GREEN HYDROGEN TECHNOLOGIES FOR DECENTRALIZED INFRASTRUCTURE SOLUTIONS

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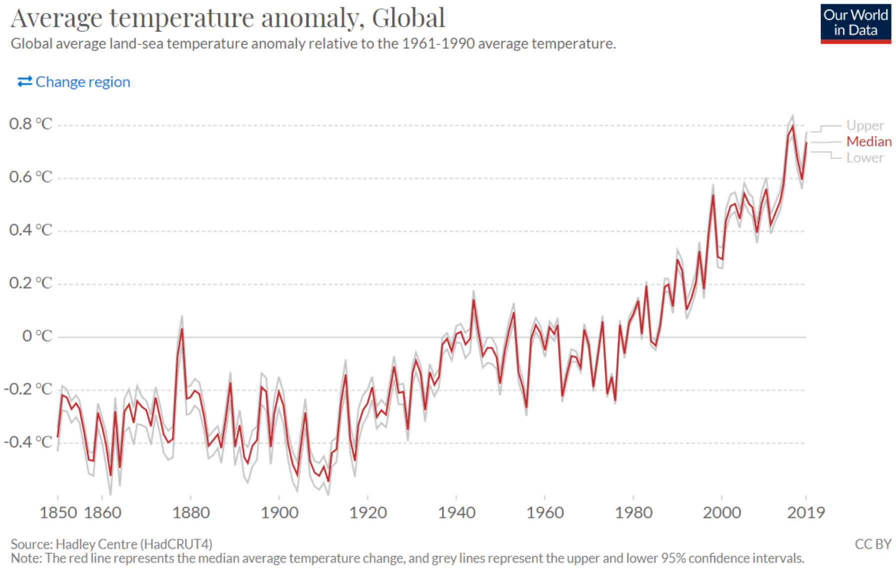
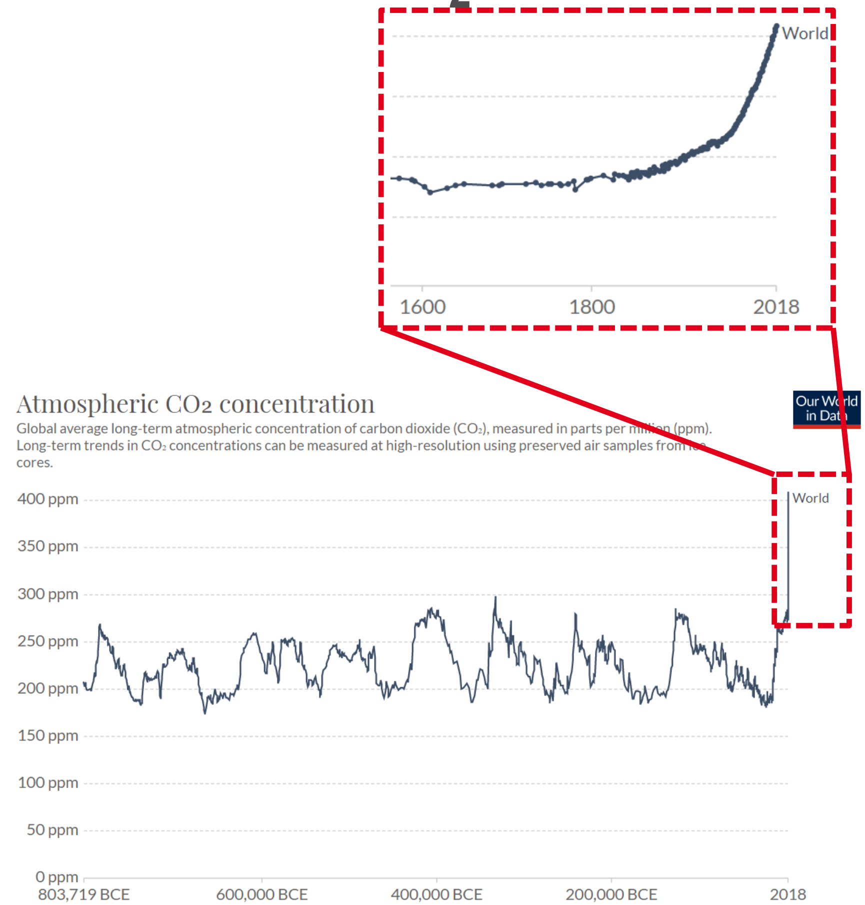
CONTENT

Introduction

AVERAGE GLOBAL TEMPERATURE AND CO_2 CONC.

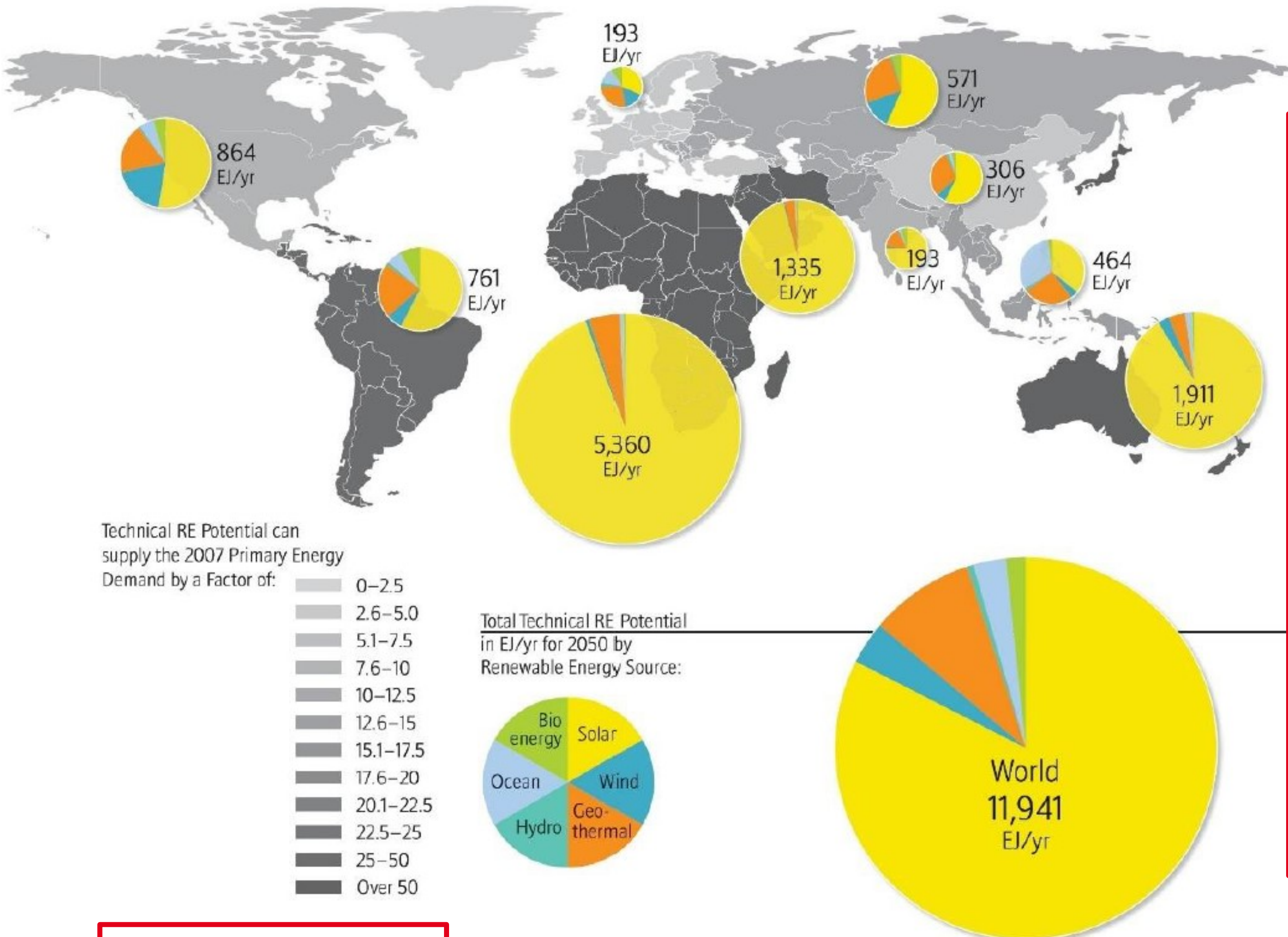




- Main reason for temperature increase: GHG emissions (e.g. CO_2)

