Market Introduction of Electric Vehicles
- Opportunities and Challenges

Prof. Dr. Christian Mohrdieck, 30 September 2013
Daimler AG
Responsibility for our Blue Planet

- Growing world population
- Growing mobility need
- Ecological Awareness
- Limited resources
- Climate change

- Worldwide rising demand for mobility will increase CO$_2$ emissions challenge.
- Fossil resources are limited and will therefore become more expensive
Global regulations impose major challenges

- Europe -

Mercedes-Benz Cars fleet:
Significant CO2 reduction achieved

OEM targets

- 40%

- 10%

CO2 Emissions (g/km)

230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

1995 2006 2008 2009 2010 2011 2012 ... 2016 ... 2020

9,2 l 7,3 l 6,9 l 6,4 l 6,3 l 6,0 l 5,6 l 5,0 l 4,0 l

2008

173

160

158

150

140

125

95 g

Prof. Dr. Christian Mohrdieck / Daimler AG
Our Roadmap to a Sustainable Mobility

Highly Efficient Internal combustion engines

A 180 CDI BlueEFFICIENCY
3.6
l/100 km
92 g CO2/km

S 500 PLUG-IN HYBRRID
3.0
l/100 km
69 g CO2/km

Full and Plug-In Hybrids

Electric vehicles with battery and fuel cell

B-Class electric drive

Smart ed B-Class electric drive

B-Class F-CELL
0
l/100 km
0 g CO2/km
The Powertrain Portfolio for the Mobility of Tomorrow

Long Distance
- ML 250 BlueTEC 4MATIC
- S 400 HYBRID
- S 500 Plug-in HYBRID
- smart fortwo electric drive
- B-Class F-CELL

Interurban
- Efficient Combustion Engine
- Hybrid
- Plug-in Hybrid

City Traffic
- Electric Vehicle with Battery
- Electric Vehicle with Fuel Cell

Combustion Engine
Emission free mobility
The new S 500 PLUG-IN HYBRID
Driving pleasure, efficiency, comfort & safety at its best

245 + 80 kW
480 + 340 Nm
30 km electrical range
3 l/100km 69 g CO2

Emission-free driving in urban areas and pure driving comfort on long distances.
Daimler’s Electric Vehicle Technology Roadmap
Electric vehicles with fuel cell & battery

Daimler is dedicated to commercialize electric vehicles with fuel cell
smart fortwo electric drive
Overview of the electrical drive train components

<table>
<thead>
<tr>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle</td>
</tr>
<tr>
<td>Engine</td>
</tr>
<tr>
<td>Range</td>
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<tr>
<td>Top Speed</td>
</tr>
<tr>
<td>Battery</td>
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</tbody>
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Charge socket
Drivetrain cooling system
Electric motor
Inverter
On-board charger
Lithium-ion battery
Gearbox
The New Mercedes-Benz B-Class Electric Drive

<table>
<thead>
<tr>
<th>Specifications*</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle</td>
<td>Mercedes-Benz B-Class Electric Drive</td>
</tr>
<tr>
<td>Launch</td>
<td>2014: USA (followed by Europe)</td>
</tr>
<tr>
<td>Engine</td>
<td>130 kW</td>
</tr>
<tr>
<td>Range</td>
<td>200 km (NEFZ), 115 Miles (US City)</td>
</tr>
<tr>
<td>vmax</td>
<td>160 km/h (100 mph)</td>
</tr>
<tr>
<td>Acceleration</td>
<td>7.9 sec</td>
</tr>
<tr>
<td>Battery</td>
<td>Lithium-Ion</td>
</tr>
<tr>
<td>Charging time:</td>
<td>ECE: 1,5 h @ 400V / USA: 2 h @ 240V</td>
</tr>
<tr>
<td>100 km (NEDC)</td>
<td></td>
</tr>
<tr>
<td>60 miles (US City)</td>
<td></td>
</tr>
</tbody>
</table>

* preliminary values
Technological Challenges of e-mobility

1. **Lightweight Construction**
   - Carbon Fibre Reinforced Plastic
   - Intelligent Design
   - Aluminium
   - ...

2. **Air Conditioning/Energy Management**
   - Cabin-Isolation
   - Body-Near Air Conditioning
   - Utilisation Of Waste Heat
   - ...

3. **Energy Efficient E-Drive Components**
   - E-Drive
   - Power Electronics
   - Compressor
   - ...

4. **Battery Development**
   - Material/Cell-Chemistry
   - Cooling
   - Power Density
   - ...

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History of e-mobility – limitations of battery technology prevented successful commercialization

Limitations:

- weight, size, cost: \(\uparrow\)
- lifetime, energy: \(\downarrow\)

- Electric bus (1972) with battery exchange (860 kg)
- “Baby Benz“, BR 190 (1993) with zebra-battery in the front and rear
- Sedan (1982) with nickel-iron-battery (600 kg) in the trunk
Potential of High-Voltage Batteries
Usable Energy of Cells in Dependence on Power

The redox potential of the elements determines the capability for the utilization in batteries / accumulators

- The Li-Ion battery has limited potential concerning energy and power density
- Worldwide research programs with target of > 200 Wh/kg
- Promising battery concepts (e.g. LiS, LiO₂) are in early research stage

<table>
<thead>
<tr>
<th>Year</th>
<th>Spec. Energy [Wh/kg]</th>
<th>Range [km]**</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>120</td>
<td>135</td>
</tr>
<tr>
<td>2012</td>
<td>140</td>
<td>160</td>
</tr>
<tr>
<td>2017</td>
<td>160</td>
<td>180</td>
</tr>
</tbody>
</table>

