Trends in fuel cell power train

1st Training in Bahia Blanca, ARG

12-14th of November 2018

Fuel Cells

Running on hydrogen and air => emitting just water!

The ultimate solution???

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Fuel Cells –Questions

Basic questions:

- What can we expect from fuel cells (FCs)?
- What are fuel cells?
- What is the driver for fuel cells and what can fuel cells do better than batteries?
- Are they in competition with batteries?
- What are the draw backs and shortcomings?

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Fuel Cell - Basics

Basic principle:

- Fuel cell (FC) is an electro-chemical energy converter with continuous supply of fuel and oxidant (air, similar ICE)
- FC is a „direct energy converter“
- the cell has a very high efficiency up to 70% - 90%
- small heat loss = „cold combustion“.
- no moving parts, except auxiliaries (compressor and pumps)
  - no (low) noise
- no CO_2, no pollutants, only water or steam

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Fuel Cell - Basics

Basic principle:

- Basic overall reaction (hydrogen gas reaction, cold)
  - $H_2 + ½\ O_2 => H_20$
- Electrolyte
  - base (NaOH, KOH)
  - acid (H_2SO_4, H_3PO_4)
  - solid (polymere, ceramics)
- Electrodes need precious metals for the activation (expensive!)

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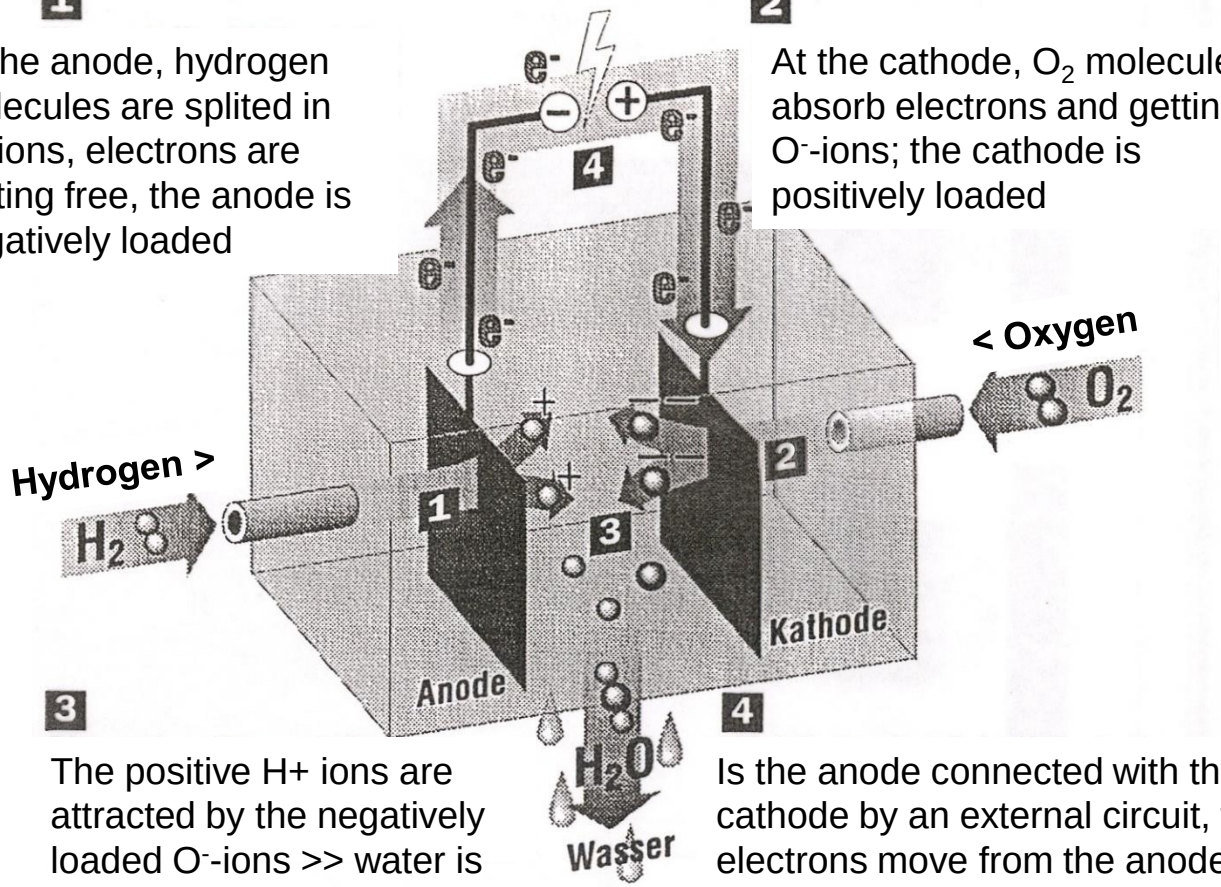
Fuel Cell - Principle

