Europe’s evolving fuel situation
A view from Daimler

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Business Environment & Corporate Regulatory Strategy

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Overview

1. Motivation and market forecasts
2. Passenger Cars: Drivetrain concepts and electric vehicles
3. Emissions regulations for HD vehicles
4. Natural gas – the alternative fuel?
5. Future CO₂ emissions and fuel challenges
6. Summary and outlook
Automotive market - a growing industry
Primarily driven by Non-Triad automotive demand

**World automotive market** – annual new registrations of passenger cars and commercial vehicles (in m units)

<table>
<thead>
<tr>
<th>Year</th>
<th>Non-Triad</th>
<th>Triad (NAFTA, WEU, J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>28.3 m</td>
<td>41.9 m</td>
</tr>
<tr>
<td>2008</td>
<td>29.4 m</td>
<td>37.3 m</td>
</tr>
<tr>
<td>2009</td>
<td>31.7 m</td>
<td>33.4 m</td>
</tr>
<tr>
<td>2010</td>
<td>38.9 m</td>
<td>34.8 m</td>
</tr>
<tr>
<td>2011</td>
<td>42.8 m</td>
<td>35.4 m</td>
</tr>
<tr>
<td>2015</td>
<td>56 - 58 m</td>
<td>40 - 41 m</td>
</tr>
<tr>
<td>2020</td>
<td>115 - 120 m</td>
<td>40 - 42 m</td>
</tr>
</tbody>
</table>

**Automotive market growth**

<table>
<thead>
<tr>
<th>Year</th>
<th>Triad</th>
<th>Non-Triad</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011-‘15</td>
<td>5 m</td>
<td>19 m</td>
</tr>
<tr>
<td>2015-‘20</td>
<td>1 m</td>
<td>22 m</td>
</tr>
</tbody>
</table>

- World vehicle population above 1 Billion units since 2010.
- Long-term demand growth only in non-Triad markets.

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Forecast transportation performance by 2020
TRIAD vs. BRICS countries

Comparison of road freight transport performance in different regions (in billion ton-kilometers)

Road transportation forecast for BRICS countries with very high growth rates: legislation and efficiency measures are highly challenged regarding social and environmental aspects.

Source: Progtrans 2012
Future key-role in truck business will be in emerging markets. Asian growth in truck markets dominating global sales

Fluctuating sales volume growth especially in HDT, MDT directionally less volatile

Asian volume growth comes in markets other than China, even though China’s volume is of major influence on the global industry volume.
Due to high costs of new vehicles average vehicle fleets are ageing: Example truck sales in Brazil from 1957 - 2012

Introduction of new technologies is complex and results in additional customer costs

Changes in emission standards followed by market reactions

Especially in emerging markets it will take a long time to replace old vehicles

Source: Cummins 2013
Growing vehicle fleets in the non-Triad markets resulting in changing fuel demands and increasing discussions about CO₂

World-wide fuel demands for road transportation

Fuel consumption and resulting CO₂ emissions - heavily influenced by HD vehicles
Mainly driven by growth in fleets and road transportation in emerging markets

- Emerging markets with higher payload have advantages in transport efficiency – but constantly increasing fuel demand driven by fleet growth.
- Technology compensating penalties in fuel consumption by emission regulation in Triad markets.

Europe’s evolving fuel situation - A view from Daimler
Coming changes in legislation with strong influence on markets
Many topics coming up looking towards 2020

Announced regulations with major challenges – not only for the automotive industry

**CO₂ emission legislation**
Demanding efficient vehicles and new/enhanced drivetrain technologies

- e.g. NG drivetrain
  1. Tanks
  2. Shut-off valve
  3. Gas pressure control and filter
  4. Gas injection system
  5. Control system
  6. Methane catalyst

**Fuels**

- Sulfur
- Quality
- Biofuels
- ...

- Diesel sulfur content is changing in emerging markets
- Important engine technologies are hindered by high sulfur content in fuels especially in emerging markets

**Infrastructure**

- 2020 NG
- Member States EU
- EISA - USA
- China
- Brazil
- ....

