"Strategies for the reduction of CO₂-emissions from Commercial Vehicles - are alternative powertrains the solution?"

Vienna, November 15, 2011

Dr.-Ing. Manfred Schuckert
Senior Manager, Corporate Strategy, Daimler AG, Germany
Sustainability: The Key Driver of the Next Decade

Global Warming and Energy Security
- IPCC Reports 2007
- Demand for gasoline/diesel greater than oil supply
- Shortage of oil and gas in some markets

Legislation and regulations
- Emissions (NOx, PM, CH)
- City regulations
- Regional regulations

Alternative Powertrain & Alternative Fuels
- Hybrid
- CNG-engine
- F-Cell
- Biodiesel
- Compressed Natural Gas
- NexBTL, BTL (Biofuels 2nd generation)

Alternative means of transportation
- Ship
- Train
- Airplane

Conventional Technology Optimization
- Vehicle Operation
- Aerodynamics
- Optimization of Auxiliaries
  Etc.

Sustainable Transport of Goods and People
- Economical viability (Lower fuel consumption, tax benefits, reduced maintenance cost, ...)
- Sustainable Transport
- Green Procurement and image

Customer Benefit
- Sustainable Transport
- Green Procurement and image

Strategy & Alliances
Society is changing

Customers have new attitudes and new values!
Criteria Pollutant Regulations have dominated the HDV development the last three decades

- **Customer Benefit**
  - Economical viability (lower fuel consumption, tax benefits, reduced maintenance cost, ...)
  - Sustainable Transport
  - Green Procurement and image

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- **Alternative means of transportation**
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  - Train
  - Airplane

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  - Emissions (NOx, PM, CH)
  - City regulations
  - Regional regulations
By 2014/16 the Triade Markets will have similar requirements – many other countries like China will follow European emission regulations.

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**History of emission limits for USA, Japan and Europe - The well known facts -**

- **EPA**
  - 1990: NOx = 0.27, PM = 0.013
  - 1994: NOx = 0.18, PM = 0.01

- **Japan**
  - 1990: NOx = 400 ppm, PM = 0.7
  - 2005: NOx = 0.7, PM = 0.01

- **Europe**
  - 1992: NOx = 15.8, PM = 0.4
  - 2013: NOx = 0.4, PM = 0.01
Clean Air for Europe (2005): Especially with regard to NO\textsubscript{x} and PM beyond Euro VI HDV there is no need for further emission legislation in the Triad markets.

Heavy-Duty commercial vehicles in Germany: Development of NO\textsubscript{x} and PM-emissions

![Graph showing NO\textsubscript{x} and PM emissions over time, with Euro emissions levels indicated.](image)

Source: calculation with TREMOD 4.17 (Daimler, GR/VGE)  Heavy-Duty Commercial Vehicles: Buses, Trucks and Semi-Tractors
...but in the NON-Triad markets there is still a long way to go
PM10 concentration annual mean

### Worldwide by country

![Worldwide PM10 concentration map](source: WHO 2011)

### European capitals

![European PM10 concentration map](source: WHO 2011)

<table>
<thead>
<tr>
<th>WHO recommendation annual mean:</th>
<th>EU limit value annual mean:</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 µg/m³ (50 µg/m³ daily mean)*</td>
<td>40 µg/m³ (50 µg/m³ daily mean; max. 35 days per year)**</td>
</tr>
</tbody>
</table>

*WHO air quality guidelines (2005)
**EU directive 2008/50/EG

On an average country view WHO recommendation is exceeded by most countries
EU limit value is exceeded particularly in cities of South and Eastern Europe

![Strategy & Alliances](source: WHO 2011)
Sustainability: The Key Driver of the Next Decade
Alternative powertrains driven by CO2 legislation

- IPCC Reports 2007
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- Shortage of oil and gas in some markets
- Emissions (NOx, PM, CH)
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Alternative means of transportation:
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- Vehicle Operation
- Aerodynamics
- Optimization of Auxiliaries
- Etc.