Source: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

GLOBAL POTENTIAL FOR RENEWABLES



Total Energy Consumption 2014: 574 EJ

Total Energy Consumption 2018: 582 EJ

Estimated Energy Consumption 2050: 620 – 830 EJ

Potential for Energy Production from renewables: 11.941 EJ

Source: REN21. 2017

FRONIUS VISON: 24 HOURS OF SUN

We develop solutions & products, for efficient

production,

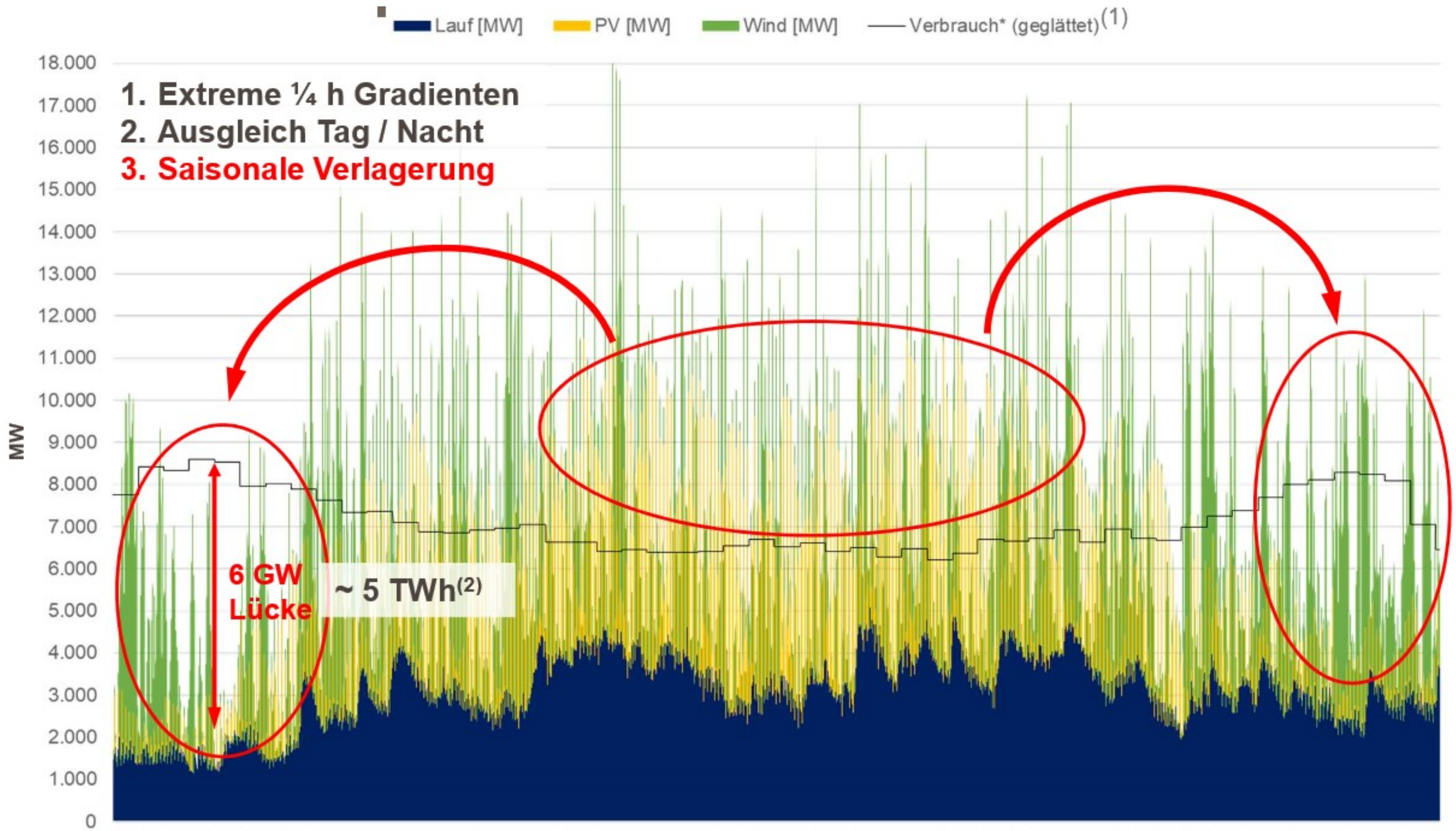
storage

distribution

and **utilization**

of energy from renewable sources

ENERGY PRODUCTION AND DEMAND

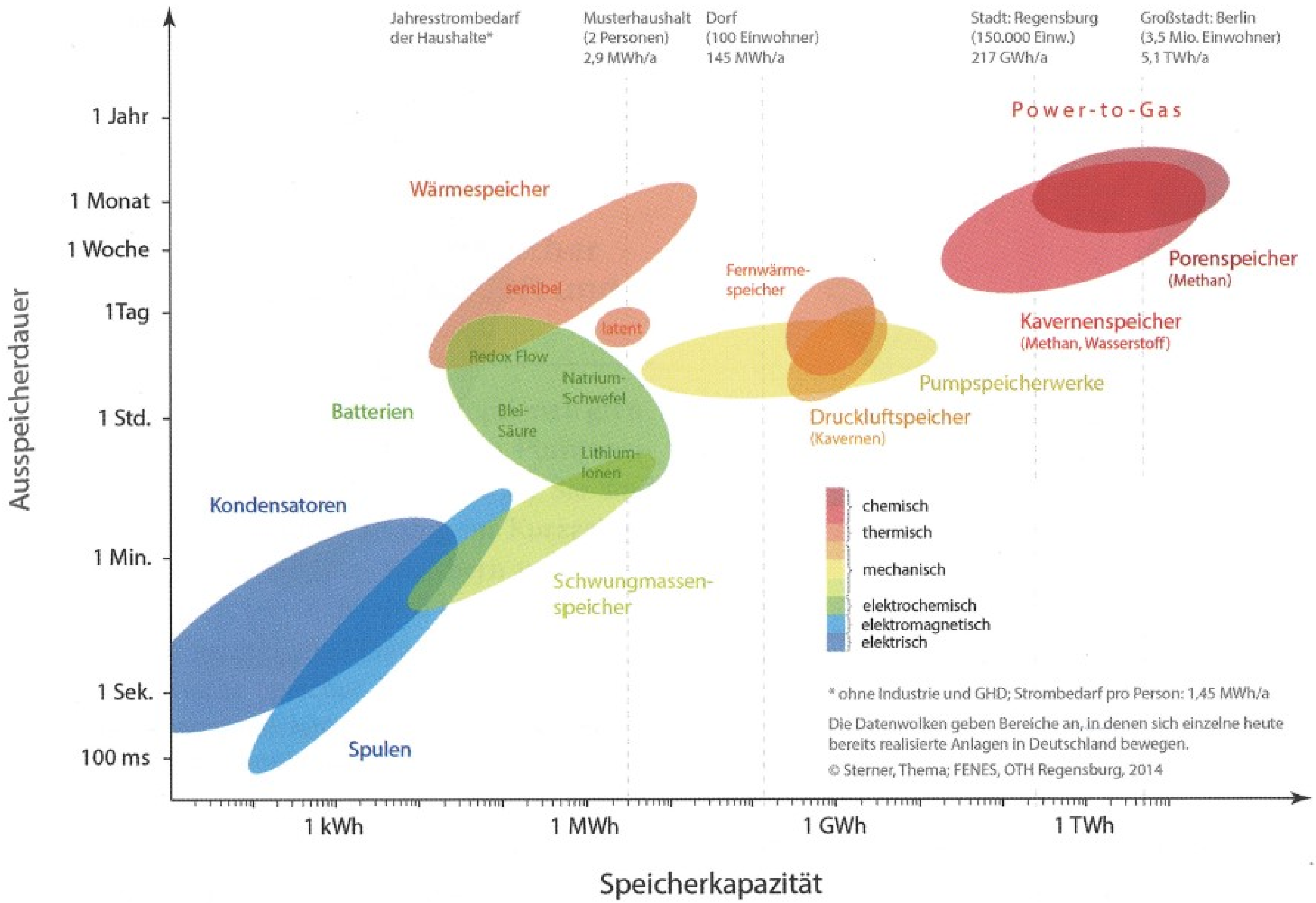


(1) Mittelwert aus den wöchentlichen Minima und Maxima
(2) Von 07.01. bis 21.02. durchgängige Unterdeckung über 46 Tage im Ausmaß von 4,8 TWh