- European LNG corridor with stations every 400 km (181 in total, today 38)
- LNG fueling infrastructure for waterborne transport at 139 maritime and inland ports

- Different CO₂ regulations and targets in the markets are challenging.
New/tightened consumption-/emission regulations
Ambitious challenge which will change the automotive industry

**Fuel Consumption / GHG limits**

<table>
<thead>
<tr>
<th></th>
<th>Passenger Cars</th>
<th>Light Commercial Vehicles</th>
<th>Heavy Duty Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Targets</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012:</td>
<td>130 g CO₂/km</td>
<td>175 g CO₂/km</td>
<td>• Fuel consumption measurement procedure under development</td>
</tr>
<tr>
<td>2020:</td>
<td>95 g CO₂/km</td>
<td>147 g CO₂/km</td>
<td>• CO₂ reduction strategy announced by EC for 1.Q. 2013</td>
</tr>
<tr>
<td><strong>California</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• CAFÉ ca. 34,1 mpg (2016)</td>
<td></td>
<td></td>
<td>• Signed by President Obama, August 2011</td>
</tr>
<tr>
<td>• California: 22% Zero Emission Vehicles in 2025</td>
<td></td>
<td></td>
<td>• Work factor related legislation</td>
</tr>
<tr>
<td>2017 – 2025:</td>
<td>54,5 mpg in 2025</td>
<td></td>
<td>• Engine &amp; vehicle related targets until 2019</td>
</tr>
<tr>
<td><strong>Top Runner</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010-2015-2020:</td>
<td>• Specific targets depending on segment</td>
<td></td>
<td>• Top Runner related</td>
</tr>
<tr>
<td><strong>Chinese Fuel consumption regulations (phase 1-3)</strong></td>
<td></td>
<td></td>
<td>• 5% and 10% over-fulfillment will be subsidized</td>
</tr>
<tr>
<td><strong>CAFC</strong></td>
<td></td>
<td></td>
<td>• Regulation under development</td>
</tr>
<tr>
<td>2020:</td>
<td>CAFC for 2020 likely to be targeted around 5l/100km</td>
<td>Phase 1 and 2 decided</td>
<td>• Finalized by 2013</td>
</tr>
</tbody>
</table>

**Motivation and frame conditions**

- Measures:
  - ICE optimization - Hybridization - Clean fuels - Emission-free powertrains (battery/fuel cell)
**CO₂ target for passenger cars in Europe by 2020**

95 g CO₂/km target will significantly change the 'Mobility Mix'.

**CO₂ roadmap 2020: conventional drives and hybrid vehicles**

- The application of emission free powertrain technologies (ZEV: Zero Emission Vehicle) is needed to reach the fleet target.
- Will consumer behavior follow?

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*Europe's evolving fuel situation - A view from Daimler*
GHG limits for passenger cars in major markets enacted

- Average car fuel consumption differed widely between major markets in the past.
- Due to similar tight GHG limits in many regions OEMs will be challenged by similar requirements worldwide.

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Sources: EC (2012), VDA 2012
GHG limits for passenger cars in all major markets enacted

Historical fuel consumption and future GHG limits

• Average car fuel consumption differed widely between major markets in the past.
• Due to similar tight GHG limits in each region OEM are faced with same demands worldwide

Sources: ICCT (2013), EC (2012)
Automotive industry is working on solutions
The wide variety of drivetrain concepts can hardly be handled

**Innovative powertrain systems for sustainable mobility**

<table>
<thead>
<tr>
<th></th>
<th>Conventional Engines</th>
<th>Conventional Hybrid</th>
<th>Electric Vehicles</th>
<th>Fuel Cell Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>passenger cars and vans</strong></td>
<td>Petrol: E5, E10, E20, E85, E100</td>
<td>Diesel: B5, B7</td>
<td>conventional + full hybrid</td>
<td>battery range 100-250/400 km</td>
</tr>
<tr>
<td></td>
<td>Gas: CNG</td>
<td></td>
<td>conventional + plug-in hybrid</td>
<td>various power ranges, up to 1,000 km</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>conventional + range extender</td>
<td>F-CELL</td>
</tr>
<tr>
<td><strong>trucks and buses</strong></td>
<td>Diesel: B5, B7, B10, B20</td>
<td>Gas: CNG, LNG (type 1), LNG (type xy)</td>
<td>conventional + full hybrid</td>
<td>battery range 100-150 km</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>conventional + plug-in hybrid</td>
<td>coach and truck ?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>conventional + range extender</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fuso Canter E-CELL</td>
</tr>
</tbody>
</table>

- Which is the right technology for the future?
- How do we handle fuel topics – e.g. sulfur content?
Development of modern vehicles
Optimization of Diesel engines – and entire vehicle aspects

