BMW CleanEnergy
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Overview of Hydrogen storage activities at BMW

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Storage of Hydrogen.
Central Challenge.

BMW Energy Strategy.
Short-Term and Long-Term Solutions.

Motivation:

- **reduction of greenhouse gases**
- **conservation of limited fossile ressources**
- **long term security of energy supply**

Short- and mid-term Targets:
Reduction of fuel consumption

Gasoline, eg.
VALVETRONIC

Diesel, e.g.
Common-Rail
2nd Generation

EfficientDynamics: Hybrid

Long-term Targets :
Development of competitive and sustainable products:

Hydrogen Vehicles

Hydrogen-Research-Vehicles
Five Generations from 1979 – 2002

Commitment CleanEnergy.
CleanEnergy WorldTour.

Series Development of 6th Generation.
Bi Fuel Concept for First Market Introduction.

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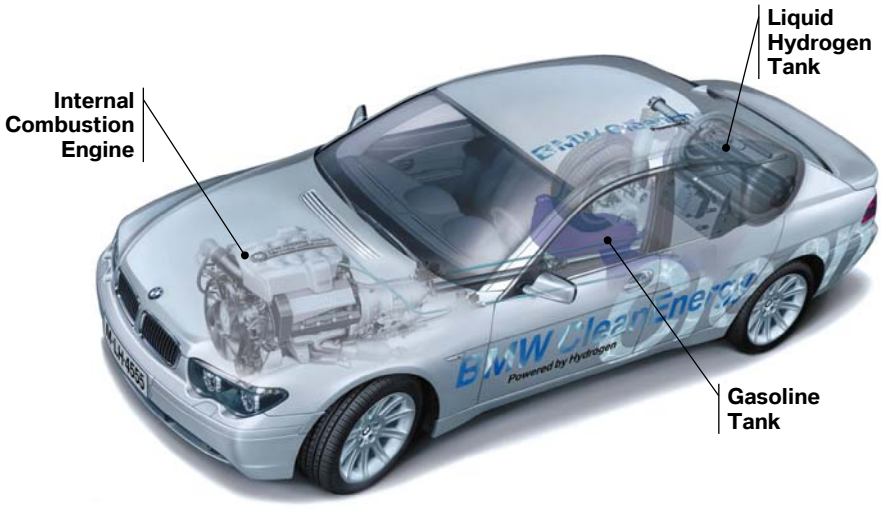
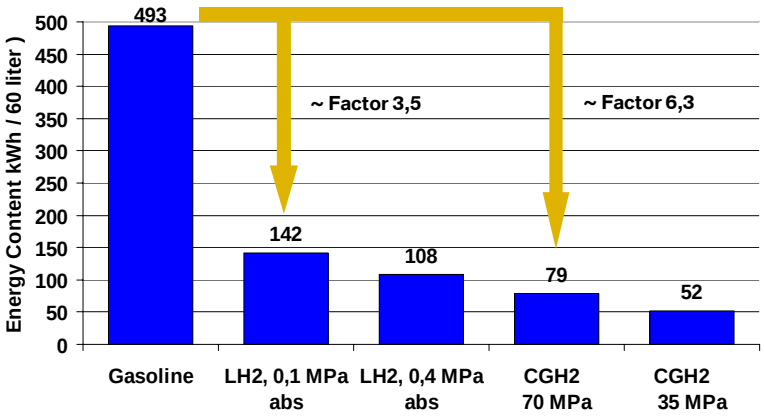
Bi Fuel Concept for First Market Introduction.