1

At the anode, hydrogen molecules are splited in H^+-ions, electrons are getting free, the anode is negatively loaded

2

At the cathode, O_2 molecules absorb electrons and getting O^--ions; the cathode is positively loaded



The positive H+ ions are attracted by the negatively loaded O^--ions >> water is built

Is the anode connected with the cathode by an external circuit, the electrons move from the anode to the cathode – current is flowing

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Fuel Cell – Principle II

- The theoretical voltage of an hydrogen/oxygen fuel cell is 1,23 V @ 25°C
- The voltage depends on the fuel, the quality of the cell and on the temperature.
- To get higher voltages a lot of cells are connected in series
  - Build so called fuel cell stacks
- Under load the chemical and electrical processes result in lowering of the voltage
  - In real fuel cells voltages between 0.5 – 1 V can be achieved

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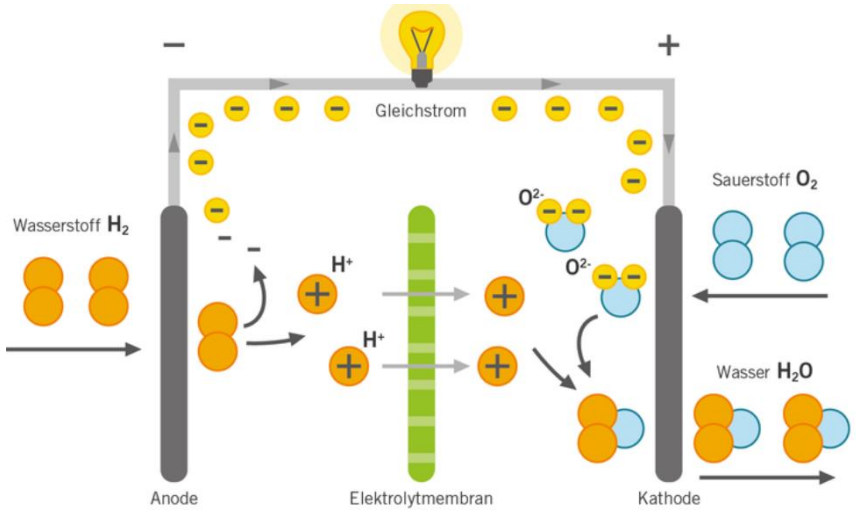
Fuel Cell – Principle III

- A fuel cell delivers approximately the same amount of electric energy and heat
- the temperature level of the dissipated heat is relatively low
  - that means the temperature difference to ambient temperature is low
  - therefore cooling of a fuel cell is more difficult than cooling of an ICE



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Types of Fuel Cells

Fuel Cell Type	Operating Temperatur	Electrolyte	Ionic Conduction	Fuel gas	Oxydant	CO_2 Tolerance	Electric Efficiency	Application	Remarks
AFC Alkaline Fuel Cell	60 - 80 °C	KOH(OH^-)	OH^-	H_2	O_2	< 1 ppm	Cell: 60 - 70 % Syst.: 60%	Space, Military, Vehicles	needs pure H_2 and O_2 corrosion!
DMFC Direct Methanol FC	~ 80 °C	Proton condut. Membran	H^+	CH_3OH	O_2 (Air)		Cell: 20 -30 %	Small devices, Camping	low efficiency
PEMFC LowTemp Polymer Membran FC	60 - 120 °C	Proton condut. Membran	H^+	H_2	O_2 (Air)	< 100 ppm	Cell: 50 - 75 % Syst.: 45 - 60%	Vehicles, Space, Stationary devices	high power density
PEMFC HighTemp Polymer Membran FC	120 - 200 °C	Proton condut. Membran	H^+	H_2	O_2 (Air)	< 500 ppm	Cell: 50 - 75 % Syst.: 45 - 60%	Vehicles, Space, Stationary devices	high power density
PAFC Phosphoric Acid FC	160 - 200 °C	Concentrated Phosphoric Acid	H^+	H_2	O_2 (Air)	< 1 %	Cell: 55 % Syst.: 40%	smaller power stations big vehicles	corrosion problems
MCFC Molten Carbonate FC	~ 650 °C	Alkali carbonate	CO_3^{--}	CH_4; Coal & bio gas, H_2	O_2 (Air)	ok	Cell: 55 % Syst.: 50%	power stations big vehicles	Complex operating, corrosion problems
SOFC Solid Oxide FC	~ 1000 °C	doped Zirconium oxide	O^{--}	H_2, CO, Hydrocarbon	O_2 (Air)	ok	Cell: 60 - 65 % Syst.: 55 - 60 %	power stations, Auxilliary power units	

