Anforderungen an das Automobil der Zukunft.

Prof. Dr.-Ing. habil. Raymond Freymann
BMW Group Forschung und Technik
120 Years of Car Development.
A Story of Success.
Population and Vehicle Distribution.
Significant Differences Between World Regions.

<table>
<thead>
<tr>
<th>Region</th>
<th>Population (Million)</th>
<th>Passenger Vehicles (Million)</th>
<th>Passenger Vehicles per 1000 Persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>6555</td>
<td>737</td>
<td>112</td>
</tr>
<tr>
<td>USA</td>
<td>747</td>
<td>300</td>
<td>112</td>
</tr>
<tr>
<td>EU-25</td>
<td>464</td>
<td>242</td>
<td>111</td>
</tr>
<tr>
<td>Germany</td>
<td>598</td>
<td>522</td>
<td>46</td>
</tr>
<tr>
<td>Japan</td>
<td>1311</td>
<td>445</td>
<td>112</td>
</tr>
<tr>
<td>China</td>
<td>1122</td>
<td>141</td>
<td>9</td>
</tr>
<tr>
<td>India</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Megatopics in the Automotive Industry.
The Challenges of the Future.

Individual Mobility

- Energy
- Raw Materials
- Environmental Compatibility
- Safety
- Traffic Management
- Social Acceptance
- Costs
- Society Dynamics
- ........
Sustained Growth Scenario of World Energy Demand.

Source: Shell AG
Possible Types of Energy for Passenger Cars.
From Primary Energy to Fuel.
A Sustainable Hydrogen Economy.

The CleanEnergy Cycle.

Storage, distribution and filling

Power generation by the clean combustion of hydrogen

Generation of hydrogen from unlimited and renewable sources
Research in Hydrogen Technology.
From Basics to Attractive Technologies.

- First LH₂-Vehicle
- LH₂-Fill up
- LH₂-Engine Testbench
- H₂ Record Car
- LH₂ Robot Filling Station at Munich Airport
- PEM-APU
- LH₂ Testing Facilities
- Cryo
- DI
- CleanEnergy WorldTour
- Hydrogen 7

Timeline:
1980 1990 2000
CleanEnergy – BMW H7.
Hydrogen Storage.
Many (Theoretical) Possibilities Existing.
Liquid Hydrides - A Realistic Vision of an Alternative Fuel Scenario?

PRODUCTION & DISTRIBUTION

FUEL FILLING STATION
Fuel Cell APU.  
42 V / 5 kW.

GENERATION 1

GENERATION 3
Power/Mass Characteristics of Vehicles with Different Drive Train Systems.
Hydrogen Internal Combustion Engine.
Plenty of Power and a High Efficiency.

BMW H7 / Bifuel
12 Cylinder
Displacement 6 l
Power 190 kW

BMW H2 R today
12 Cylinder
Displacement 6 l
Power 190 kW

BMW Monofuel
4 Cylinder
Displacement 2 l
Power 200 kW

BMW H7 / Bifuel
Plenty of Power and a High Efficiency.

BMW H2 R today
Plenty of Power and a High Efficiency.
H$_2$-Internal Combustion Engine Development.

Engine Test Bench.
Energy Efficiency of Vehicles.
The Target is to Increase the Overall Efficiency.

Energy Flow Related to the Best Operating Point of an Internal Combustion Engine
BMW Turbosteamer.
Diversity of Energy Forms in a Vehicle.
From Fuel to Vehicle Functions.

Fuel -> Engine Fan
Fuel -> Coolant Pump
Fuel -> Oil Pump
Fuel -> Internal Combustion Engine

Mechanical Energy

Traction Force

Electrical Energy -> Alternator
Hydraulic Energy -> Pump
Pneumatic Energy -> Compressor
Cooling Capacity -> A/C Compressor

Vehicle Functions

Electrical Systems

Hydraulic Systems

Pneumatic Systems

Thermal Systems

Exhaust -> Thermal Losses
Coolant -> Hydraulic Losses
Mechanical Losses
Electrical Losses

Heat Losses
BMW Research – Alternative Drivetrains.
Electric and Hybrid Vehicles.