Example Mercedes-Benz E-Class

Mercedes-Benz E-Class
(1984)

200D / Diesel (72 hp): efficient and modest, fuel consumption appr. 8 to 9 l/100km

- Before introduction of emission legislations

BlueEFFICIENCY: All measures required to reach ambitious targets

- The newly introduced Mercedes-Benz E-Class combines most modern technologies – validated by an environmental certificate by German TÜV.
An example for future-ready technology
Mercedes-Benz B 200 NGD and E-Class with Natural Gas Drive

Mercedes-Benz B 200 NGD – introduced in September 2012, followed by E 200 NGD

Ready for the future:
• Energy-Space body concept
• Euro 6 emission standard
• 115 kW engine

B200 NGD: Fuel consumption 4.2 kg/100km
• 16% less CO₂ emissions
• 50% less fuel cost than Diesel or petrol
• 500 km reach with natural gas

• Proof of the capability of natural gas driven vehicles - agile engine with efficient technology.
Heavy dependency on diesel fuel today - example Germany: Need for alternative fuels especially in road freight transport

Scenario: implications of changes in fuel demand and types of fuel available

Calculated future energy demand

Expected diesel consumption of PVs and CVs

Adapted TREMOD scenario (2012)

current developments published in latest studies taken into account for economic and transport growth.

- Further improvements in engine technology and alternative drivetrains will help to reduce dependency on diesel/gasoline.
- Liquefied natural gas especially interesting for heavy duty applications.
# GHG regulation in major world regions

## Europe still without any CO₂ regulations for HD vehicles

### Overview on regulations in force and legislative activities

<table>
<thead>
<tr>
<th>Region</th>
<th>Regulation</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EPA GHG program</strong>&lt;br&gt;phase 1: 2013-2019; phase 2 in preparation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fuel consumption limits</strong></td>
<td>regulation in force to be expected July 2014</td>
<td></td>
</tr>
<tr>
<td><strong>Fuel efficiency standard</strong></td>
<td>already issued, coming into force 2015 regulation post 2020 in discussion</td>
<td></td>
</tr>
<tr>
<td><strong>CO₂ limits in discussion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PC regulation 2015 / 2020 / 2025</strong>&lt;br&gt;limits in place, resp. in discussion</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LCV regulation 2017 / 2020 / 2025</strong>&lt;br&gt;limits in place, resp. In discussion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Second wave of limits (HDV)

- **2020**: Ambitious CO₂ targets in all relevant markets likely.
  - Necessity of harmonized FE simulation procedure.
- **2022**:
- **2025**:

### Two main drivers for EC:
1. EU is the only important market without CO₂ regulation for HDV.
2. Long-term CO₂ reduction targets for transport sector set in EU White Paper
Successful implementation of technologies: The new Actros long-haul in the context of the development of fuel efficiency

‘NOₓ vs. particle mass and fuel consumption’: Trilemma as a target conflict of Diesel engine

Source: Lastauto Omnibus, Test Reports 1967 - 2010 and Mercedes-Benz Record Run (Dekra, 2011)

- 30%

2015

Natural Aspired Engines
Turbo Charged Engines
Intercooled Charged Air
MB-Vehicles after '92
Linear (MB-Vehicles after '92)

- 7.6%

Improvement of the best in its class

-4.6% Euro VI
-7.6% Euro V

2008

Actros Euro V

New Actros 2011

• Competition driven drastic reduction of fuel consumption of HDV overcompensated effects of emission legislation – new Actros further improves benchmark position.

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Heavy Duty Engines: High efficiency through Diesel process
Additional optimization measures

Continuous development work and improvement

Approaching 50% BTE

<table>
<thead>
<tr>
<th>BTE %</th>
<th>Roadmap</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td></td>
<td></td>
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<tr>
<td>43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 51% BTE
- 50% BTE (Waste Heat Recovery)
- 48% BTE
- 47% BTE
- 46% BTE
- 45% BTE
- 44% BTE

Main steps in technology
- Downsizing
- Reduction of parasitics
- Compression ratio improvements
- Waste Heat Recovery
  (complex assembly space)

Source: Super Truck Project, DOE Report Feb 2012

• Research is under way to reach 50% thermal efficiency in a heavy duty engine, but still many years away from a series introduction.