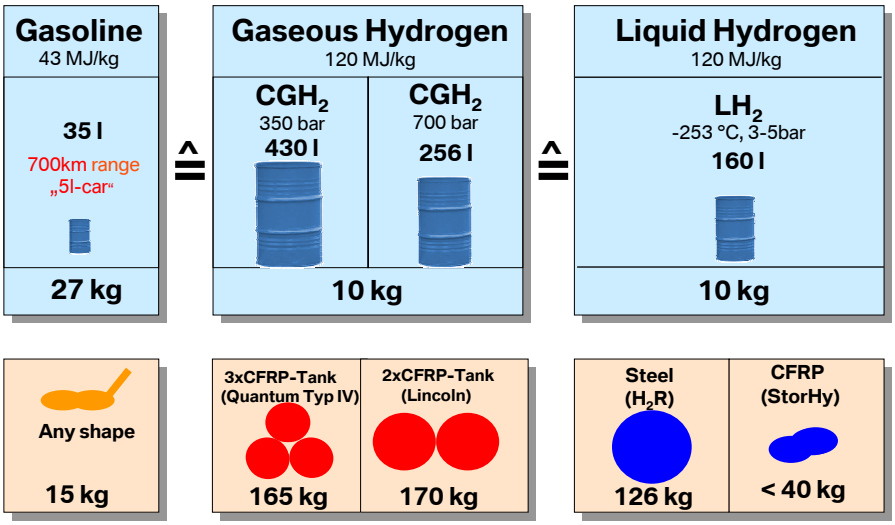


Energy Storage.
Volumetric Energy Densities.

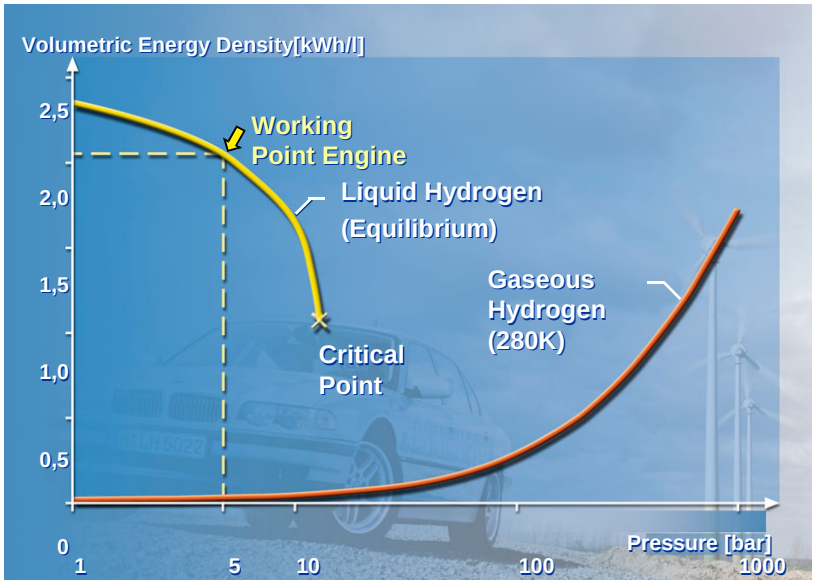


Energy content of a virtual tank volume of 60 Liter.

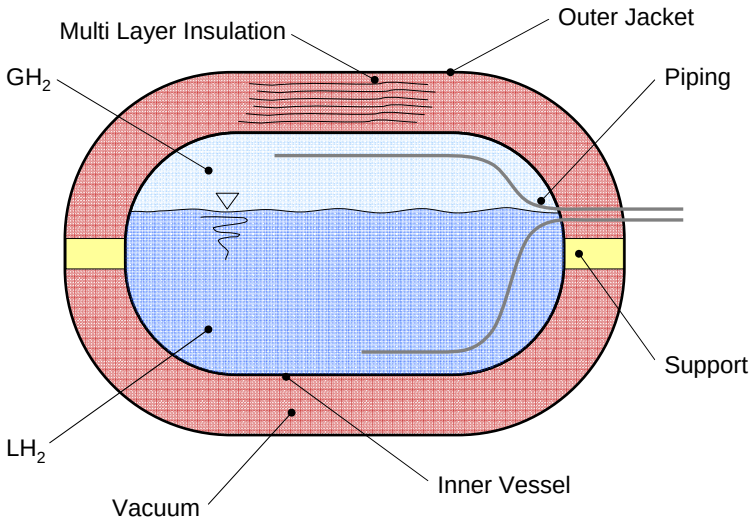
Alternative Fuels
Energy Equivalent Gasoline / Hydrogen



