G-Tronic

**Fuel Consumption**
7,8 Liter/100km SunDiesel
(7,5 Liter with EN590 Diesel)

**CO₂-Emissions**
Well-to-Wheel: ca. 20 g CO₂/km SunDiesel
Tank-to-Wheel: ca. 185 g CO₂/km with SunDiesel
(194-202 g CO₂/km with EN590 Diesel)

**Savings (vs. fossile Diesel)**
CO₂: ca 90 % Well-to-Wheel
Fuel: + 5% volumetric, - 5% gravimetric
Hydrogenated Vegetable Oils (HVO’s) Pro’s & Con’s

**Pro’s**
- Excellent fuel quality
- Suitable for blends with conventional diesel in a wide range
- Lower boiling range, compared to FAME, makes HVO blends more suitable for modern diesel vehicles with particulate filters
- Better oxidation stability compared to FAME
- Considerable CO2-reduction potential (similar to biodiesel)

**Con’s**
- Limited cold flow properties compared to conventional diesel
- Restricted biomass potential, depends on the availability of vegetable oil
- Lower CO2-reduction potential compared to BTL

Destillation Curve for Biofuels Compared to conventional Diesel

Compared to FAME (blue line) HVO’s (green line) boiling range is about 40°C lower.
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Technology Costs And CO$_2$-Emissions For Different Propulsion Systems

Costs (incl. EGN)

Gasoline
DI+...

Emission Regulation

Target

Diesel

CO$_2$

Alternative Propulsions

Target

PI
Conclusions

β Internal combustion engines will remain the dominant powertrain over the next decade. The degree of hybridization will depend on market and car segment.

β For optimum results, further improvements in fuel quality are necessary. Intensive interactions between oil industry and car manufacturers are required to ensure the availability of clean conventional fuels, synthetic fuels and hydrogen.

β DaimlerChrysler is committed to develop appropriate technologies to secure a sustainable and affordable mobility.
Thank you for your attention!

DAIMLER CHRYSLER