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Shale gas policies in major markets differ
Europe with a mixed picture

World: exploration and production

- **Shale “boost” in the US since 2006.** Government follows strategy of energy security whilst low energy costs. Shale gas production contributes to it significantly.
- **First production drilling started in Australia end of 2012.** Besides China and USA Australia have one of the biggest shale gas resources.

EU: non-uniform policy

- **EU parliament rejected a ban on shale gas and asked for a robust regulatory regime to address environmental concerns (21st Nov. 2012).**
- **EU Commission is expected to come up with a framework for managing risks in 2013.**
- **Shell invests € 7.5 bn for shale gas production in Ukraine - biggest shale gas deal in Europe so far.**
- **Chevron got certificates to explore for shale gas in eastern Romania (31st January 2013).**

- **Gas boom in US serves as an example for China, Ukraine, Poland or Australia to increase energy security and to receive low energy costs whilst reducing GHG emissions.**
- **In contrast, high concerns about risks of fracking dominate in some important European countries.**

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Europe's evolving fuel situation - A view from Daimler
Liquefied natural gas as addition to existing natural gas supply but also with new applications – might change the energy landscape.

Expectations on a high growth (and profit) rate application in the transport sector is one of the main targets of the natural gas industry.

Main developments:
- **Supply**
  - Shale gas exploitation in the US
  - New shale gas contracts in China, Ukraine, Romania, UK etc.
  - Environmental pressure to capture NG during shale oil process
- **Demand**
  - Unclear demand for power production to be investigated - replacement of hard coal US - Less use of NG for power D
- **Supply**
  - Massive investments of oil & gas companies > 100bn € until 2015
  - Massive investments in new LNG tanker → Worldwide trade
  - Extensive build-up of new LNG terminals in EU and China

**Natural Gas** (gaseous)

**Liquefied Natural Gas** (LNG)

**Japan**: short-term production electric power. Long term?
**China**: LNG to compensate use of hard coal in the housing sector

Expectations on a high growth (and profit) rate application in the transport sector is one of the main targets of the natural gas industry.
Need for fuel alternative in Heavy-Duty sector:
Natural gas with cost and environmental advantages

**Increasing costs**

Diesel net price trend EU until 2011

**Price advantages**

Total fuel costs HD long haul for two years

**Low carbon content**

CO₂ emissions WTW

- Cost advantages and lower CO₂ emissions of natural gas might lead to a significantly growing gas demand towards 2020.
- Price advantage currently highly depending on natural gas price and tax policy in the EU.
LA to DC on CNG Cross Country Tour Summary

- What: Drive Cascadia with ISX12 G from Long Beach, CA to Washington, DC


- Where: Four (4) stops between Long Beach and Washington:
  - Phoenix
  - OKC
  - Little Rock
  - Nashville
Future infrastructure for sustainable mobility will be complex

- Mix of available fuels and electricity requires combined efforts!
- Large variety of fuels can hardly be handled by automotive and oil industry!

### Required supply of different fuel qualities and various electrical power ranges

- Gasoline E5
- Gasoline E10
- Gasoline Exx
- Diesel B7
- CNG 200bar
- LNG saturated for trucks
- LNG unsaturated for trucks
- H2 700 bar 350 bar*
- Electric outlet xx kW
- Electric outlet yy kW
- El. fast charger zz kW
- Electric outlet xx kW
- Electrical outlet yy kW
- Electrical outlet zz kW

* For FC city buses
Summary and outlook

Fuel specifications and alternative fuels required to meet evolving/new technologies

- **Challenging world-wide CO₂-legislation** will significantly influence future fuel demand.
- Large **variety of drivetrain concepts hardly to be handled** by manufacturers:
  - Fuel consumption reduction potentials given for all vehicle groups, but not always economical.
  - Electric vehicles facing difficulties in market acceptance.
- **Conventional drivetrains** still with **significant development potentials** for the future: Diesel demand remains high – might even grow depending on CO₂ requirements.
- **Natural gas** (CNG and LNG) especially in the truck business with **high CO₂ reduction potential** - depending on type of vehicle and technology. Especially LNG in trucks seems to become a highly interesting fuel for the US and other markets.
- Long term there is no way around **battery electric driven** and **fuel cell passenger cars** – regulations seem to require it, but nobody knows **customer acceptance** and **affordability**.

- **Challenges are huge - but automotive industry is preparing!**
- **Together with the oil industry we need to handle future expectations.**
Thank you for your attention