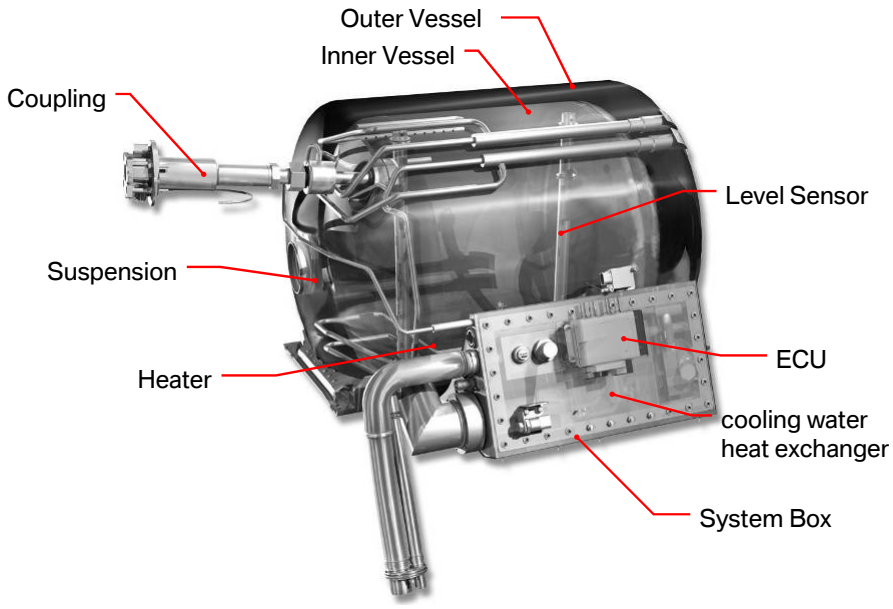
LH2 and CGH2.
Volumetric energy density of.



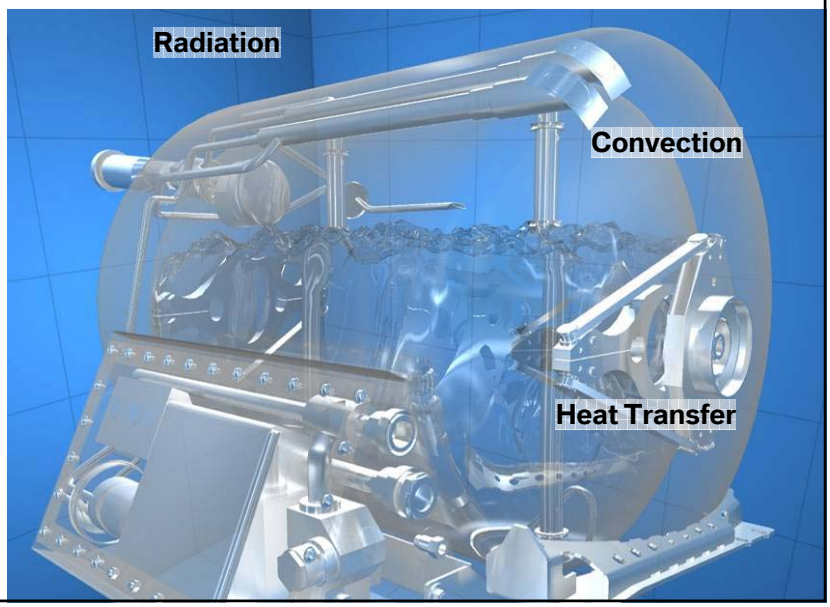
LH_2 Fuel System.
Principle.



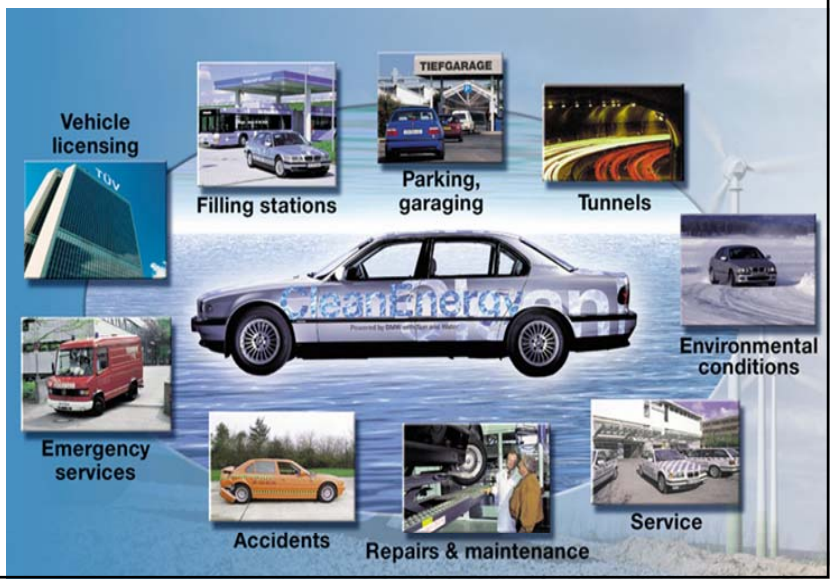
LH_2 Fuel System.
Assembly.



