Automotive Fuels – The Challenge for Sustainable Mobility

Directions in Engine-Efficiency & Emissions Research
DEER 2012

Dr. Wolfgang Warnecke,
Chief Scientist Mobility
THE CHALLENGE - THE WORLD IN 2050

- 9 billion people
  - 2.5 billion more than today

- World population 70% urban
  - Every week equivalent of a new million-city is needed since doubling the urban population of developing countries

- 4 – 5 times richer
  - Increased wealth in developing countries

- Doubling of energy consumption
  - Twice as much energy used

- Renewables play increasing role
  - 30% of energy supply will come from RES

- Hydrocarbons remain indispensible
  - About two thirds of global energy supply

* (UN-Habitat 2006)
ENERGY DEMAND WILL INCREASE IN MANY REGIONS

GDP/Capita and energy consumption 1980-2008

- >$25k/capita: Marginal energy needed to fuel economic growth is small
- >$15k/capita: Services start to dominate growth of GDP.
- >$5k/capita: Industrialisation and mobility take off.
- Emerging countries are climbing the energy ladder

Source: Worldbank Database
Global CO₂: +3% in 2012 vs 2011 (all-time high of 34 blnt in 2011)

- **China:** avg. CO₂ emission increased by +9% to 7.2 t per capita. China is now within the range of 6-19 t per capita emissions of major industrialized countries.

- **EU:** CO₂ emissions -3% to 7.5 t per capita.

- **US:** remain one of the largest emitters of CO₂ (17.3 t per capita), despite a decline due to recession in 2008-2009, high oil prices & increased share of natural gas.

The Grand Challenge: **Elements defining Future Mobility**

**Access to Energy/Fuels**
- Which energy sources will meet the growing demand for mobility?

**Total Cost of Ownership**
- Which fuel/vehicle combination will allow mobility to remain affordable?

**World Population Growth & Urbanisation**
- How will mobility & infrastructure concepts change mobility in Mega cities?

**Reduction of GHG and local emissions**
- Which fuel/vehicle combination will lead to the lowest amount of GHG and local emissions?

**New Technology Options**
- Vehicle Autonomous Drive, Continuous Connectivity, Safety Features (Night Vision, active braking, distance control, advanced stability control…)

**Changing Consumer Values & Social Acceptance**
- New consumer values – „Mobility on Demand“. Which factors drive social acceptance & the resulting uptake of new fuel/powertrain solutions?
Future Fuel Options

Dr. Wolfgang Warnecke
Chief Scientist Mobility
SHELL – FUTURE TRANSPORTATION FUELS

<table>
<thead>
<tr>
<th>Premium Fuels</th>
<th>GTL Fuel</th>
<th>CNG/LNG</th>
<th>Biofuels</th>
<th>Hydrogen</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>V-Power fuels:</strong></td>
<td>Pioneer in the development of Gas to Liquid technology</td>
<td>Natural gas will account for over half of Shell’s total production in 2012</td>
<td>Leading in current and future biofuels</td>
<td>World’s largest public transport joint venture</td>
<td>Evaluation of Options</td>
</tr>
<tr>
<td>Best performance in Latest engine technology</td>
<td>Premium diesel containing GTL Fuel launched in: Austria, Germany, Greece, Italy, Netherlands, Switzerland and Thailand</td>
<td>• Established CNG offers in dedicated markets • LNG for large engines (heavy duty on road / off-road, rail, marine)</td>
<td>First-generation • 9.5 billion litres (2010) e.g. Brazilian Sugarcane Ethanol (COSAN JV) Second-generation</td>
<td>Concentration of Demonstration projects in EU/D and USA, China</td>
<td></td>
</tr>
<tr>
<td>• In 60 markets since 1998 • VP-Diesel with unique GTL component • V-Power racing with 100 Octane and FMT- Technology • Shell Fuel Save for improved Fuel Economy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Performance fuels
Energy Diversification

... based on CO₂ solutions
Transportation Fuels Today: 94+ % are crude oil based fuels

Source:
- Petroleum (37%)
- Natural Gas (25%)
- Coal (21%)
- Renewable Energy (8%)
- Nuclear Electric Power (9%)

Sector:
- Transportation (28%)
  - Industrial (20%)
  - Residential & Commercial (11%)
  - Electric Power (20%)

Source: EPA
MARKETS FOR 'MORE GAS' FOR TRANSPORT TO BE EXPLORED

Stranded Gas

Coal Bed Methane (CBM)