Customer Benefit:
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Sustainability: The Key Driver of the Next Decade
Alternative powertrains driven by CO2 legislation
New/tightened consumption-/emission regulations – a steady ambitious challenge

<table>
<thead>
<tr>
<th>Fuel Consumption / GHG limits</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passenger Cars</strong></td>
<td><strong>Light Commercial Vehicles</strong></td>
<td><strong>Heavy Duty Vehicles</strong></td>
</tr>
<tr>
<td><strong>Targets</strong></td>
<td><strong>Targets</strong></td>
<td><strong>Targets</strong></td>
</tr>
<tr>
<td>• 2012: 130 g CO2/km</td>
<td>• 2012: 175 g CO2/km</td>
<td>• First fuel consumption measurement procedure</td>
</tr>
<tr>
<td>• 2020: 95 g CO2/km</td>
<td>• 2020: 147 g CO2/km</td>
<td></td>
</tr>
<tr>
<td><strong>GHG regulation</strong></td>
<td>• Signed by president Obama August 2011</td>
<td>• Signed by President Obama August 2011</td>
</tr>
<tr>
<td>250 g CO2/km</td>
<td>• Work factor related legislation</td>
<td>• Engine vehicle related targets until 2019</td>
</tr>
<tr>
<td>CAFÉ ca. 34,1 mpg (2016)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• AB 1493 in California et seq.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Top Runner 2010-2015-2020:</strong> Specific targets depending on segment</td>
<td><strong>Top Runner related</strong></td>
<td><strong>Top Runner related</strong></td>
</tr>
<tr>
<td><strong>Chinese consumption regulations (phase 1-3)</strong></td>
<td><strong>Phase 1 and 2 decided</strong></td>
<td><strong>China:</strong></td>
</tr>
<tr>
<td><strong>South Korean, Swiss consumption regulation</strong></td>
<td></td>
<td>• Regulation under development</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Finalized by 2013</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measures</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>ICE optimization</td>
<td>Hybridization</td>
<td>Clean fuels</td>
</tr>
<tr>
<td>Emission-free powertrains</td>
<td></td>
<td></td>
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<tr>
<td>(battery/fuel cell)</td>
<td></td>
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</tr>
</tbody>
</table>

Strategy & Alliances
CO₂ target for passenger cars in Europe by 2020: 95 g CO₂/km target will significantly change the ‘Mobility Mix’

The application of emission free powertrain technologies (ZEV: Zero Emission Vehicle) is needed to reach the fleet target of Mercedes-Benz Cars

CO₂ roadmap 2020: conventional drives and hybrid vehicles

ACEA fleet EU [g/km]

Share of emission free vehicles


Strategic planning Strategic horizon
Vision S 500 Plug-in HYBRID

Advantage of Plug-In Hybrids:
Emission free driving in urban areas
Hybrid driving in rural areas

Benefits

• More power at less consumption
• High comfort
• Recuperation of braking energy
• Better energy management

But
Costs....
### Regulatory activities on CO₂ for HDV in major regions

<table>
<thead>
<tr>
<th>Year</th>
<th>USA</th>
<th>China</th>
<th>Japan</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Aug.: Rule Signed</td>
<td>Industrial FC Standard in place</td>
<td>FE regulation defined since 2006</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>Initial Engine &amp; Vehicle Standards in force</td>
<td>National GB standard in place</td>
<td>Recommended approach: CO₂ declaration procedure for HDV</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>Tightened Engine &amp; Vehicle Standards in force</td>
<td>National GB standard in place</td>
<td></td>
<td></td>
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<tr>
<td>2014</td>
<td></td>
<td>National GB standard in place</td>
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<tr>
<td>2015</td>
<td></td>
<td>National GB standard in place</td>
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<td>2016</td>
<td></td>
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<td>2017</td>
<td></td>
<td>National GB standard in place</td>
<td></td>
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<tr>
<td>2018</td>
<td></td>
<td>National GB standard in place</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td></td>
<td>National GB standard in place</td>
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</tr>
</tbody>
</table>

- GHG reduction standards/performance requirements in all key markets in place or under development apart from Europe.
- What is the most effective approach for Europe?
  - Performance requirements vs. CO₂ declaration?
  - Regulatory approach vs. market oriented approach?
Current ongoing work with EC resp. EC consultants on a CO₂ strategy for HDV

<table>
<thead>
<tr>
<th>Commission studies</th>
<th>Lot 1</th>
<th>published in 03/ 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment of reduction potential</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Task 1: Vehicle Market and Fleet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Task 2: Fuel Use and CO₂ emissions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Task 3: Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Task 4: Policy Assessment</td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lot 2</th>
<th>Method to quantify CO₂ emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Methods</td>
</tr>
<tr>
<td></td>
<td>• Cycles</td>
</tr>
</tbody>
</table>

ACEA
was/is actively involved in the process e.g.:
• LOT 1: Segmentation and sales figures are provided by ACEA
• LOT 2: Test Vehicles are provided for measurements and to establish a continuous exchange

Commission studies underline: Significantly higher complexity of HDV industry compared to LD/LCV – industry – no "easy" realization of regulation possible.