LH_2 Fuel System.
Insulation.



Introduction of Hydrogen.
Challenges from the Environment.



Series Development of of Hydrogen Vehicles.
Testing under extreme conditions.

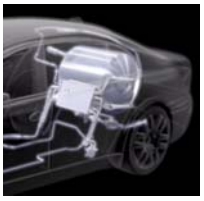
- High speed track tests
- Very cold climate condition tests
- Hot climate tests

➔ Proved for customers use

Hydrogen Safety Concept.
Passive Safety.

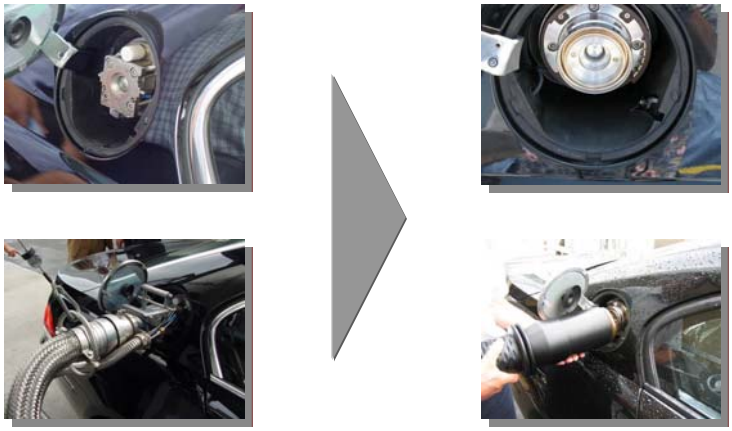
Step 1 – Legal and BMW Internal Requirements
- „crash safe“ package
- No deformation of hydrogen tank

Step 2 – Severe Accidents at the Limit
- Controlled release of hydrogen over the roof/bottom of the vehicle



Stufe 3 – Worst Case Scenario
- No bursting or explosion of tank system
- H_2 just burns away

Automotive Hydrogen Coupling.
Joint Development with GM and Honda.



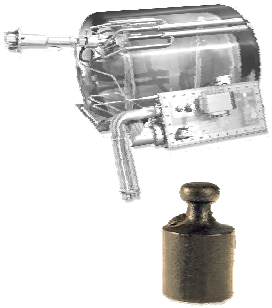
„Development of a standardised LH_2-filling system for autocars.“

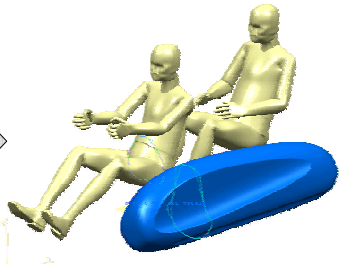
Field Testing of Hydrogen Vehicles.
Clean Energy Partnership (CEP).

Ford Focus	Opel Zafira	DaimlerChrysler	BMW
FCEV-Hybrid	HydroGen3	A-Klasse F-Cell	H_2-7 Series

Different approaches, common infrastructure

Liquid Hydrogen Storage.
Perspective.





Challenges:

- **Vacuum stability**
- **Material properties**
- **Thermal shock**
- **Recycling**

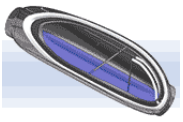
State of the Art

- Stainless steel
- Cylindrical vessels
- Plant specific design

Future System

- Lightweight materials
- Free form geometry
- Automotive design
- Reduced heat entry

EU Funded Project at BMW.
StorHy: H_2 Storage for automotive applications.