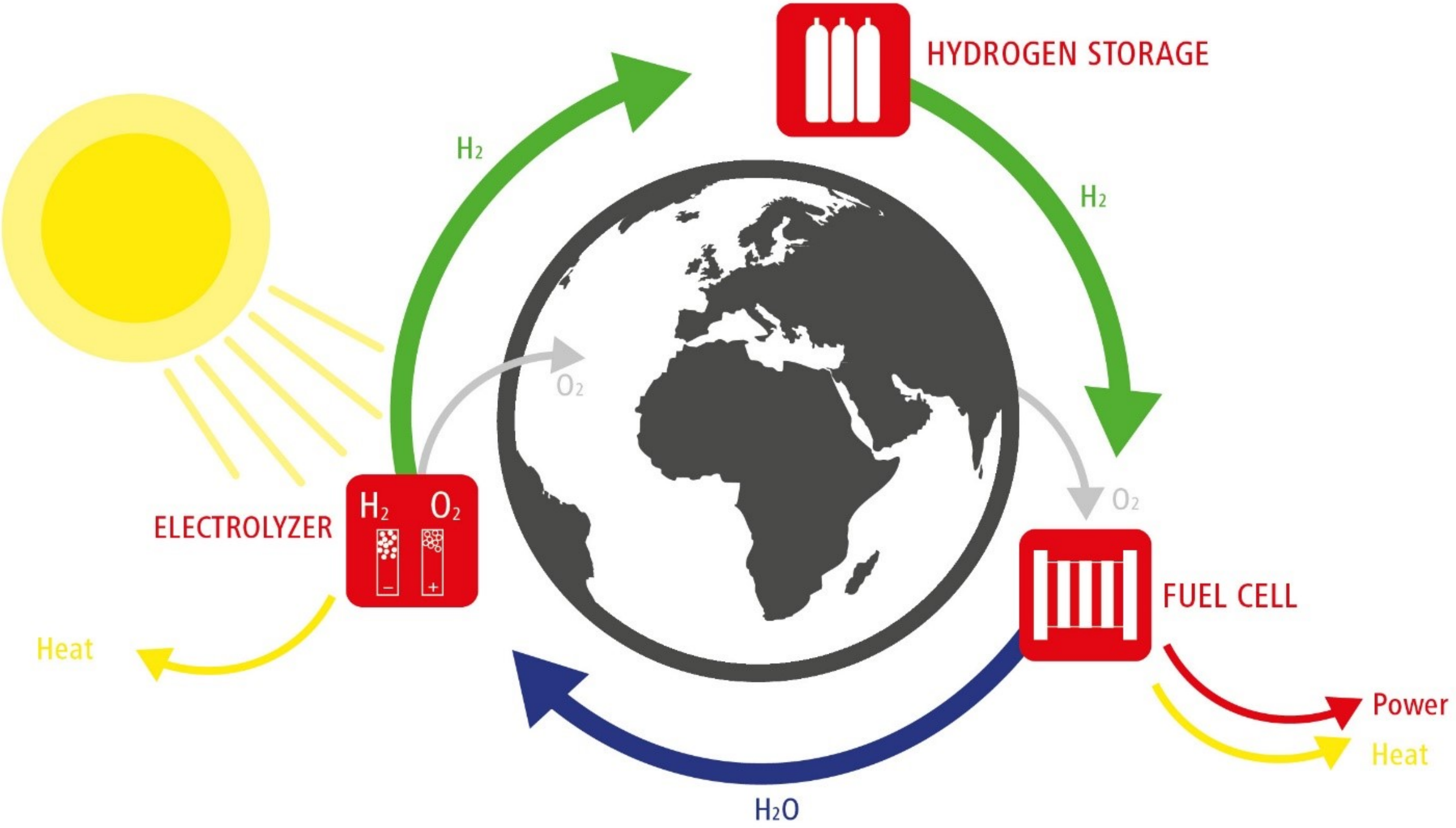
AUSTRIAN POWER GRID AG

[7] APG (2019), Konzepte zu Power-to-Gas

STORAGE SOLUTIONS



HYDROGEN CYCLE



Fronius Solhub

FRONIUS SOLHUB

DECENTRALISED HUB FOR SOLAR ENERGY

2018 staatspreis Clean Technology Austria

State award for environment and energy technology / category research & innovation (30.10.2018)

FRONIUS SOLHUB AT A GLANCE

Adaptive System

Modular Setup
(Retrofit-Applications)

Increment Adaption
(Upgrade to increase perfomance)

Components

- Electrolyser
- Compression
- Storage
- Dispenser
- Fuel Cell

H_2 production where it is needed.

Onsite production of green hydrogen

Sector Coupling

Mobility

Re-electrification

Waste Heat utilisation

Storage

Integration of Renewables

Green hydrogen instead of brown, grey, pink or blue H_2

TARGET MARKET SOLHUB

Communities, Enterprise (logistic, trade,…) & Agriculture

- Large roof area for PV
- Local production of green H_2
- H_2 utilisation for clean mobility and transport
- Waste heat utilisation
- (in future optional saisonal storage)

FRONIUS SOLHUB

Hydrogen Production

- Water Purification
- Electrolysis 35 bar
- Low Pressure Storage

Reconversion

- Fuel Cell

Medium Pressure System

- Comp-ression 450 bar
- Medium Pressure Storage
- 350 bar Refuelling

High Pressure System

- Comp-ression 900 bar
- High Pressure Storage
- 700 bar Refuelling

Electrolysis

ELECTROLYSIS

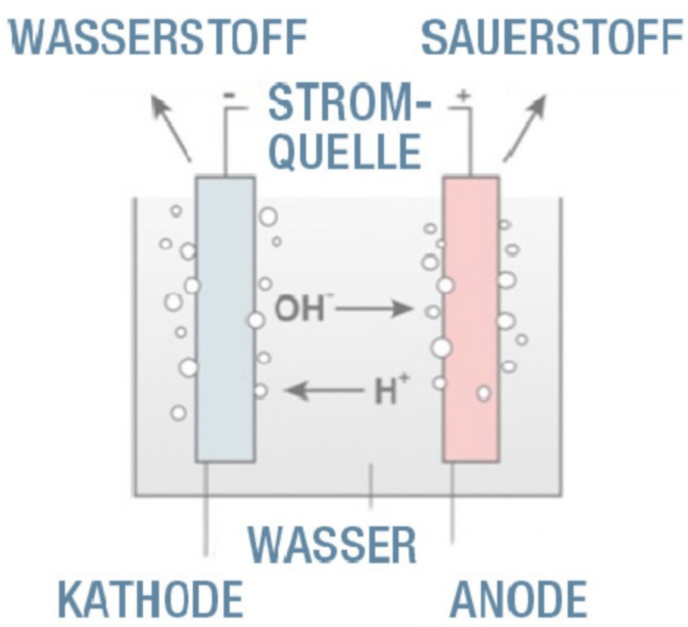
- The electrochemical splitting of water is the only technologically mature method for the emission-free production of hydrogen
- The prerequisite for this is that the electricity required comes from renewable energy sources: wind, water or solar energy
- Depending on the technology and design, efficiencies of up to 85% can be achieved
- In general, there are three basic technologies for electrolysis:
- Alkaline Electrolysis (AEL)
- PEM (polymer electrolyte membrane) electrolysis (PEMEL)
- High temperature electrolysis (HTEL)
- There is also a kind of mixed form of PEMEL and AEL, alkaline electrolysis with polymeric anion-conducting solid electrolytes (AEMEL)

ELECTROLYSIS

/ The splitting of water into hydrogen and oxygen requires a relatively high expenditure of energy.