- Passenger cars (M1)
  - defined ✓
- Light CV/ Vans (N1)
  - defined ✓
- Trucks / Buses (N2/M2/N3/M3) > 3.5t GVW

Finalization expected end of 2012
LOT 1 - Business as Usual Scenario (BAU)

Key Assumptions:
- Segmentation used based on ACEA proposal (trucks) with 3.5 to 7.5 segment added
- Baseline year: 2010
- Vehicle Mileage: Stock-model based calculation: assuming constant yearly mileage per segment.
- Yearly FC Improvements rates (Vehicle & Powertrain)
- Penalties: Euro VI & Euro VII (!) each 3%

Businesses As Usual (BAU) demand compensates assumed yearly FC reduction.

BAU scenario shows significant increase of CO₂ despite annual reduction rates for HDV.
- Will vehicle mileages rise as forecasted by LOT1 study?
- Are annual reduction rates realistic?

Development Vehicle Mileage

\~18\% & 35\% increase in mileage (vkm) to 2020 & 2030, respectively

CO₂ Tank to wheel

CO₂ Well to wheel

Well to Wheel: Until 2020 demand increase is offset by increased biofuel blends.
NAS-Results: Technology and Costs of Reducing Fuel Consumption of HDV: 2015 to 2020

US National Academy of Science study expects high potential from engines and hybrids – technology costs at least for Europe not acceptable
Innovative powertrain systems in all business fields will be the fundament for sustainable mobility

Further optimization of conventional internal combustion engines
- BlueTec
- BlueEfficiency
- Direct injection

Increase efficiency with hybridization
- Hybrid
- Plug-In Hybrid

Locally emission-free driving

A set of technologies will be necessary to fulfill environmental and economical requirements for all transportation tasks
The New Mercedes-Benz Actros Benchmark in Fuel Efficiency


<table>
<thead>
<tr>
<th>Tour</th>
<th>Vehicles</th>
<th>Route</th>
<th>Consumption Measurement</th>
<th>New Actros</th>
<th>Economical Driving</th>
<th>Photo Gallery</th>
<th>Press Section</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Actros 1844 (Euro 5)</td>
<td>9020 km</td>
<td>77.5 km/h</td>
<td>27.1 l/100 km</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>New Actros 1845 (Euro 5)</td>
<td>9020 km</td>
<td>77.5 km/h</td>
<td>25.1 l/100 km</td>
</tr>
<tr>
<td></td>
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Strategy & Alliances
History: big wins in fuel economy of HDV
–30% reduction in fuel consumption

• Reduction of fuel consumption is one of the most important customer purchase criteria.
• Competition driven drastic reduction of fuel consumption of HDV observable.
• Strong emission reduction measures restrict further fuel economy improvements.

* Test cycle not fully comparable to Lastauto Omnibus
Environmental Benefits – The New Actros Saves*:

- **Euro V**: ~800'000 toe fuel savings, corresponding to nearly total annual oil consumption for water heating in Germany.
- **Euro VI**: fuel savings cover about half of the total annual oil consumption.

- **Euro V**: ~2.6 Mio t CO₂ emission reduction, corresponding to 60% of total annual CO₂ emissions of City of Stuttgart (600,000 inhabitants).
- **Euro VI**: ~1.3 Mio t CO₂ emission reduction, corresponding to 30% of total annual CO₂ emissions of City of Stuttgart.

- **Euro V**: no savings
- **Euro VI**: Emission reductions in the magnitude of annual NOₓ emissions of a medium EU member state (e.g. Ireland.)

