Challenge Electromobility

Barclays Future Powertrain Symposium
Dr. Tobias Lösche-ter Horst

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The brands - our Customers
Value creation in the automotive industry is undergoing change

- Downsizing
- Digitalization
- CO₂ emissions
- Plug-In-hybrid
- Urbanization
- Hydrogen
- Sustainability
- E-mobility
- Car sharing
- Connected Car
- Major cities
- Battery technology
- Lithium-ion
- Peak Oil
- Climate change

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Challenge no. 1: Reduction of CO₂ emissions

<table>
<thead>
<tr>
<th>Region</th>
<th>Regulation for fleet CO₂ emissions</th>
<th>Draft fleet fuel economy legislation (Phase IV)</th>
<th>Greenhouse Gas II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>2020 95 g CO₂/km</td>
<td>2020 5 l/100 km</td>
<td>2020 125 g CO₂/km</td>
</tr>
<tr>
<td></td>
<td>as of 2025 to be defined</td>
<td>as of 2025 «5 l/100 km</td>
<td>2025 101 g CO₂/km</td>
</tr>
<tr>
<td>China</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA</td>
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</tbody>
</table>
CO₂ trend in the Volkswagen Group

- Technologies for efficiency
- Optimization of conventional aggregates
- Vehicle measures
- Alternative powertrains
- Fuel cell
- Battery-electric vehicle

CO₂ emissions
VW group

EU27 Fleet value 2006
166 g CO₂/km
EU28 Fleet value 2013
134 g CO₂/km
EU28 Fleet value 2020
95 g CO₂/km

2006 2014 2015 2020

Technologies and energy sources

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Possible Evolution of Sustainable Energy for the Automotive Sector

Time

Energy (100%)

Conventional fuels

Biofuels

Electricity

Short distance mobility

Long distance mobility

ICE

Hybrid

PlugIn

Range Extender

BEV

Long distance BEV

FCEV

ICE
Mobility in Urban Areas
### Technical Data

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum speed:</td>
<td>140 km/h</td>
</tr>
<tr>
<td>Electric motor:</td>
<td>85 kW</td>
</tr>
<tr>
<td>Torque:</td>
<td>270 Nm</td>
</tr>
<tr>
<td>Consumption, NEDC:</td>
<td>12.7 kWh/100 km</td>
</tr>
<tr>
<td>Electrical range (NEDC):</td>
<td>190 km</td>
</tr>
<tr>
<td>Energy content battery</td>
<td>24.2 kWh</td>
</tr>
</tbody>
</table>
Lithium-ion battery: Roadmap for high-energy batteries

All-electric range in km **

Conventional lithium-ion technology

- **190 km**
  - 260 Wh/L*

- **300 km**
  - 380 Wh/L*

- **300 km**

Electrode: Increasing the energy density through improved design and precision in manufacturing
cathode: Increasing the nickel content, innovative materials for high-capacity batteries
Anode: Replacing carbon with silicon

* Energy density per cell
** Based on a battery with a cell volume of approx. 100 litres

Timescale research level
Challenges of Charging

Charging capacity
HV-batteries with high energy content require higher charging capacities.

Operation
Economic efficiency of operation of charging stations

Regenerative energy
Further expansion of CO₂-neutral mobility

Charging infrastructure
Extensive provision of charging stations

Charging interface
Worldwide standardization of the charging plug

Charging comfort
Automatic charging via induction

Access charging station
Standardized authentication and billing
Long-Range Mobility

- Passat BlueMotion
- Jetta Hybrid
- Q5 Hybrid
- Touareg Hybrid
- Cayenne Hybrid
- Panamera Hybrid
- BlueMotion
- Caddy EcoFuel
- Passat EcoFuel
- EcoFuel
- Touran EcoFuel
- Golf TDI BlueMotion
- Jetta Hybrid
- Touran EcoFuel
- Panamera Hybrid

Powertrain research
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## CO₂ measures – research activities

<table>
<thead>
<tr>
<th>Engine efficiency measures</th>
<th>Direct shift gearbox</th>
<th>Drivetrain</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ Extreme pressure injection</td>
<td>➢ Downspeeding</td>
<td>➢ Thermal management</td>
</tr>
<tr>
<td>➢ Combined motor charging</td>
<td>➢ Reducing friction</td>
<td>➢ Use of exhaust gas heat</td>
</tr>
<tr>
<td>➢ Variable valve train</td>
<td>➢ Alternative materials</td>
<td>➢ Micro Hybridization</td>
</tr>
<tr>
<td>➢ Variable compression</td>
<td>➢ Optimized lightweight construction</td>
<td></td>
</tr>
<tr>
<td>➢ Cylinder deactivation</td>
<td>➢ Coating</td>
<td></td>
</tr>
<tr>
<td></td>
<td>➢ Ratio</td>
<td></td>
</tr>
<tr>
<td></td>
<td>➢ Efficiency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>➢ Starting performance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>➢ Low rotational speed concepts</td>
<td></td>
</tr>
</tbody>
</table>
Highly electrified solutions for individual mobility