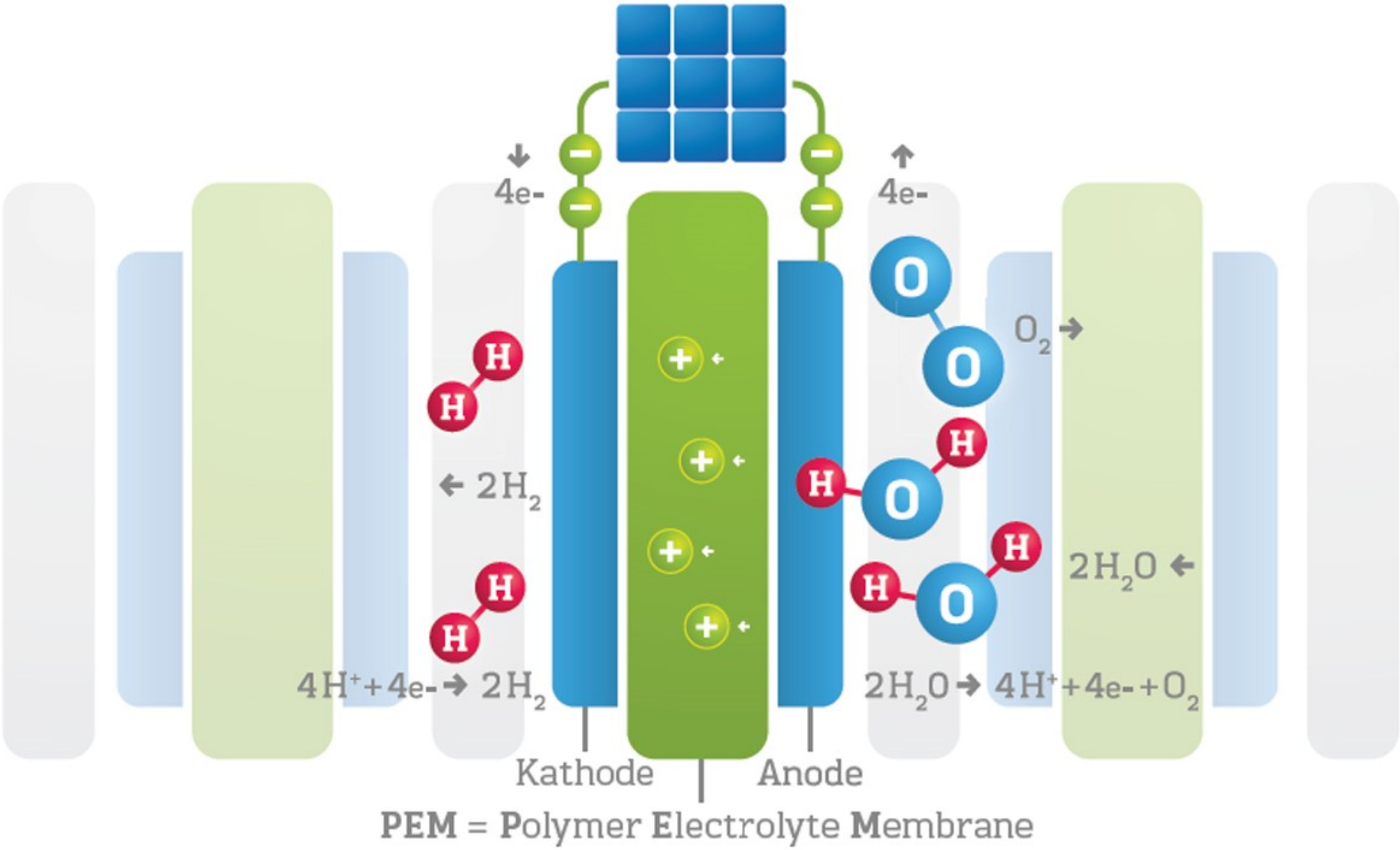
$$H_2O(l) \rightarrow H_2(g) + \frac{1}{2}O_2\,(g) \qquad \Delta_R H_m^0 = 285{,}83\left[\frac{kJ}{mol}\right]$$

- Theoretically, one kmol of water is obtained from one kmol of hydrogen with an energy input of 286 MJ
- In the ideal case, 142 MJ or 39.4 kWh are required to generate 1 kg of hydrogen (molar mass of H2 = 2.016 kg / kmol)
- This corresponds to the calorific value of hydrogen => efficiency = 100%

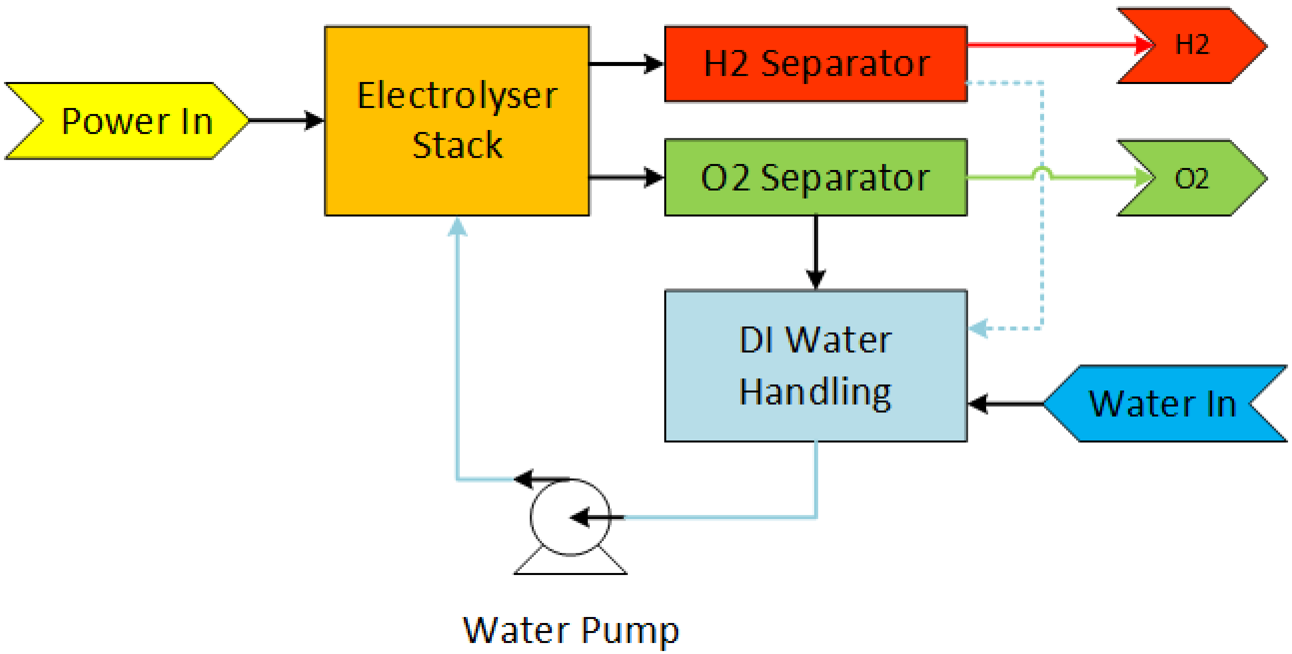


Source: CEP

ELECTROLYSIS



BASIC FUNCTIONALITY ELECTROLYSIS



ELECTROLYZER STACK

- Number of cells 35 (max. 85 cells)
- Production rate 13 Nm^3/h
- Supply voltage 69,7 – 84,0 VDC
- Current 90 - 900 A
- Current density 3 A/cm^2
- Power consumption EOL 75,6 kW
- Product gas pressure 36 bar
- Temperature range 20 – 70 °C

ELECTROLYSIS POWER SUPPLY

In-house power source

- 4 pieces per stack
- Maximum tension 102 V
- Maximum current 210 A
- Very fast load changes possible