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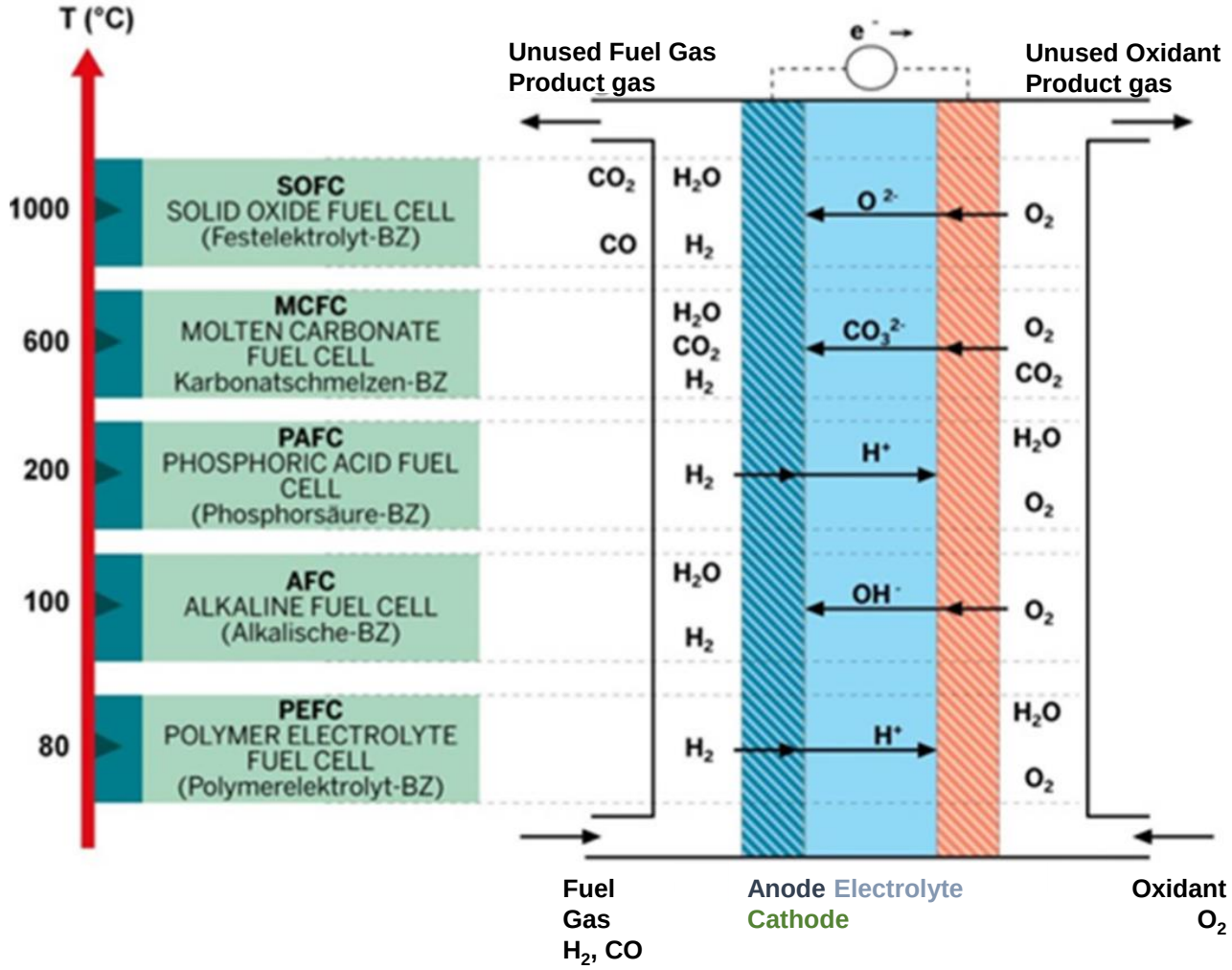
Temperature ranges of fuel cell types