- Golf GTE
- XL1
- Golf TwinDrive
- 918 Spyder
- Passat GTE
- Passat HyMotion
## Passat Variant GTE

### Technical Data

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Maximum speed:</td>
<td>225 km/h</td>
</tr>
<tr>
<td>Fuel consumption, combined:</td>
<td>1.6 l/100 km</td>
</tr>
<tr>
<td>CO₂ emissions, combined:</td>
<td>37 g/km</td>
</tr>
<tr>
<td>Electrical range (NEDC):</td>
<td>50 km</td>
</tr>
<tr>
<td>Range in total (NEDC):</td>
<td>1,091 km</td>
</tr>
<tr>
<td>Unloaded weight:</td>
<td>1,660 kg</td>
</tr>
</tbody>
</table>
Advantages of the parallel hybrid concept

- High fuel-saving potential
- Sporty driving performance
- Repeatable driving properties
- Module capability
- E-traction module
- Scalability
- Degree of electrification
- Mild- / Full- / Plug-In Hybrid
- TDI®, TSI®, DSG®
- Modularity of powertrain components
Long-Range Electromobility

BEV

eFuel

FC
Beyond lithium-ion battery: Solid state battery

Conventional lithium-ion technology

- 2010: 190 km, 380 Wh/L*
- 2020: 380 km, 510 Wh/L*
- 500 km, 650 Wh/L*
- 700 km, 1000 Wh/L*

New battery technologies

- Solid-state battery

All-electric range in km **

Electrode: Increasing the energy density through improved design and precision in manufacturing
Cathode: Increasing the nickel content, innovative materials for high-capacity batteries
Anode: Replacing carbon with silicon

* Energy density per cell
** Based on a battery with a cell volume of approx. 100 litres

Timescale research level

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Battery with solid-state electrolyte

**Technological leap:**
- Higher energy densities compared to lithium-ion-technology
- Better safety
- Compact design

**Materials:**
- Bad ionic conductivity in the solid-state electrolyte
- High volume change between charged and discharged cell
- Lower efficiency

**Challenges:**
- Complicated processing of the layers
- Ensuring the atomic scale of the interphase morphology
- High costs

**Processes:**
- Complicated processing of the layers
- Ensuring the atomic scale of the interphase morphology
- High costs
Fuel cell

Audi A7 Sportback h-tron quattro

Volkswagen NMS HyMotion
HyMotion4 – two vehicle concepts with one fuel-cell system

Fourth generation of fuel cell vehicles in Volkswagen Group research

Volkswagen NMS HyMotion

- E-machine: 100 kW
- $v_{\text{max}}$: 160 km/h
- 0-100 km/h: 12 sec
- Range: 420 km
- Battery: 1.1 kWh

Audi A7 Sportback h-tron quattro

- E-machine: 2 x 85 kW
- $v_{\text{max}}$: 180 km/h
- 0-100 km/h: 8 sec
- Range: > 500 km
- Battery: 9.5 kWh

HyMotion 4

Performance: 80 kW
Challenges of fuel-cell technology

- Simplification of system complexity
- Ensuring life-time requirement
- Reduction of costs
- Development of a supplier landscape
- Regeneratively produced hydrogen
- Extensive provision of filling station infrastructure
Electric vehicles – challenge filling time

**Petrol**
- **Pump:**
  - 27,000 kW (approx. 50 dm³/min)
- **1,000 km/min**

**Electricity**
- **3 x 230V:**
  - 10 kW (three-phase current)
- **1 km/min**

**Hydrogen**
- **Filling station**
  - 2,000 kW (approx. 1 kg/min)
- **100 km/min**
Options for storing and using „green“ electricity

The question after future vehicle concepts can only be answered in context with future energy solutions of the energy sector.
Mobility scenarios for 2050


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Basic architecture of MQB

variable

uniform

variable

variable

variable
## Powertrains of MQB

<table>
<thead>
<tr>
<th>Conventional</th>
<th>Alternative/Regenerative</th>
<th>Electric</th>
<th>Fuel Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>Ethanol</td>
<td>Plug-In Hybrid</td>
<td>Hydrogen</td>
</tr>
<tr>
<td>Gasoline</td>
<td>CNG</td>
<td>Electric powertrain</td>
<td></td>
</tr>
</tbody>
</table>

### Use of different powertrains in different segments and brands possible
Coexistence of propulsion systems

- CO\(_2\) neutral electricity
- Conventional electricity
- Conventional fuels
- CO\(_2\) neutral fuels (liquid, gaseous)

Fuel cell
- Battery electric vehicle
- Plug-In Hybrids
- Hybrids
- Internal combustion engines

CO\(_2\) neutral and sustainable mobility
Thank you!

Powertrain research

Dr. Tobias Lösche-ter Horst