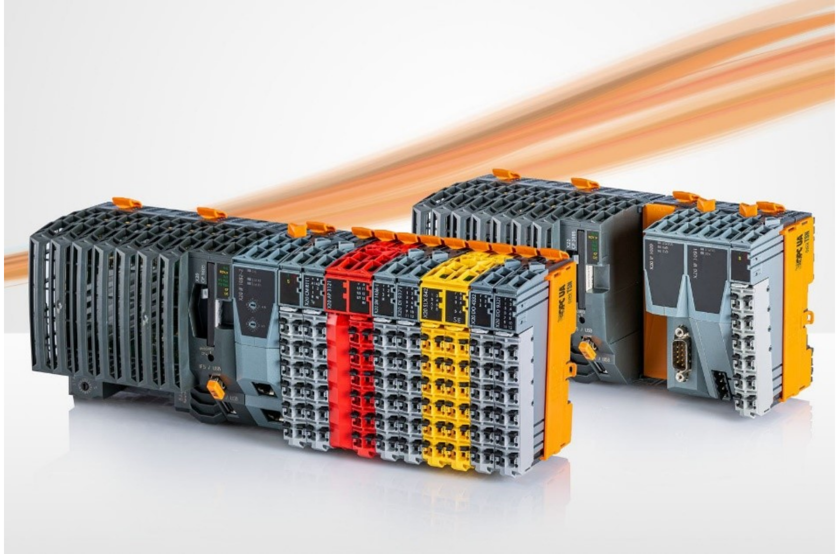
ELECTROLYSIS CONTROL

X20 System

- X20 control generation with Intel-Apollo-Lake-I-Processors
- Disk-based I / O and control system
- OPC-UA-over-TSN-able

Safety PLC

- openSAFETY-Container
- Suitable for applications up to PL e or SIL 3
- Safe analog inputs



ELECTROLYSIS

Specifications

- Max. Production 23 Nm³/h ≈ 49,6 kg/day
- Production rate 2,3 Nm³/h – 23 Nm³/h
- Product gas pressure 36 bar
- Continuous input power 143 kW/400V
- Dimensions: 2100 x 750 x 1800 mm
- Weight: 1000 kg

CONCLUSION ELECTROLYSIS

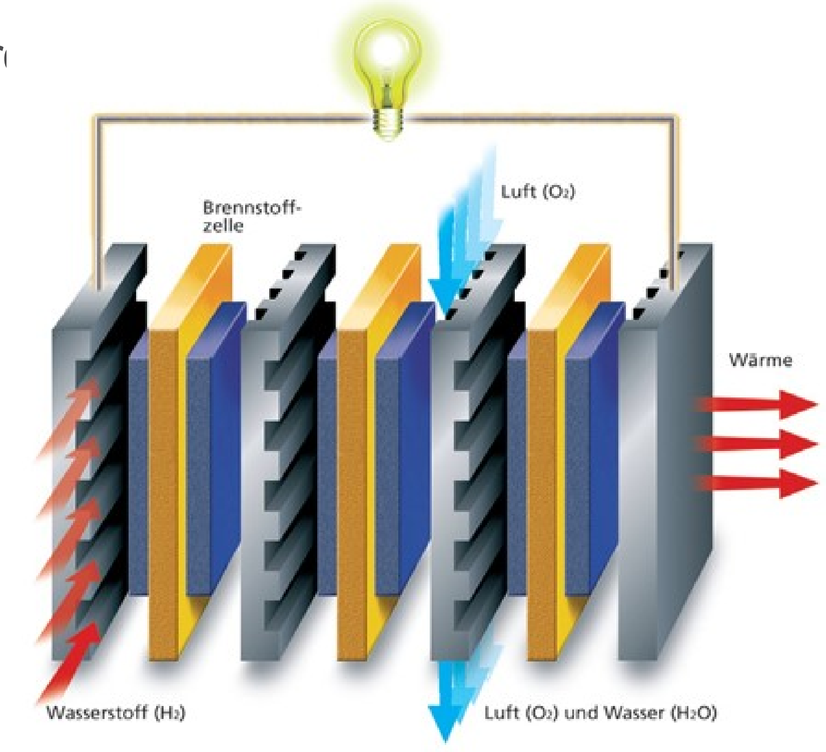
- High safety standard thanks to device-integrated functions for safety and explosion protection (explosion protection depending on the safety concept)
- Hydrogen generation efficiency> 60% and energy efficiency> 75% when using the 65 ° C waste heat
- High availability, partial load capability and performance dynamics thanks to the modular concept
- Best hydrogen quality for operation with fuel cells, in analytics or industry
- Interface for data communication (CAN)

Fuel Cell

FUEL CELL

- Direct conversion of chemically bound energy directly into electrical energy
- Potentially high degrees of efficiency at low temperature levels, as it is not tied to the Carnot process
- **No emissions** of pollutants or noise (with hydr
- No moving parts => **low maintenance**

- Current challenges:
  - **High manufacturing costs**
  - **Lifetime**
  - **Efficiency**
  - **Dynamic behaviour**



FUEL CELL

- **Polymer-Elektrolyt-Membran BZ (PEMFC – Proton Exchange Membrane FC)**
- Low temperature fuel cell
- Electrolyte = acidic, proton-conducting polymer membrane (solid)

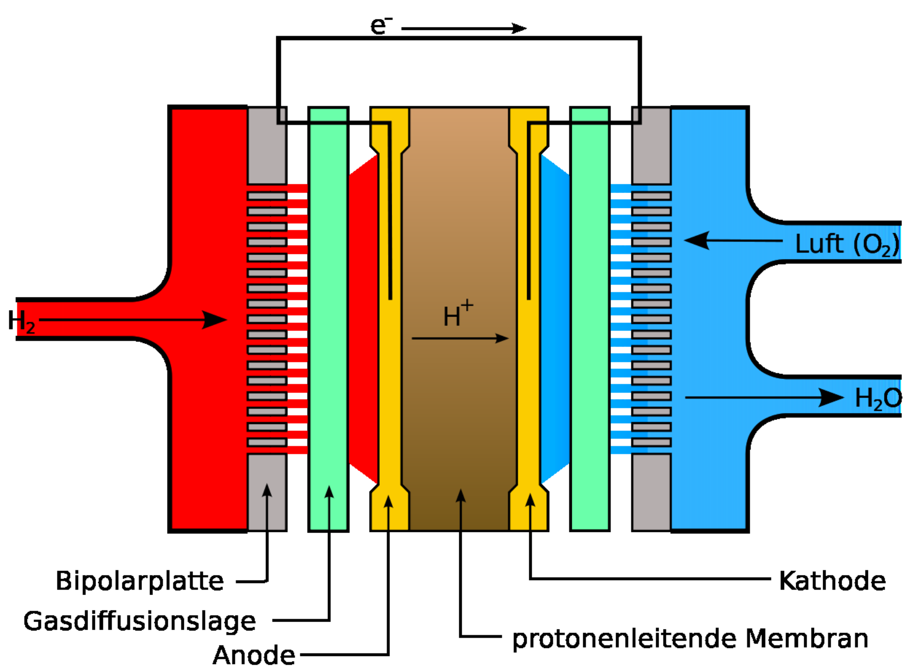
- Supply of hydrogen to the anode
- Reaction (oxidation) at anode:

$$H_2 \rightarrow 2H^+ + 2e^-$$

- H + ions through the membrane to the c
- Reaction (reduction) at the cathode:

$$2H^+ + 2e^- + \tfrac{1}{2}O_2 \rightarrow H_2O$$

- Overall reaction: $H_2 + \tfrac{1}{2}O_2 \rightarrow H_2O$



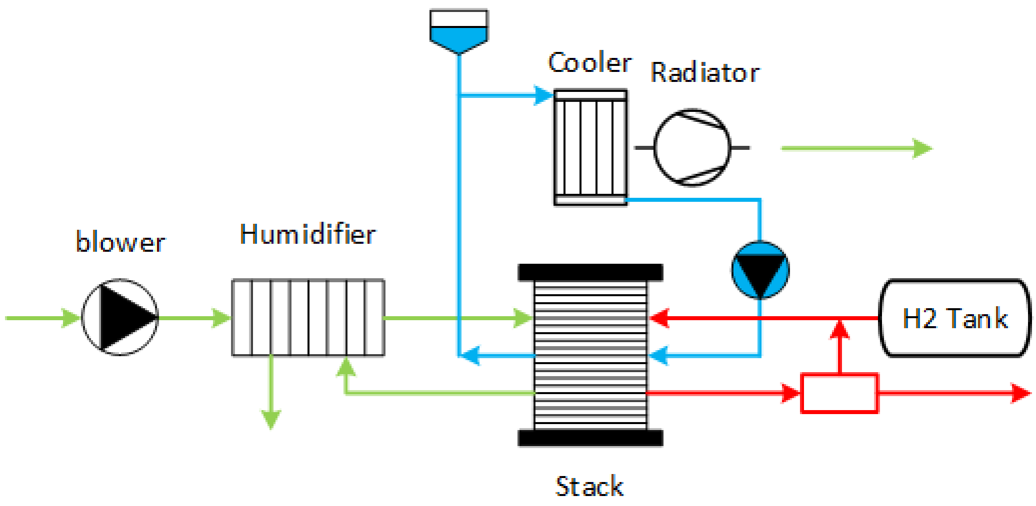
FUEL CELL

- **Fuel cell stack**
- Total amperage depending on cell area
- Max. Cell voltage in the range 0.5 - 0.8 V
- Stacking the cells to achieve the desired performance rar
  - Usual 100 kW fuel cell stack with approx. 400 cells