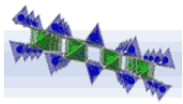


liquid

Cryogenic
bei -253 °C

gas

Highpressure
bei 700 bar

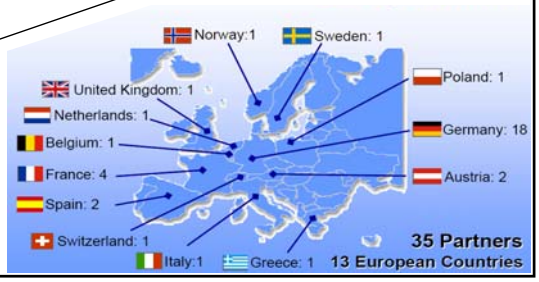


solid

Solid storage

STORHY

Duration: 4,5 Years
Budget: ~ 20 Mio. €



Specification of different vehicle applications 1

Parameter	FC vehicle (large fuel cell system and small battery)	LH_2 ICE vehicle	Hybrid FC Vehicle (small fuel cell system and large battery) City Car	Fuel cell bus
Range	600 km	300 km H2 600 km Gasoline	200 km H2 100 km battery	400 km
Storage System	CGH2 tank	LH2 tank+ gasoline tank	CGH2 tank+ battery	CGH2 tank
Net Driving power	70 kW	150 kW	70 kW	100-150 kW
Battery	Starter Battery only 1.5kWh	Starter Battery only	15kWh	0.5 -1.0 kWh
H2 Storage Mass (kg)	6 kg	10 kg	2.5 kg	40 kg
Reference cycle	New European Drive Cycle NEDC	New European Drive Cycle NEDC	New European Drive Cycle NEDC	SORT
Market size	See Hyways Or H2TP	See Hyways Or H2TP	See Hyways Or H2TP	See Hyways Or H2TP
Interchangeable rack	No	No	Yes	No
Safety Requirements	See draft ECE CGH2 reg.	See draft ECE LH2 reg.	See draft ECE reg.	See draft ECE reg.
Life Cycle	200.000 km 10 years	200.000 km 10 years	200.000 km 10 years	1 000 000 km 10 years

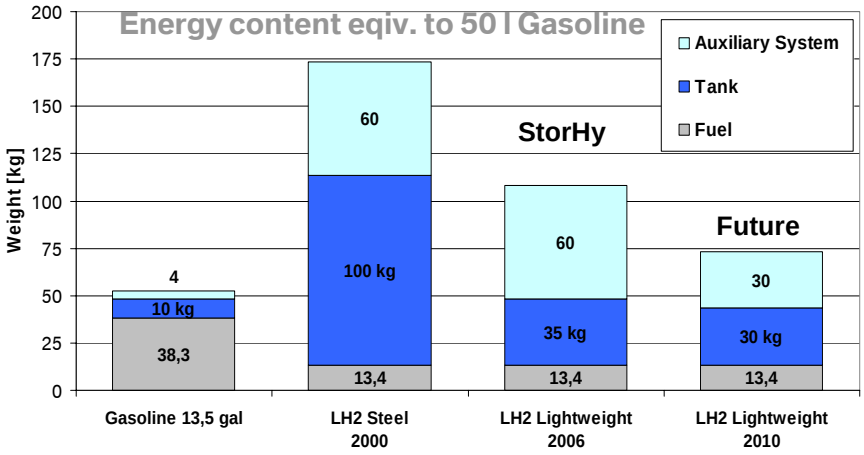
Source: http://www.storhy.net/pdf/IPHE_Storage-Targets_2005-06-20.pdf