The new Actros with Euro VI technology will be the environmental Benchmark in the Heavy Duty Industry.
Innovative powertrain systems in all business fields will be the fundament for sustainable mobility

**MB Cars**
“Green Technology Leadership”

**Trucks**
“Shaping Future Transportation”

**Buses**

**MB Vans**
“Professional answers to green challenges”

Further optimization of conventional internal combustion engines
- BlueTec
- BlueEfficiency
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Increase efficiency with hybridization
- Hybrid
- Plug-In Hybrid

Locally emission-free driving

A set of technologies will be necessary to fulfill environmental and economical requirements for all transportation tasks
Modular hybrid technologies - one step to reach the future target of ZEV (Zero Emission Vehicle)

Concentration of competence and resources: CO₂ efficiency by hybridization and electrification
Integrated battery production in Kamenz, Germany is a win-win situation for all the stakeholders.

Business and employment opportunities:

<table>
<thead>
<tr>
<th>OEMs</th>
<th>Supplier &amp; engineering service provider</th>
<th>Chemical industry</th>
<th>Logistics</th>
<th>Plant / process engineering</th>
<th>Electric / electronics</th>
<th>Scientific community</th>
</tr>
</thead>
</table>

DAIMLER
Atego BlueTec Hybrid is based on the modern EURO5 BlueTec EEV power train – Truck of the Year 2010

Technical specification:
- New Atego, 1222L EURO5 BlueTEC EEV
- Engine: 4 cylinders, OM924 160 kW, 810 Nm
- Hybrid system: P2 parallel hybrid
- Electric engine: 44kW, 420Nm
- Battery: 2kWh Li-Ion Battery, 340V

Technical targets:
- Contribute to sustainable mobility
- Reduce fuel consumption by 8-12%
- Reduce CO2, NOx and particle emissions significantly
- Reduce noise level
The components of the parallel hybrid system are integrated into the Mercedes-Benz drive train.
Innovative powertrain systems in all business fields will be the fundament for sustainable mobility

Further optimization of conventional internal combustion engines
- BlueTec
- BlueEfficiency
- Direct injection

Increase efficiency with hybridization
- Hybrid
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Locally emission-free driving

A set of technologies will be necessary to fulfill environmental and economical requirements for all transportation tasks.
Vito E-CELL: electromobility for everyday use

- Electric vehicles from Mercedes-Benz are by no means "hair shirt" vehicles
- Reliability – durability – safety – comfort – driving enjoyment
Growing interest in electric vehicles with zero local emissions: Vito E-Cell

**Vehicle Specifications and Performance**
- Gross Vehicle Weight: 2.8t or 3.05t
- Payload: 600kg or 850kg
- Speed (max): 80km/h (speed limiter)
- Range: 130 km
- Acceleration (0-50 km/h): 6.5 sec.

**Engines and Batteries:**
- Engine Power: 60 kW (80 hp; 280 Nm)
- Battery: 16 lithium(Li)-ion batteries
- Capacity: 36 kWh
- Recharge Time: ~ 5 hours (400 V); 10 hours (230V)
Heavy Duty Trucks: Today's battery technology does not yet allow full electric driving in heavy commercial vehicles application.

- What keeps us from driving fully electrically?

<table>
<thead>
<tr>
<th>Range</th>
<th>Diesel</th>
<th>100% electric propulsion through Li-Ion Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 km 12t Delivery Truck</td>
<td>100 litres 85 kg</td>
<td><img src="image" alt="2.6 m³ 5.3 t" /></td>
</tr>
<tr>
<td>3000 km 40t Long-distance Truck</td>
<td>990 litres 836 kg</td>
<td><img src="image" alt="26 m³ 52t" /></td>
</tr>
</tbody>
</table>

Calculation: consumption: 20 l/100 km / 33 l/100 km, efficiency: diesel engine = 40%, electric motor = 80%, energy content: diesel = 11.8 kWh/kg, Li-Ion battery = 0.19 kWh/kg, weight: diesel = 0.845 kg/l, Li-Ion battery = 2 kg/l.
Fuso Canter E-CELL – Prototype: All options need to be considered

Vehicle Specifications and Performance
- Gross Vehicle Weight: 3.5 t
- Payload: 895 kg
- Speed (max): 80km/h (speed limiter)
- Range: 120 km