Source: ElringKlinger

FUEL CELL

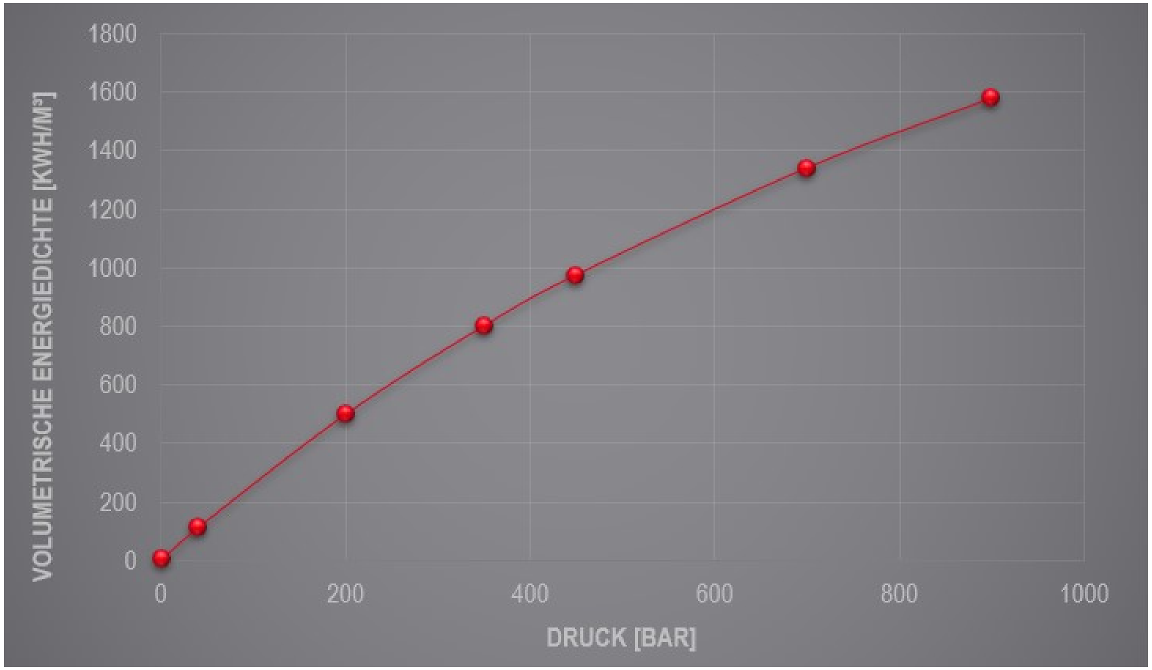
- **Fuel cell system**
- Fuel cell stack
- Hydrogen supply (anode path)
- Air supply (cathode path)
- Thermal management



Storage, Compression, Refuelling

STORAGE OF GASEOUS HYDROGEN

/ Energy density at different pressure levels (reference temperature = 15 °C)



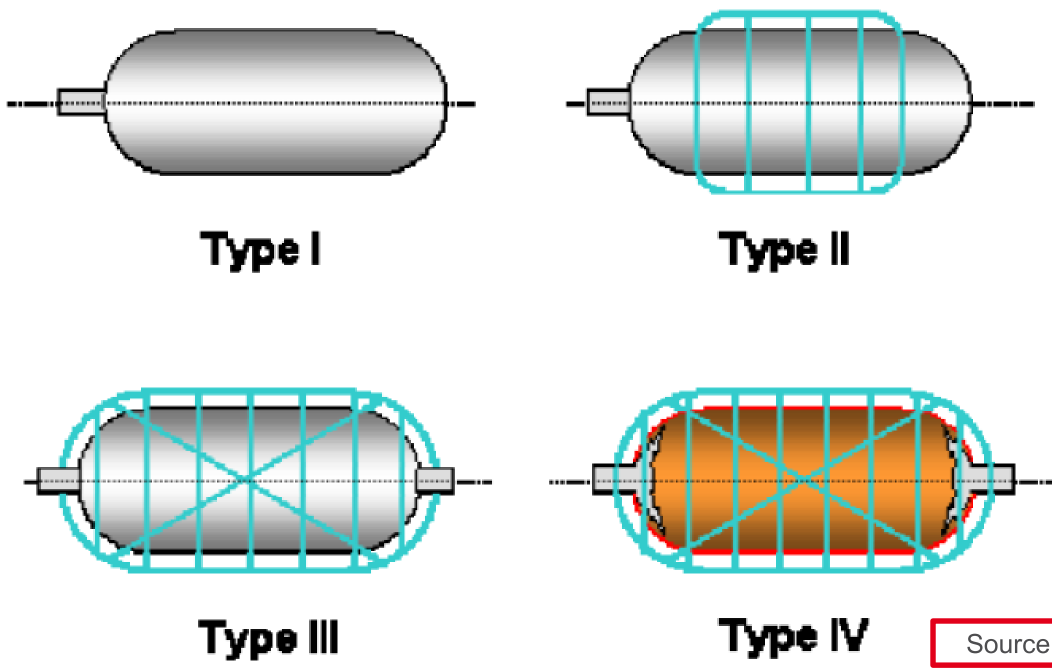
Example: In a 150 L vehicle storage cylinder at **350 bar approx. 3,6 kg** and at **700 bar approx. 6 kg** can be stored.
This results in **+67 % increase of stored hydrogen** when the pressure is doubled

Pressure [bar]	1,01325	50	200	350	450	700	900
Density [kg/m³]	0,0899	3,29	14,94	24	29,23	40,17	47,31
Vol. En. Density* [kWh/m³]	3	110	498	800	974	1339	1577

*related to Lower Heating Value (LHV): 33,33 kWh/kg

GASEOUS STORAGE

- **Type I:** seamless metall cylinder
- **Type II: seamless metall cylinder, circumferential carbon fibre windings**
- **Type III:** carbon fibre storage cylinder with metal liner (inner container, usually aluminium)
  Type IV: carbon fibre storage cylinder with plastic liner (usually HDPE)



Source: Department of Energy

HYDROGEN COMPRESSION

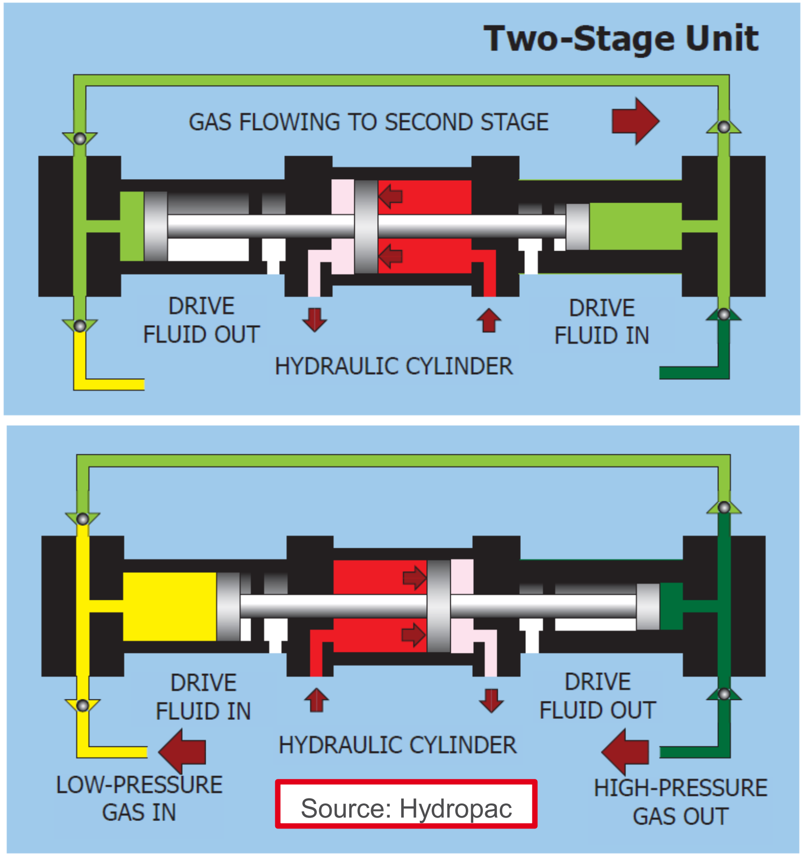
- **Hydraulic driven piston compressor**
- To prevent contaminations of hydrogen, non-lubricated piston compressors are used
- The gas section and hydraulic section are separated through sealings and an air filled intermediate space
- Suitable for pressure levels up to 1000 bar (and higher)
- Different flow rates
- Simple structure
- Disadvantages:
  - Noise emissions
  - Maintenance effort
  - Space requirements