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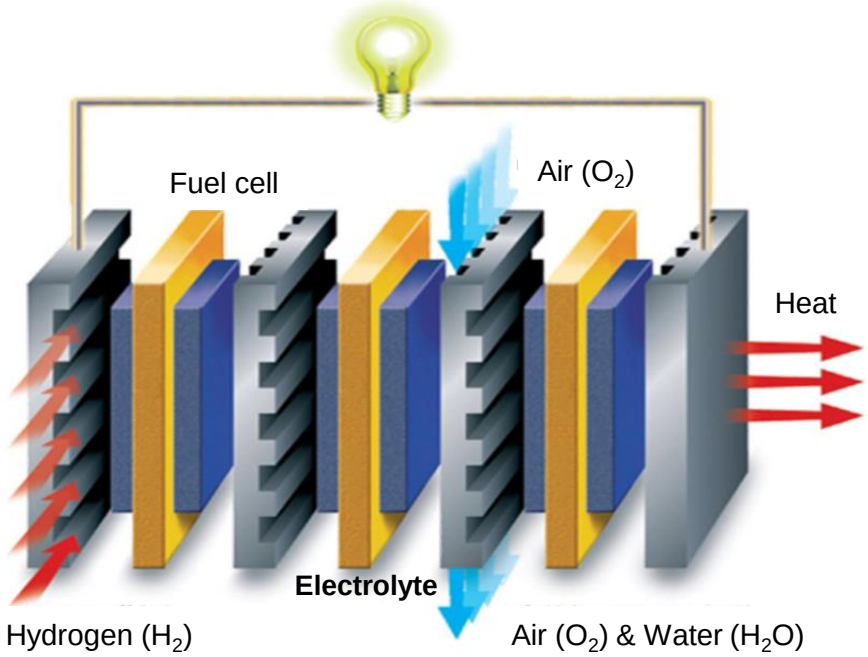
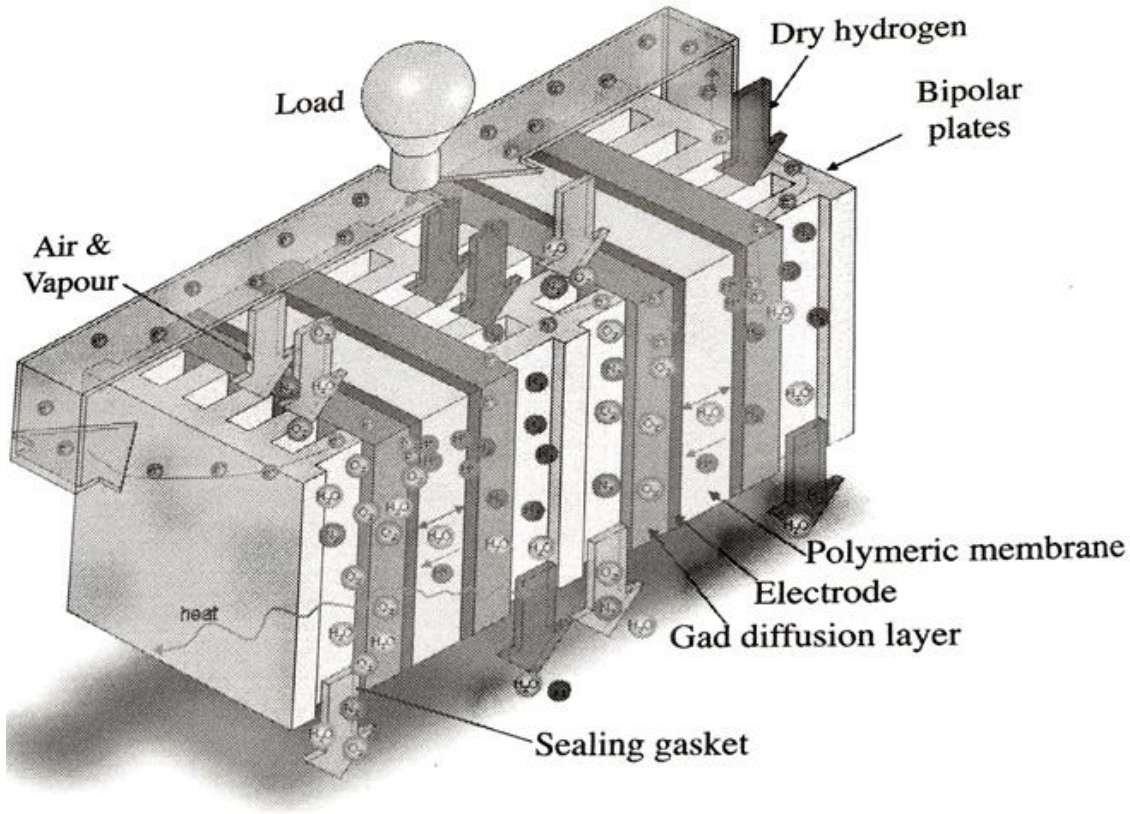
Stack Design