* Source: Daimler AG, RWTH Aachen
** Range of the smart electric drive

The Li-Ion battery has limited potential concerning energy and power density
Worldwide research programs with target of > 200 Wh/kg
Promising battery concepts (e.g. LiS, LiO₂) are in early research stage
Challenges for the market penetration of e-mobility

- Optimize energy and materials use
- Developing next generation battery
- Secure raw materials supply
- Infrastructure
- Incentives
- Customer Acceptance

Eine Initiative der Bundesregierung
The Current Generation of Fuel Cell Vehicles
“Driving the Future” becomes Reality

<table>
<thead>
<tr>
<th>Technical Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle</strong></td>
</tr>
<tr>
<td>Mercedes-Benz B-Class</td>
</tr>
<tr>
<td><strong>Fuel Cell System</strong></td>
</tr>
<tr>
<td>PEM, 90 kW (122 hp)</td>
</tr>
<tr>
<td><strong>Engine</strong></td>
</tr>
<tr>
<td>Output (Cont./ Peak) 70kW / 100kW (136 hp)</td>
</tr>
<tr>
<td>Max. Torque: 290 Nm</td>
</tr>
<tr>
<td><strong>Fuel</strong></td>
</tr>
<tr>
<td>Compressed hydrogen (70 MPa)</td>
</tr>
<tr>
<td><strong>Range</strong></td>
</tr>
<tr>
<td>380 km (NEDC)</td>
</tr>
<tr>
<td><strong>Top Speed</strong></td>
</tr>
<tr>
<td>170 km/h</td>
</tr>
<tr>
<td><strong>Li-Ion Battery</strong></td>
</tr>
<tr>
<td>Output (Cont./ Peak): 24 kW / 30 kW (40 hp)</td>
</tr>
<tr>
<td>Capacity: 6.8 Ah, 1.4 kWh</td>
</tr>
</tbody>
</table>
Successful Daily Operations in Customer Hands
Mercedes-Benz B-Class F-CELL – Customer voices …

I am fascinated by the torque and the silence.

My next vehicle will be a fuel cell car again.

It is such a smooth ride.

My 13 year old kid “forced” me to demonstrate the car at school to his class mates. The FCEV was clearly the most special car around.

I never experienced any restrictions because it is a gas vehicle. I frequently take the F-CELL on the ferry.

I expected a Mercedes - and I got a Mercedes.

I am driving the future. Literally.

After driving a FCEV, you don’t want to get back to your old car.

over 3 Mio. km driven in customer hands
Packaging of Fuel Cell System

Through a further modularization of the fuel cell specific components, the packaging of future generations of FC vehicles will be simplified.

The significantly more compact dimensions would allow a accommodation in the engine compartment of a conventional vehicle.
Cooperation Nissan/Ford/Daimler
Asia, Europe and US – Unique collaboration across three continents
H₂-Infrastructure and market conditions are expected to be on an appropriate level by 2017. From 2017 onwards, we are planning for series production of F-Cell vehicles.
Electromobility with batteries and fuel cells is already a reality today. A total of nine locally emission free vehicles today.
Thanks for your attention!
The Trend to Electrification …
Market penetration of electric vehicles in 2020 (Bain & Company 2010)

Scenario 1 „Great Changes“
- Electric Power Train: 80%
  - Pure Electric: 20%
  - Range Extender: 30%
  - Hybrid: 30%
- ICE: 20%

Scenario 2 „Basis -Szenario“
- Electric Power Train: 50%
  - Pure Electric: 10%
  - Range Extender: 15%
  - Hybrid: 25%
- ICE: 50%

Scenario 3 „Almost no Changes“
- Electric Power Train: 18%
  - Pure Electric: 2%
  - Range Extender: 5%
  - Hybrid: 10%
- ICE: 83%

ICE on board
- 80%

Assumptions:
- Oil price:
  - Low: 300 US$ per barrel
  - High: Under 100 US$ per barrel
- Low Emission Zone:
  - All metropolis world-wide
  - Barely introduced
- Climate Chance:
  - Dramatic Chance
  - In discussion
- Subsidy:
  - 50-100 Mrd. US$ world-wide
  - 10-30 Mrd. US$ world-wide
  - Only locally
Battery technology determines the success of e-mobility

The battery as key component has a significant impact on the customer acceptance and the highest proportion of value-added.

<table>
<thead>
<tr>
<th>Criteria for market success</th>
<th>Battery</th>
<th>Technology</th>
<th>Politics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Drive unit with gear box and e-motor</td>
<td>Charging and interface</td>
</tr>
<tr>
<td>Range</td>
<td>X</td>
<td>X</td>
<td>Standardization</td>
</tr>
<tr>
<td>Charging time</td>
<td>X</td>
<td>X</td>
<td>Political environment</td>
</tr>
<tr>
<td>Driving characteristic</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Vehicle design</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Cost / TCO</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Safety</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Lifetime</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Charging infrastr.</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Battery technology determines the success of e-mobility:

- Range: X
- Charging time: X
- Driving characteristic: X
- Vehicle design: X
- Cost / TCO: X
- Safety: X
- Lifetime: X
- Charging infrastr.: X

The battery as key component has a significant impact on the customer acceptance and the highest proportion of value-added.
Challenges of the Fuel Cell and Hydrogen Technology

Technology
- Power density
- Cooling system
- Hydrogen storage
- Durability

Supplier Industry
- Development of a competitive component supplier network
- Joint funding projects to address demands
- Establishing and maintaining network

Infrastructure
- Reliable refueling technology
- Build-up of an area-wide infrastructure
- H2 production at competitive prices
- Availability of renewable produced hydrogen

Mass Market

Cost
- Fuel cell system & stack
- Power electronics
- H2 tank system
- Infrastructure
- Hydrogen cost