1. Gasventile
2. Zuganker
3. Gaskolben
4. Distanzstück/Laterne
5. Kolbenstange
6. Antriebszylinder
7. Sensoren
8. Elektromotor
9. Hydraulikpumpe
10. Öltank
11. Kühlmantel

Source: sera compress

HYDROGEN COMPRESSION

- In a **two-stage piston compressor** hydrogen is compressed from **35 to 450 bar**
- In a **separate one-stage compressor** hydrogen is compressed from **450 to 900 bar**
- Generally: to increase the pressure from **1 to 1000 bar**, usually **up to five compressor stages** are needed
- Pressure levels in figure:
  - Yellow: low pressure at inlet (e.g. 35 bar)
  - Light green: medium pressure (e.g. 200 bar)
  - Dark green: high pressure at outlet (e.g. 450 bar)



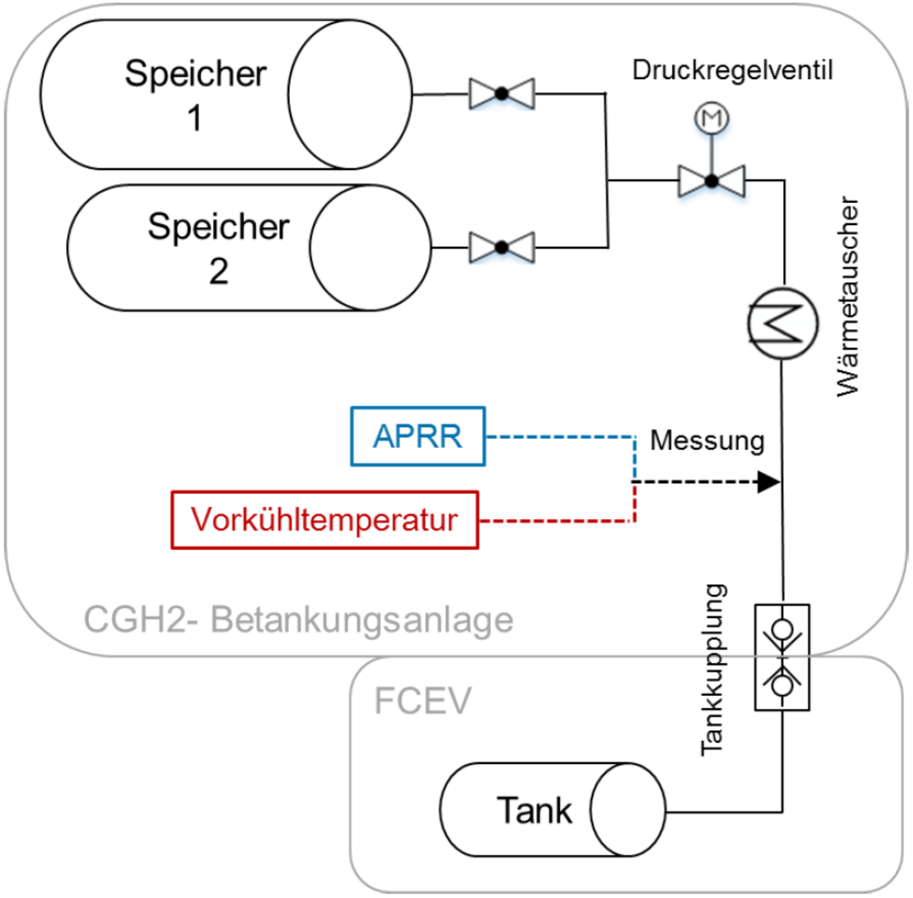
Source: Hydropac

REFUELLING PROCESS

- Hydrogen is filled to the vehicle tank via pressure compensation with the station storage
- Within this process the following parameters have to be observed:
  - **Maximum allowable storage pressure**
  - **Maximum allowable temperature**
  - **Maximum allowable SOC**

- SOC = State of Charge, is defined as:

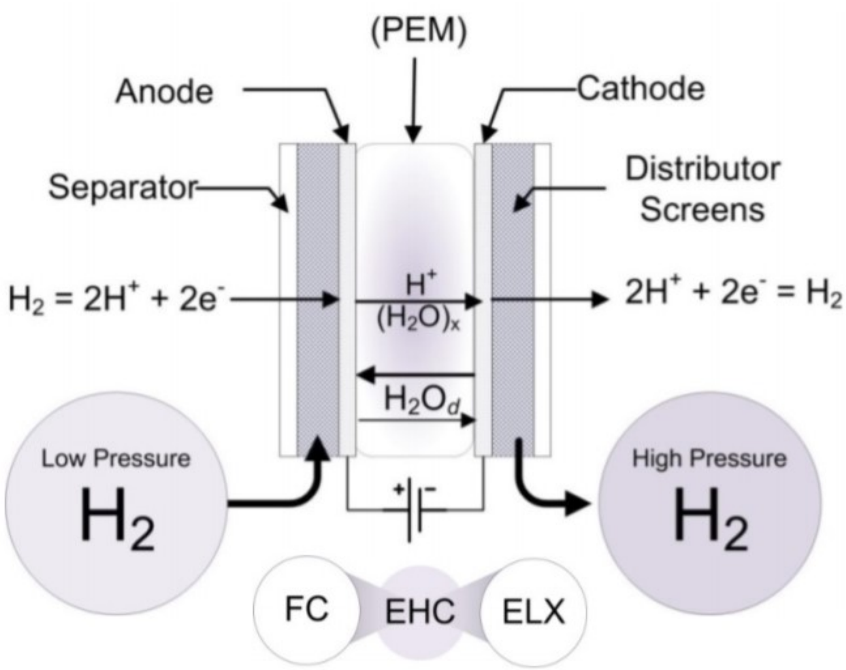
$$SOC\,(\%) = \frac{\rho\,(P,\ T)}{\rho\,(NWP,\ 15°C)}\ x\ 100$$



Future Technologies

ELECTROCHEMICAL COMPRESSION

- Hydrogen is compressed similar to asymmetric pressurized electrolysis
- The design of the anode compartment of the electrochemical compressor is similar to a **PEM Fuel Cell**
- The design of the cathode compartment of the electrochemical compressor is similar to a **PEM Electrolysis Cell**
- At the **anode** compartment **hydrogen** is supplied at low pressure, by applying DC power it is **split into H^+-Ions**
- The H^+-Ions permeate through the membrane and are **recombined to hydrogen** on the **cathode** compartment
- Pressure builds up on the cathode side via back pressure regulators
- Differential pressures of up to 1000 bar