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Fuel cell-System – H_2 / Air - components

H_2 Tank system

Auxiliaries: air filter, compressor, cooling pump, condensator, cooler, humidifier

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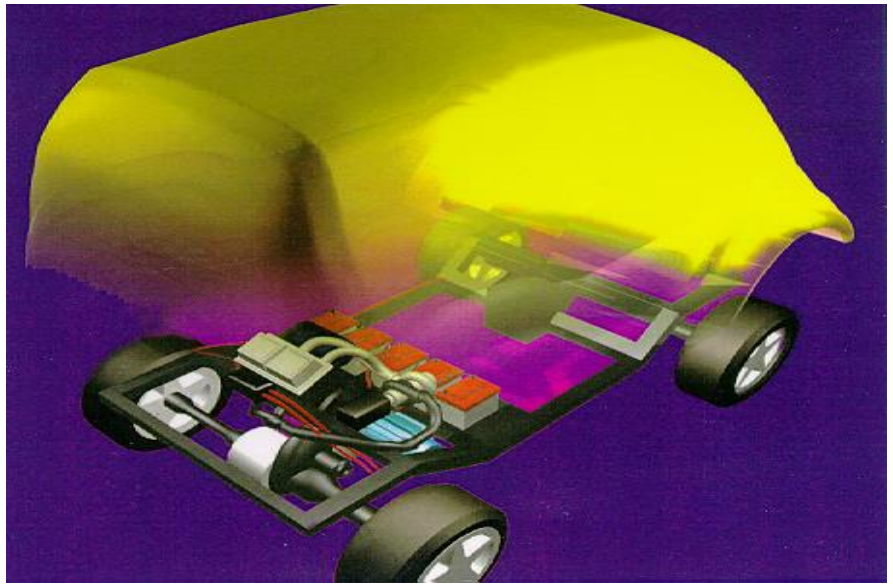
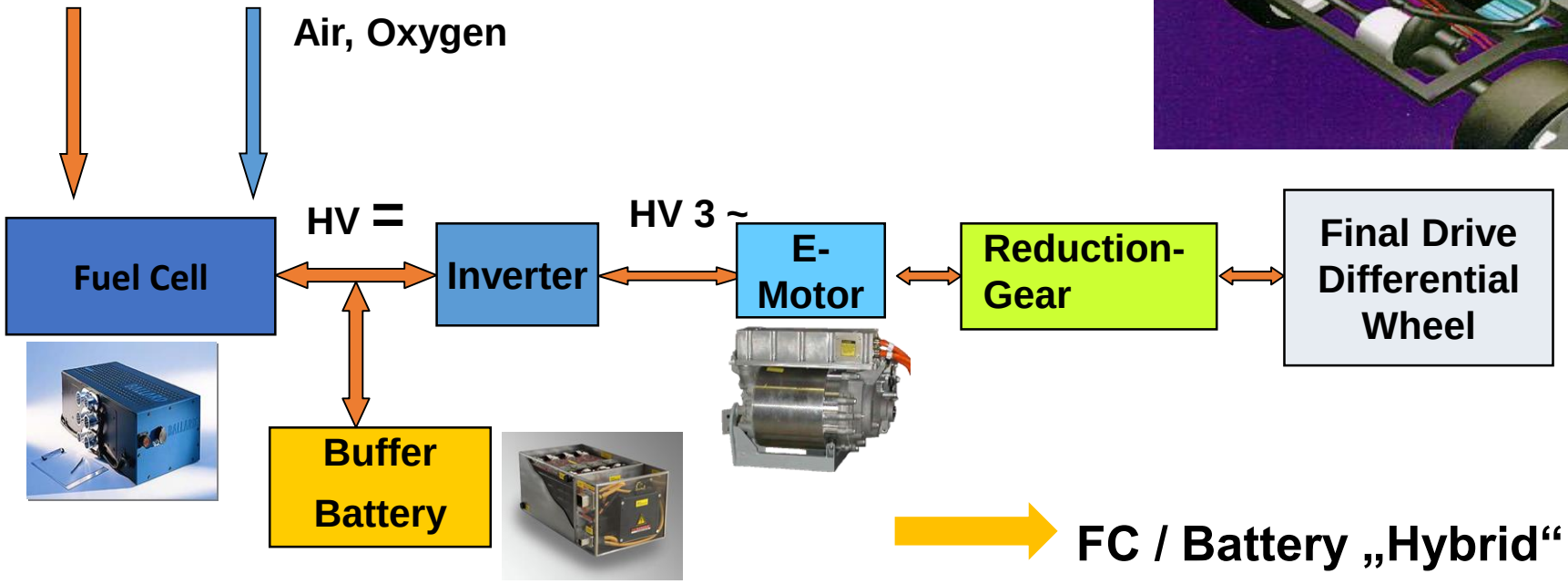
Fuel Cell Powertrain



