Wasserstoff/Sauerstoff-Brennstoffzellen für Energiespeicherung und Regelleistung – Einblicke in aktuelle Entwicklungen

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Swiss Hydrogen's Historic Overview

FOUNDED IN 2008 AS A SUBSIDIARY OF BELENOS / SWATCH GROUP

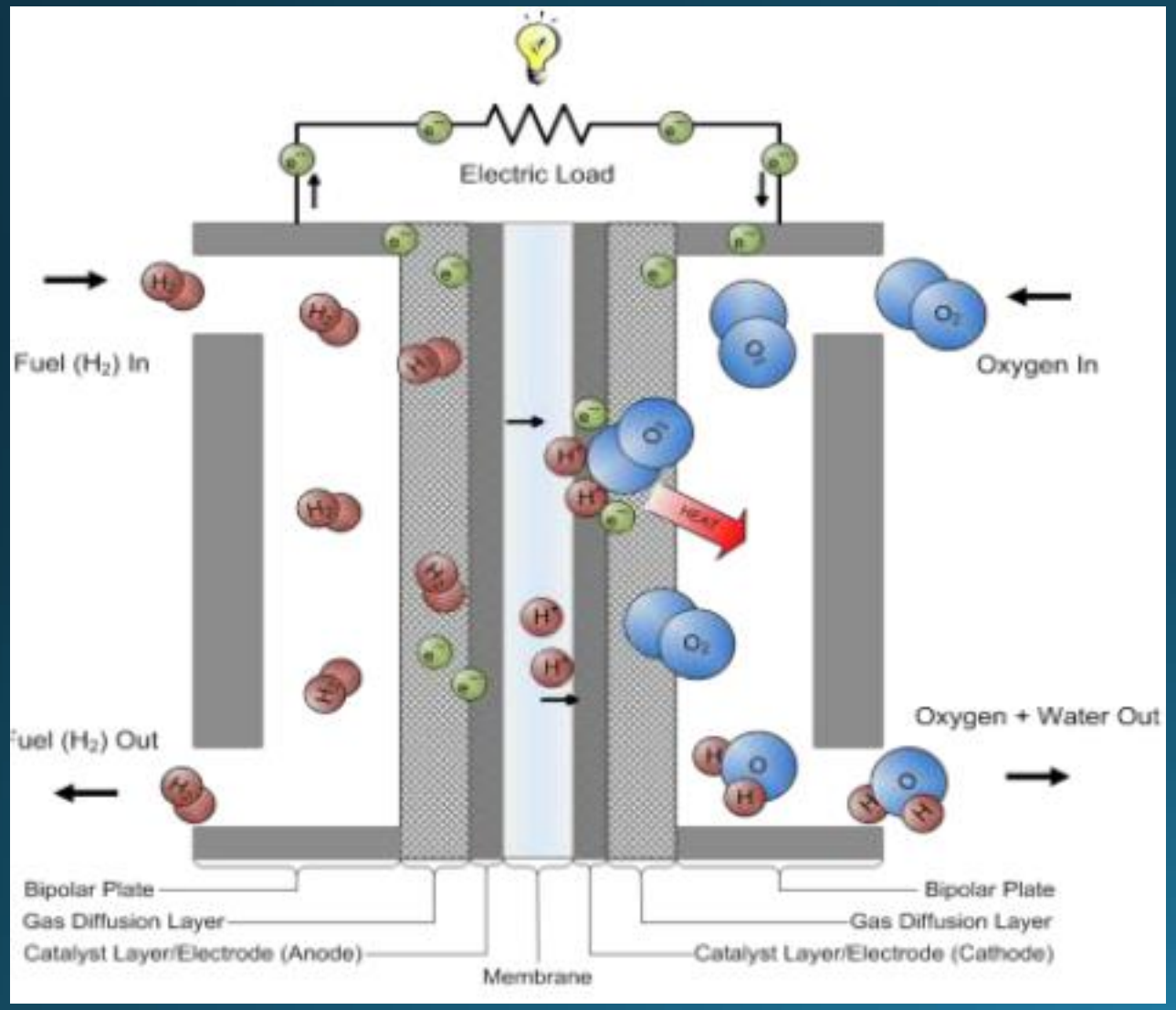
2011. Belenos presents the first H2/02 fuel cell car and boat