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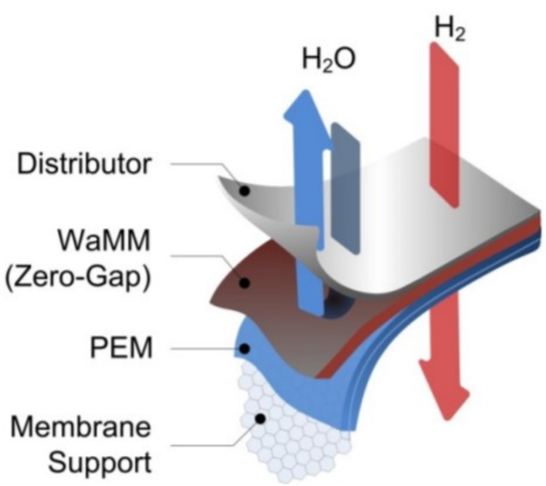
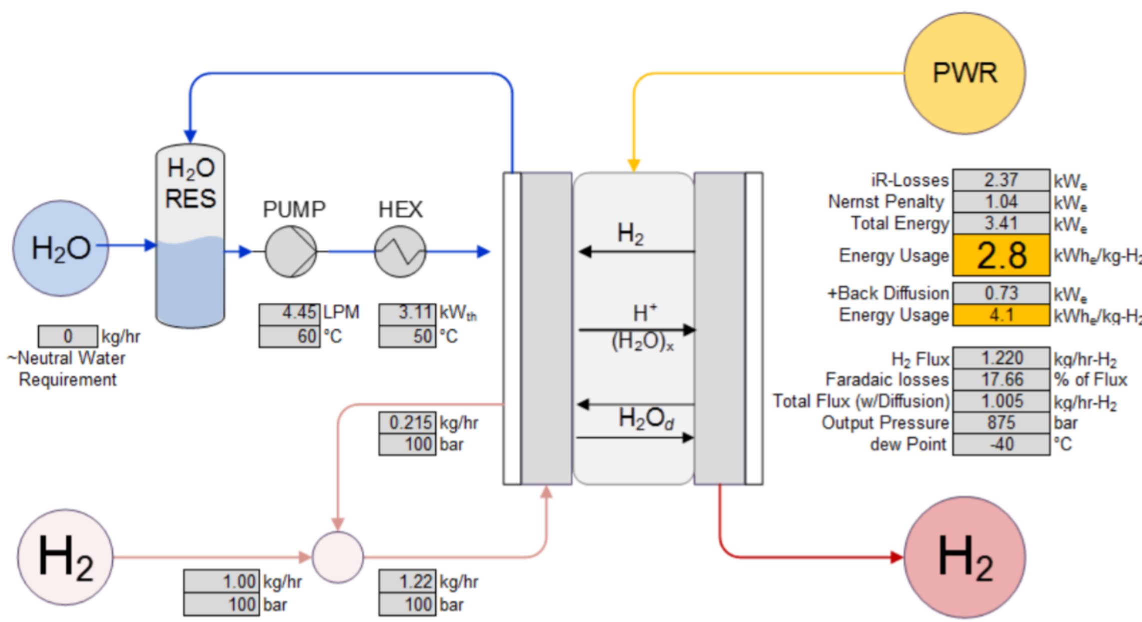
ELECTROCHEMICAL COMPRESSION

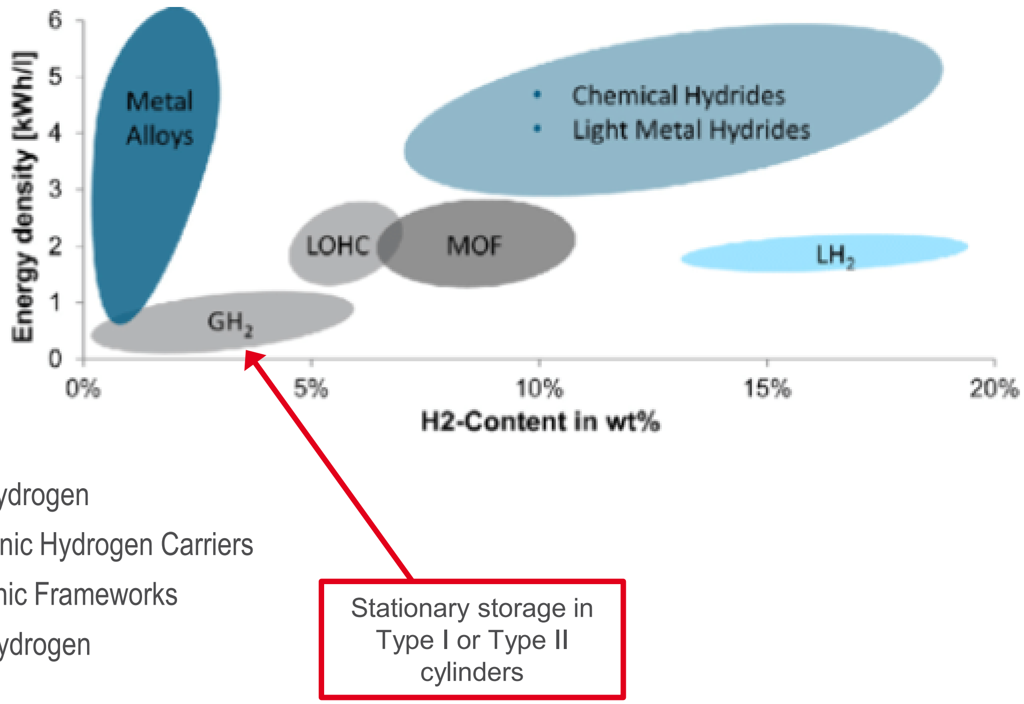
- Similar to electrolysis the MEA has to be moisturized
- The **electroosmotic drag** (permeation of water to the cathode side) is comparably high and therefore **water management** is more complex
- The overall amount of water should be lower compared to electrolysis, therefore **heat management** is also more complex





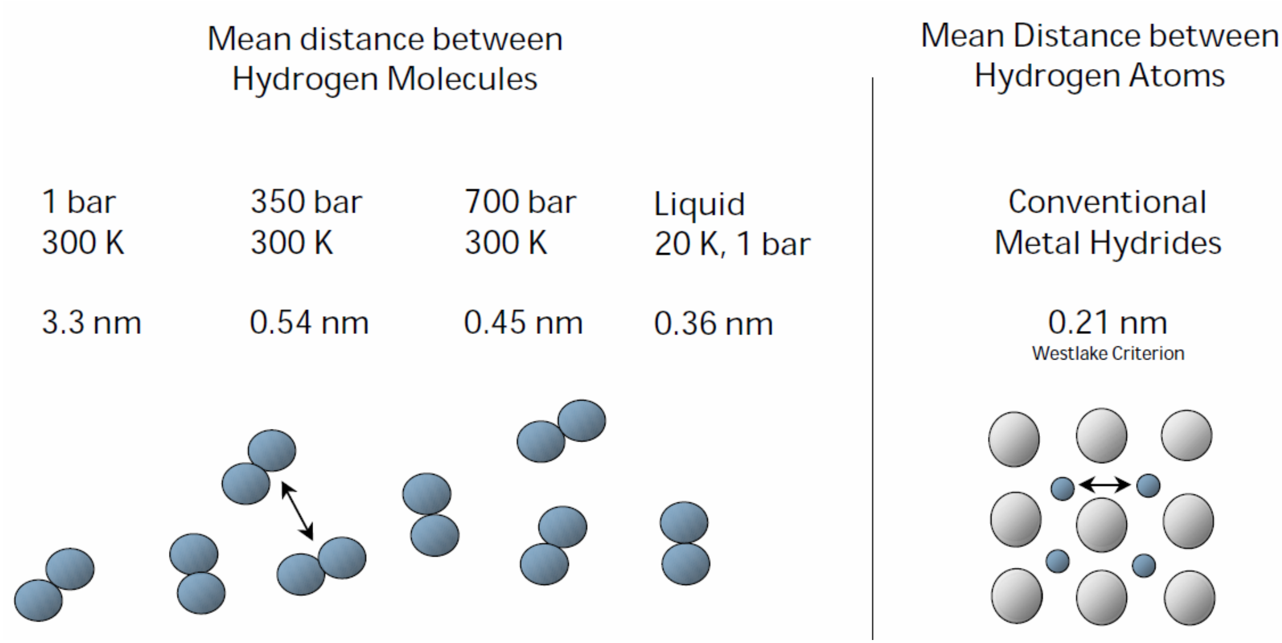
OVERVIEW HYDROGEN STORAGE TECHNOLOGIES

- High differences of :
  - gravimetric energy density of different storage technologies
  - Weight proportion of stored hydrogen compared to overall storage weight



GH_2	Gaseous Hydrogen
LOHC	Liquid Organic Hydrogen Carriers
MOF	Metal Organic Frameworks
LH_2	Liquefied Hydrogen

MATERIAL-BOUND STORAGE



/ Perfect Welding / Solar Energy / Perfect Charging