Pipeline Gas

Extended Well Test

(CNG) LNG for transport is attractive in various markets in the context of "LNG Corridors" – involves road (trucks), rail, marine & mining
UNCONVENTIONAL GAS DEFINITIONS

**TIGHT GAS**

- Occurs in ‘tight’ sandstone
- Low porosity = Little pore space between the rock grains
- Low permeability = gas does not move easily through the rock

**SHALE GAS**

- Natural gas trapped between layers between layers of shale
- Low porosity & ultra-low permeability (0.02-0.1 mD)
- Production via natural fractures

**COALBED METHANE**

- Natural gas in coal (organic material converted to methane)
- Permeability low
- Production via natural fractures (“cleats”) in coal
- Recovery rates low
UNCONVENTIONAL GAS – GLOBAL GAS MARKET INFLUENCE

World LNG Estimated April 2012 Landed Prices

Source: Federal Energy Regulatory Commission (FERC)
Small Scale LNG – Upstream and Downstream

**Drivers**

- Gas Supply
  - Stranded Gas
  - Coal Bed Methane (CBM) and other unconventional
  - Extended Well Test and flare gas
  - Pipeline Gas

**Means of Production and/or Means of Supply**

- Small Scale LNG

**Existing Infrastructure**

- Pipeline Grid
- Road transportation and rail
- ECA Marine and inland water
- Stationary Power
- Mining and drilling rigs

**LNG Demand**
BIOFUELS - THE SOLUTION IN TRANSPORT?
TODAY’S ROAD TRANSPORT BIOFUELS

Organic raw material

<table>
<thead>
<tr>
<th>Sugar cane</th>
<th>Corn</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rape seed</td>
<td>Palm oil</td>
<td>Soya bean</td>
</tr>
</tbody>
</table>

Process

- Fermentation
- Transesterification
- Hydro-treating

Product

- Ethanol (blend with gasoline)
- FAME (blend with diesel)
- HVO (blend with diesel)
ALTERNATIVE FUEL VEHICLES TECHNOLOGY OPTIONS

Spark Ignition engine based
- E20/25 or E85
- CNG/ LNG
- LPG: local options
- Advanced Gen.Bio SI
- FAME

Compression Ignition engine based
- GTL
- HVO
- Advanced Gen.Bio CI
SCALING UP ADVANCED BIOFUELS

- Progressing new technologies from lab-based process to demonstration phase and towards commercial scale-up

<table>
<thead>
<tr>
<th>Gasoline components</th>
<th>Diesel components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar Ethanol</td>
<td>Biomass to Diesel</td>
</tr>
<tr>
<td>Cellulosic Ethanol</td>
<td>HVO</td>
</tr>
<tr>
<td>Biomass to Gasoline</td>
<td>Microbes To diesel</td>
</tr>
</tbody>
</table>

- Research & Development
- Demonstration Plant
- Project Assessment
- First Commercial Plant
- Commercial Roll-out
HYDROGEN FOR TRANSPORT

Important role as an option to diversify road transport fuel
Hydrogen is used in hydrogen fuel cell vehicles
Enabling Emission Free Mobility (renewable H₂)

CO₂ benefit depends on how the hydrogen is produced
95% of hydrogen is currently produced from natural gas or gasifying coal

Requires new infrastructure
Industry cannot fund commercialisation
Government facilitated initiatives required to overcome market failure
OUTLOOK

Dr. Wolfgang Warnecke
Chief Scientist Mobility
...ENERGY UNTIL 2030

- Shift to the East continues
- Non-OECD demand climbs as economic growth continues to outstrip OECD nations
- Demand remaining strong in Middle East
- Gas % increases in the energy mix to 2030 driven by:
  - Economic development in emerging nations
  - Demand for lower carbon energy solutions
NO SINGLE ALTERNATIVE TO LIQUID FOSSIL FUELS

- All fuel options will be needed
- A range of drivers affects regional choice of fuel for mobility
- The internal combustion engine will continue to play an important role
- Natural gas (CNG, LNG & GTL) will continue to find further application in transport
- Improvements in CO₂ emissions through vehicle efficiency, fuel technology and driving habits
- Use of today’s biofuels and that of advanced biofuels will be needed
- Electric and Hydrogen will play an important role - if technical, consumer and infrastructure challenges can be overcome
THE FUTURE IS HERE TODAY...

Close to 5,000 km with 1 litre fuel.