Principal Layout / Components:

Tank system

Air, Oxygen



FC / Battery „Hybrid“!

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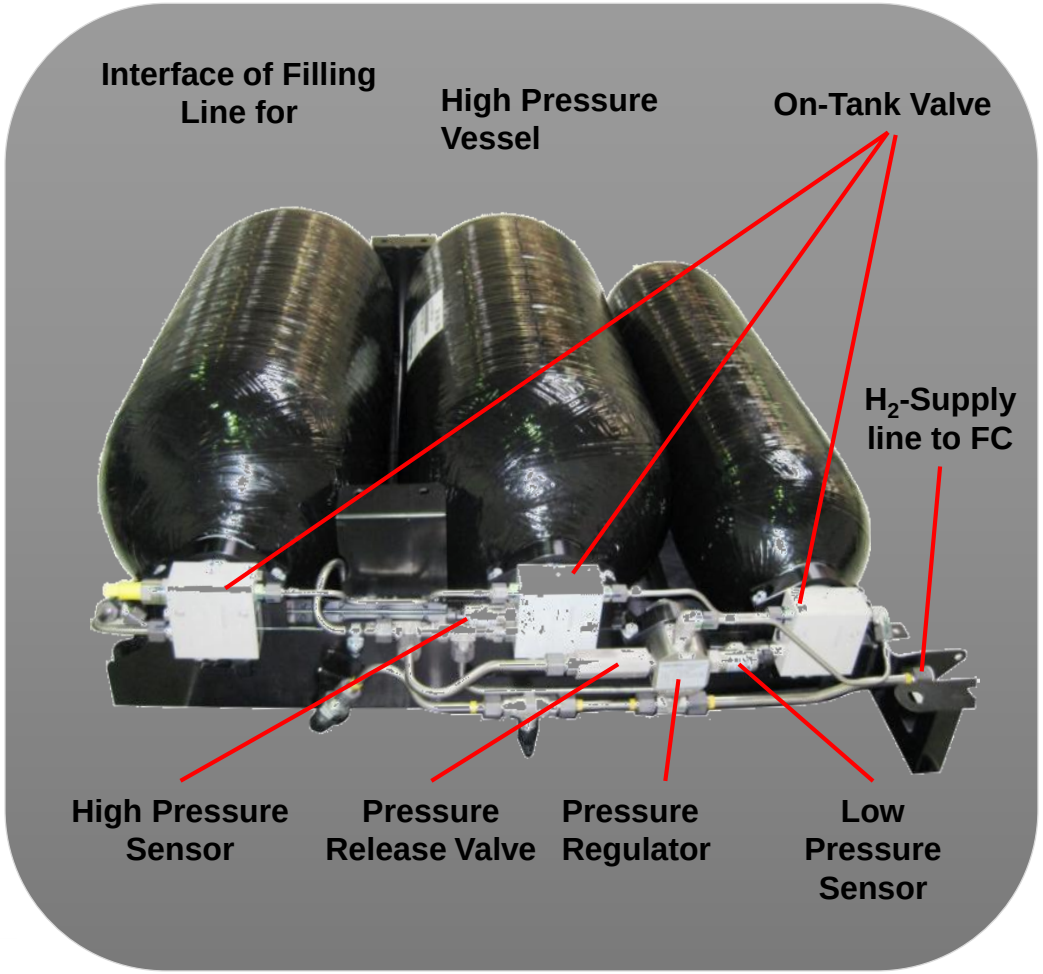
High Pressure Storage for Hydrogen



Storage system specifications:

- Fully wrapped composite cylinder with plastic liner (Type-IV)
- Storage pressure up to 70 MPa
- Plastic liner as hydrogen permeation barrier