Specification of different vehicle applications 1

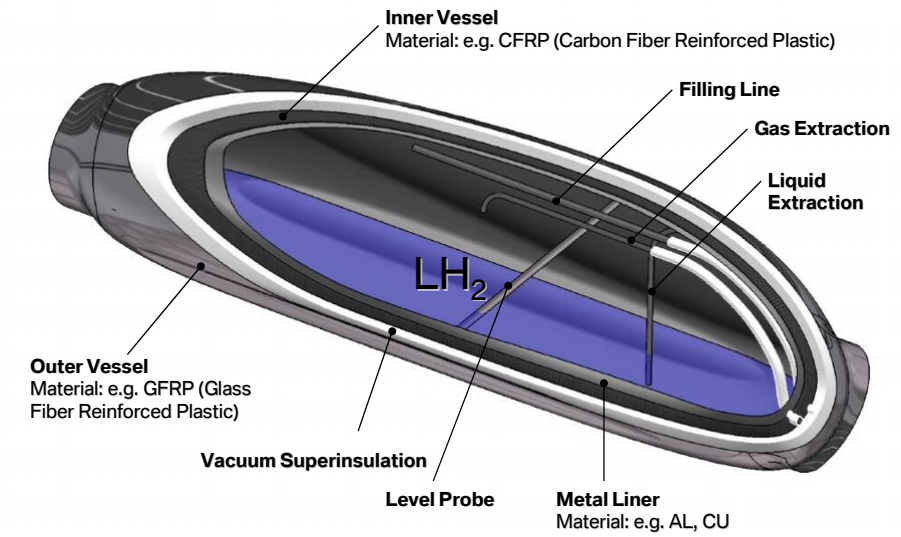
Parameter	Hybrid FC vehicle (large fuel cell system and small battery)	LH_2 ICE vehicle	Hybrid FC Vehicle (small fuel cell system and large battery) City Car	Fuel cell bus
System Gravimetric Storage Density (kWh/kg)	2	2	2	2
System Gravimetric Storage density wt%	6	6	6	6
Vol. Energy Density (KWh/l)	1.5	1.5	1.5	1.5
Max. outer volume available	150 litres	295 litres for LH2	200 litres	16.5m^3
Operating Temp.	-40 to +85 °C	-40 to +85 °C	-40 to +85 °C	-40 to +85 °C
Loss of Usable Hydrogen	-	1 (g/hr)/ kg H2 stored	-	-
Recyclability	End of Life directive 20000/53ECI	End of Life directive 20000/53ECI	End of Life directive 20000/53ECI	End of Life directive 20000/53ECI
H2 Stor. Cost targets			1 €/kWh	As low as possible

Source: http://www.storhy.net/pdf/IPHE_Storage-Targets_2005-06-20.pdf

EU Project StorHy.
Subproject Cryo / HyLighT.



HyLighT.
Lightweight Vessel for Liquid Hydrogen.

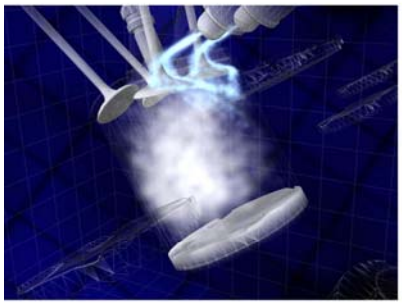


Hydrogen Combustion Engine.
Bifuel Concept for First Market Introduction.

- Power density
- BMW typical characteristics
- Serial production
- Bi-fueled

– Engine displacement 6 Litres
– Performance of more than 170 kW (231 HP) at 5.500 1/min
– maximum torque of more than 337 Nm at 2000 1/min

Hydrogen Combustion Engine.
Great Potential.



Cryogenic mixture formation
(~ –200°C)

High-pressure direct injection
(~ 200 bar)

Auxiliary Power Unit with Fuel Cell Battery.

On-board Electric Power Supply.

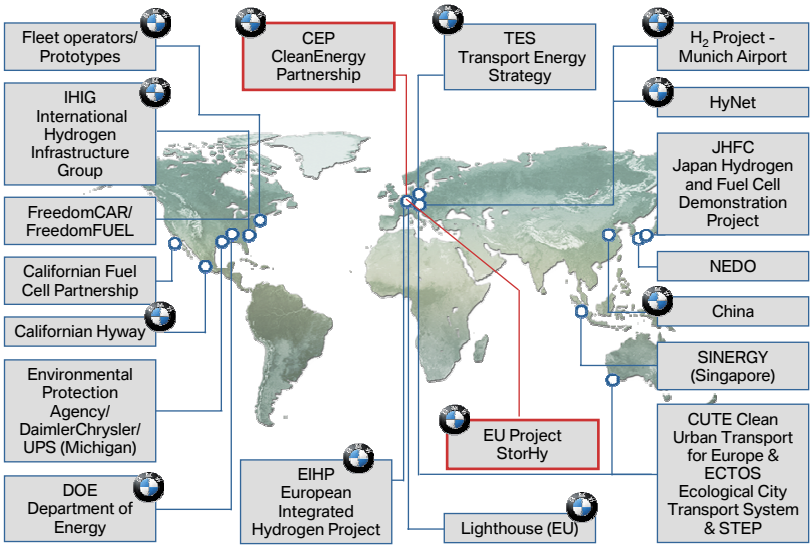
"Unlimited" supply of electricity
independent of engine operation

- Air-conditioning during stand-still
- Immediate heating/warm-up
- Communication
- Lights
- ....