1970: BMW 1602 with Acid-Lead Battery

1972: BMW 1602 with Acid-Lead Battery

1987: BMW 325 with NaS-Battery

1992: BMW 325 with NaNiCl-Battery

1993: BMW E1 with NaS-Battery

1994: 518i Parallel-Hybrid with NiMH-Battery

1995: 316i Serial Hybrid with NaNiCl-Battery

1996: BMW 325 with NaNiCl-Battery

2003: X5 Active-Hybrid with Super Caps

2006
ActiveHybrid Concept Car.
EfficientDynamics Approach.

Exceptional Vehicle Response

Saves 15% of fuel
Traffic and Accident Numbers.
The Situation in Germany.

Source: Statistisches Bundesamt 2007
ConnectedDrive.
Connecting Driver-Automobile-Environment.

More Safety
Greater Efficiency
Comfort Enhancement
Vehicle-Environment Connectivity.
Near Field Perception Capabilities.
Car2X Connectivity Scenarios.
Far Field Perception Capabilities.
Car2Car and Car2Infrastructure.

Safety Applications.

- Local Danger Warning
- Cross Traffic Warning
- Red Light Warning
- Traffic Sign Recognition
Advanced Driver Assistance Systems. ADAS Evolution.

- Cruise Control
- ABS
- Navi
- ACC
- DSC
- Lane Change
- Brake Assistant
- Night Vision
- ACC Stop&Go
- Collision Warning
- Lane Departure
- Speed Limit Info
- Park Assist
- Autonomous Stop&Go
- Intersection Assist
- Car2X-Communication
- Autonomous Driving?
E/E-Platform.
The Onboard Network of 1957.

A Cluster of Domain Computers.

- 10 Mbit/s
- 100 Mbit/s
- 1 Gbit/s
- 10 Gbit/s
- ?? Gbit/s

Ethernet

Switch

Chassis Domains Server

Engine Domain Server

Infotainment Domain Server

Comfort Domain Server

Driver assistant Domain Server

Internet Protocol

Only five ECUs in the future??
Human-Machine-Interface.

BMW 328 MM Cockpit
1938

Spirit of St. Louis Cockpit
1927
Human-Machine-Interface.

BMW 740 i Cockpit 1994

Boeing 747 Cockpit 1989
Human-Machine-Interface.

BMW 745i Cockpit
2001

Boeing 777 Cockpit
1995
Women and Cars.
Driver Distribution per Vehicle Segment and Gender in the USA and in the EU.

**USA**

<table>
<thead>
<tr>
<th></th>
<th>UKL1</th>
<th>UKL2</th>
<th>KKL</th>
<th>MKL</th>
<th>GKL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EU**

<table>
<thead>
<tr>
<th></th>
<th>UKL0</th>
<th>UKL1</th>
<th>UKL2</th>
<th>KKL</th>
<th>MKL</th>
<th>GKL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In 2050, 20% of most the world will consist of 60+ people. Most of the western world will have a figure as high as 30%
Customer Requirements.

- sportiness/performance/driveability
- innovative
- information & communication
- brand image
- ..

- styling
- robustness/reliability
- safety
- interior space
- fun to drive
- fun to operate / handle / interact
- product values / enterprise values

- well adapted interior design
- store-room within drivers reach
- security
- ..

- comfort
- easy entry and exit
driver assistance
- security/health & medicare
- ..

- "Young" Generation

- All Customers

- Women

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generation

- "Silver" Generate
Our Motivation.
A Sustainable Individual Mobility.
Anforderungen an das Automobil der Zukunft.

Prof. Dr.-Ing. habil. Raymond Freymann
BMW Group Forschung und Technik