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Overview Fuel Cell Vehicles

- Typical specs of todays Fuel Cell Vehicles:
  - PEM Fuel cell
  - Appr. 5 kg H2 in gas tanks @700 resp. @350bar
  - SUV, mid & compact class => Battery Hybrid, no transmission
  - Range >500km, typ. power 100kW full transport capability
- Almost all OEMs are developing FCVs!
  - Comittment for development and market introduction of FCVs in 2015 – 2017 from:
  - Daimler AG, Ford Motor Company, General Motors Corporation/Opel, Honda Motor Co., Ltd., Hyundai Motor Company, Kia Motors Corporation, die Allianz Renault SA und Nissan Motor Co., Ltd. und Toyota Motor Corporation

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Hyundai iX35 Fuel Cell

First series production hydrogen fuel cell vehicle

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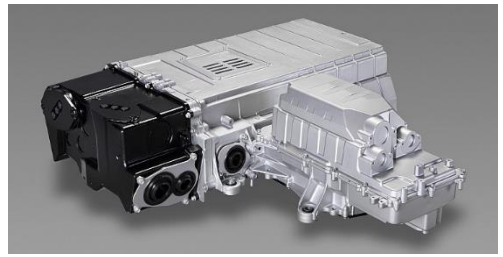
Toyota FCV - New Model 2015

- Toyota FCV 2015 Specs:
  - Power 100 kW; 65% eff.; 3kW/Liter
  - Range: 500 km to 700 km (JC08)
  - Cold start capability: -30°C
  - Price < 80000 €
- Improvements over predecessor (FCHV 2008):
  - The costs of the fuel cell have been reduced by 80%!
  - Number of tanks reduced => more interior space



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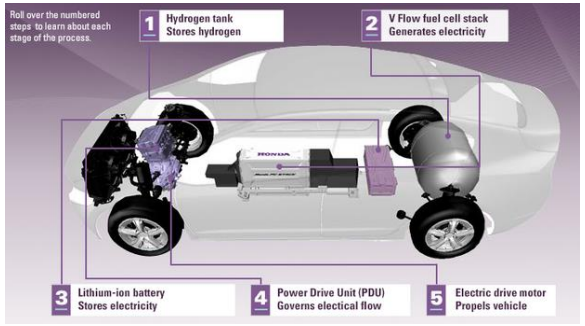
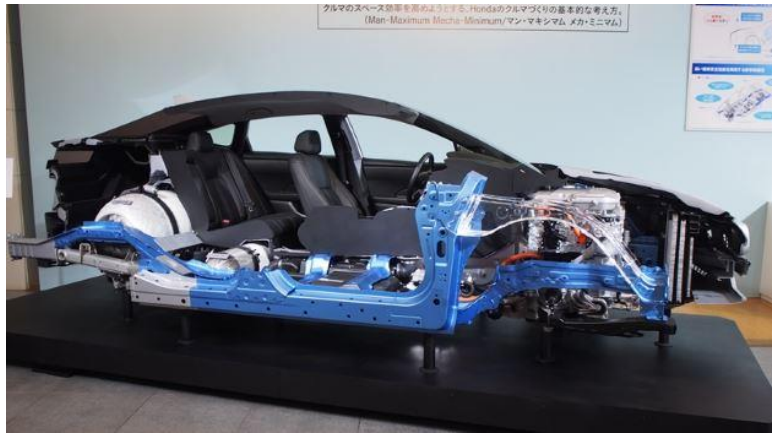
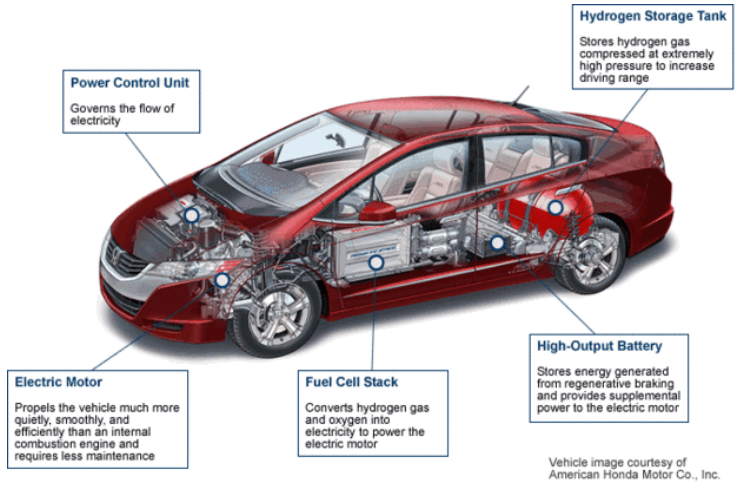
Honda FCX - Clarity