Target:
Complete replacement of alternator and lead acid battery

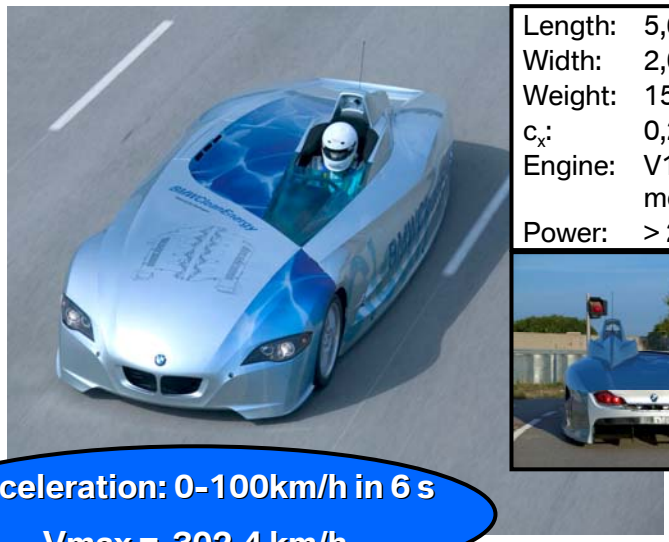
BMW CleanEnergy.

H_2 Projects in USA, Europe and Japan.



Potential of Hydrogen ICE + LH_2.

BMW Record Drive September 2004.



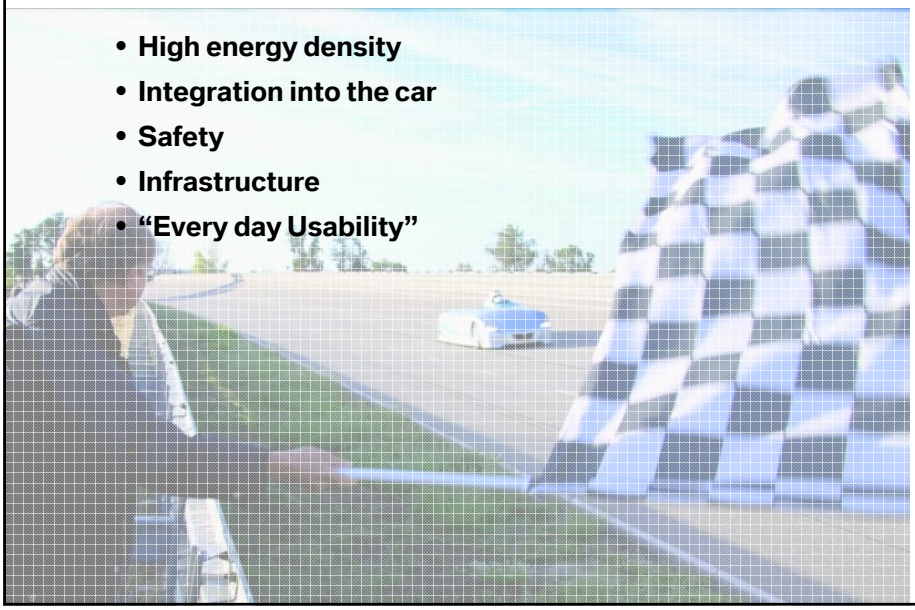
Length:	5,60 m
Width:	2,00 m
Weight:	1560 kg
c_x:	0,21
Engine:	V12, 6 litre monovalent H_2
Power:	> 200KW

Acceleration: 0-100km/h in 6 s

Vmax = 302,4 km/h

Summary.

Requirements for mobile Hydrogen Storage.



- **High energy density**
- **Integration into the car**
- **Safety**
- **Infrastructure**
- **“Every day Usability”**