Engines and Batteries:
- Engine Power: 70 kW (95 hp; 300 Nm)
- Battery: 24 lithium(Li)-ion batteries (19.5 kg/unit)
- Capacity: 40 kWh
- Recharge Time: ~ 6 hours (380 V)
# Development of Fuel Cell Vehicles at Daimler

<table>
<thead>
<tr>
<th>Concept vehicles</th>
<th>Fleet Tests</th>
<th>Market Introduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Necar 1</td>
<td>Fuel Cell Sprinter</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>Citaro Fuel Cell</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fuel Cell Sprinter</td>
<td></td>
</tr>
<tr>
<td>Necar 2</td>
<td>F-Cell A-Class</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F-Cell B-Class</td>
<td></td>
</tr>
<tr>
<td>Necar 3</td>
<td>F-Cell A-Class Advanced</td>
<td></td>
</tr>
<tr>
<td>Necar 4</td>
<td>F600</td>
<td></td>
</tr>
<tr>
<td>Necar 5</td>
<td></td>
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<td></td>
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</tbody>
</table>

- **1994**: Necar 1
- **1995**: Fuel Cell Sprinter
- **1996**: Necar 2
- **1997**: Necar 3
- **1998**: Necar 4
- **1999**: Necar 5
- **2000**: F-Cell A-Class
- **2001**: F-Cell B-Class
- **2002**: F-Cell A-Class Advanced
- **2003**: F600
- **2004**: Citaro Fuel Cell
- **2005**: Fuel Cell Sprinter
- **2006**: Citaro FuelCELL- Hybrid
- **2007**: Claro FuelCELL- Hybrid
- **2010**: Future
### Specifications Fuel Cell Citaro:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle type</td>
<td>Mercedes-Benz Citaro</td>
</tr>
<tr>
<td>Fuel Cell System</td>
<td>PEM, 160 kW (216 hp)</td>
</tr>
<tr>
<td>Drive</td>
<td>Electric hub wheel drive</td>
</tr>
<tr>
<td></td>
<td>Power (Continuous):</td>
</tr>
<tr>
<td></td>
<td>2x80 kW (2x108 hp)</td>
</tr>
<tr>
<td>High Voltage Grid</td>
<td>450 – 750 VDC</td>
</tr>
<tr>
<td>Fuel</td>
<td>Compressed Hydrogen (350 bar / 5,000 psi)</td>
</tr>
<tr>
<td>Range</td>
<td>Target: 200 km (125 miles)</td>
</tr>
<tr>
<td>Max Speed</td>
<td>80 km/h (50 mph)</td>
</tr>
<tr>
<td>Battery</td>
<td>LiIon, Power (Continuous / Peak):</td>
</tr>
<tr>
<td></td>
<td>120 kW / 100 kW, Capacity: 30 Ah, 17 kWh</td>
</tr>
<tr>
<td>Passenger Capacity</td>
<td>Up to 75</td>
</tr>
</tbody>
</table>

### Main targets:
- Improving fuel efficiency by about 100%
- Improve passenger capacity by about 20 to 30%
- Improve significantly the overall package, e.g. lifetime of FC, maintenance requirements...
The new Citaro FuelCELL-Hybrid with clear advantages compared to the 2nd generation of Fuel Cell Citaro

<table>
<thead>
<tr>
<th></th>
<th>Curb Weight</th>
<th>Passenger Capacity</th>
<th>Efficiency FC System</th>
<th>HV - Battery</th>
<th>H2 - Consumption</th>
<th>Warranty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citaro FC 2004</td>
<td>14.2 t</td>
<td>72</td>
<td>48 - 38 %</td>
<td>--</td>
<td>20 - 24 kg/100 kg</td>
<td>2 years 2,000 hrs.</td>
</tr>
<tr>
<td>Citaro FuelCELL-Hybrid 2010</td>
<td>13.2 t</td>
<td>76</td>
<td>58 - 51 %</td>
<td>26.1 kWh</td>
<td>10 - 14 kg/100 km</td>
<td>6 years 12,000 hrs</td>
</tr>
</tbody>
</table>
ACEA Vision 2020: Reduction of CO₂ emissions by 20% by 2020

Compared to 2005 in 2020 trucks need 20% less fuel and emit 20% less CO₂
The Future of the Automobile
sustainable and flexible
innovative and fascinating