- Honda FCX – Clarity Specs:
  - 100 kW e-motor on front axle
  - hydrogen fuel cell in tunnel
  - Big hydrogen tank over rear axle compromising luggage compartment





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Audi A7 h-tron (2015)

- Audi A7 h-tron Specs:
  - Plug-In FCV
  - PEM FC operating @ ~80°C;
  - Cold start capability: -28°C
- 4 Hydrogen tanks
  - 5 kg @ 700 bar
  - ~ 100 km per kilogram of hydrogen
  - Battery: Li-Ion 8,8 kWh
  - Range 500 (50 pure electric) km
- 2 PSM electric motors rated at 85/114 kW
  - Efficiency powertrain ~ 60%
  - 0 – 100 km/h in 7,9 sec

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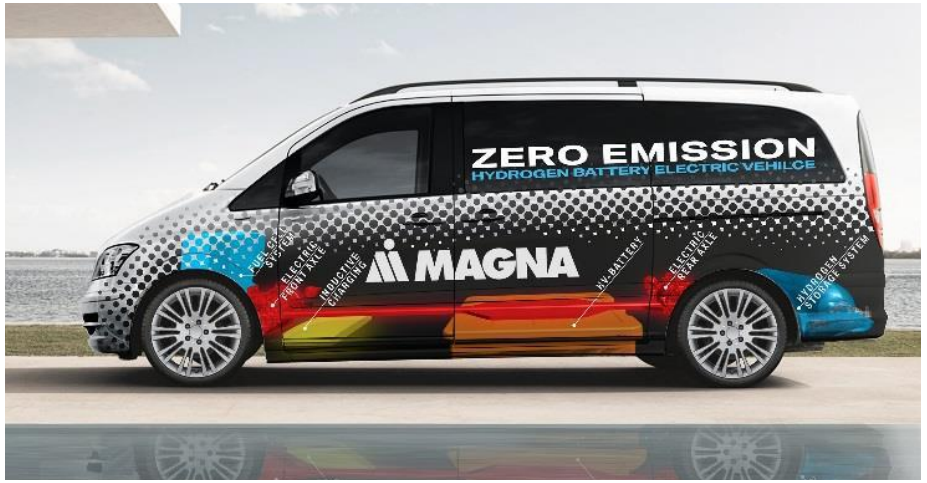
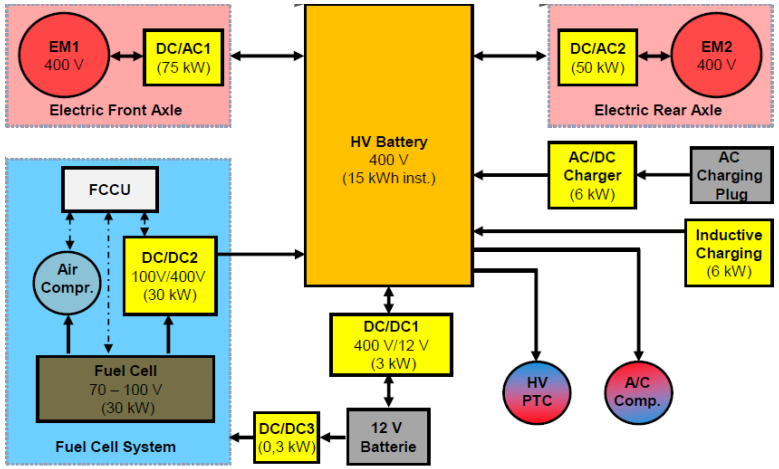
Magna Steyr FC-REEV - FC Range Extended Electric Vehicle

- Base Mercedes E-Vito (Bolt)
- Combination of a bigger capacity battery with a smaller power FC (=REX)
- Application: delivery van for more than one shift





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Fuel Cell Power Train - Conclusion

Disadvantages:

- still expensive (precious materials & catalyst metals)
- difficult to manage (especially water management)
- dynamic (control)
- stability and degradation
- starting problem (duration until ready), solved?
- cold start problem (freezing!), solved?
- necessity of a start / puffer battery (= battery hybrid)
- hydrogen generation, storage, fueling infrastructure

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Fuel Cell Power Train - Conclusion

Advantages:

- no emissions (real ZEV!)
- no moving parts, less noise (except compressor)
- high efficiency in part load condition (city traffic!)
- part of the upcoming hydrogen society/age
- better range than pure electric power train

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Trends in fuel cell power train

Questions??

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