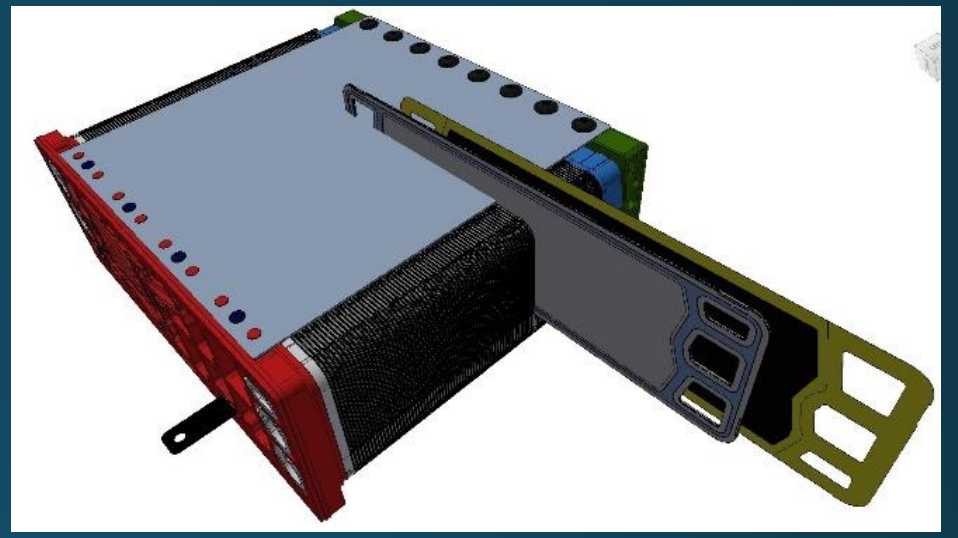
2013. Belenos develops the H2/air fuel cell systems and integrates it into a Fiat 500

SPIN-OFF FROM SWATCH GROUP IN 2015 AND RELOCATION IN FRIBOURG

ACQUISITION BY PLASTIC OMNIUM AND INTEGRATION INTO NEW ENERGIES SINCE 2018

PEM fuel cell – how does it work?

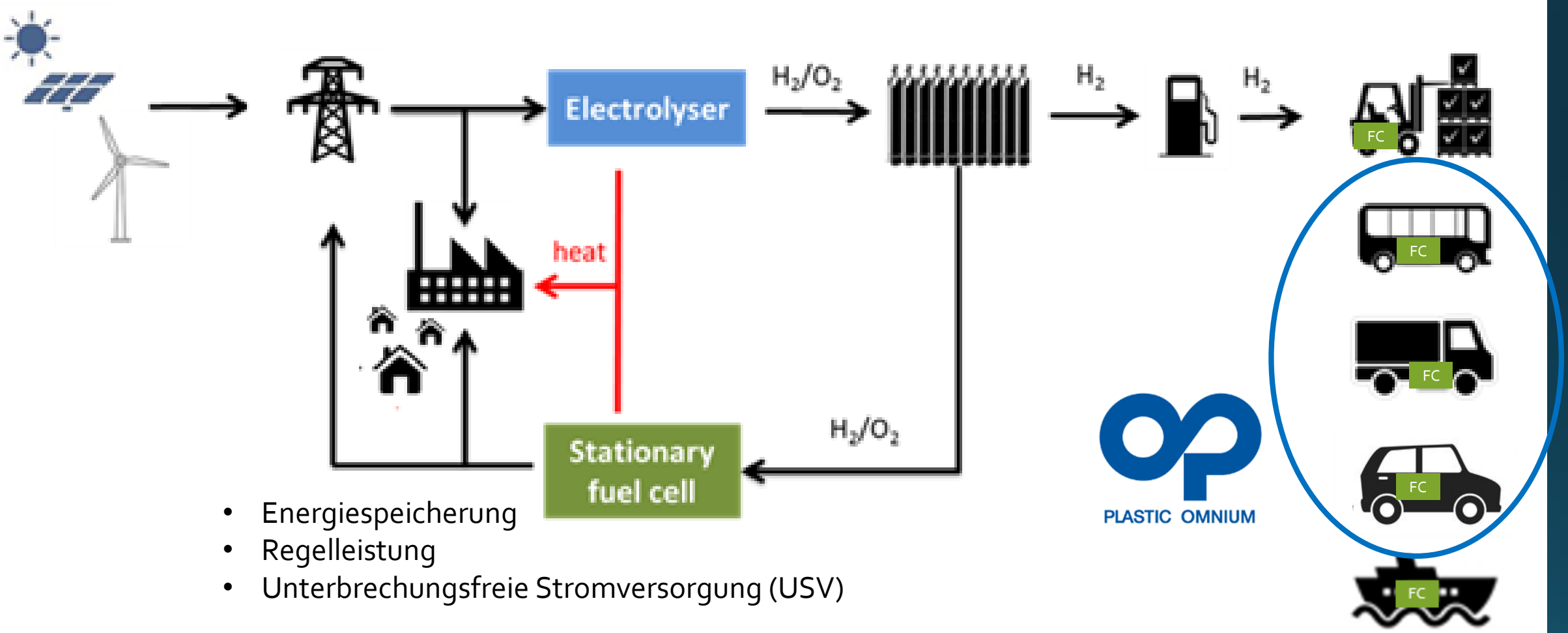




Fuel cell stack: typically 100 to 500 cells

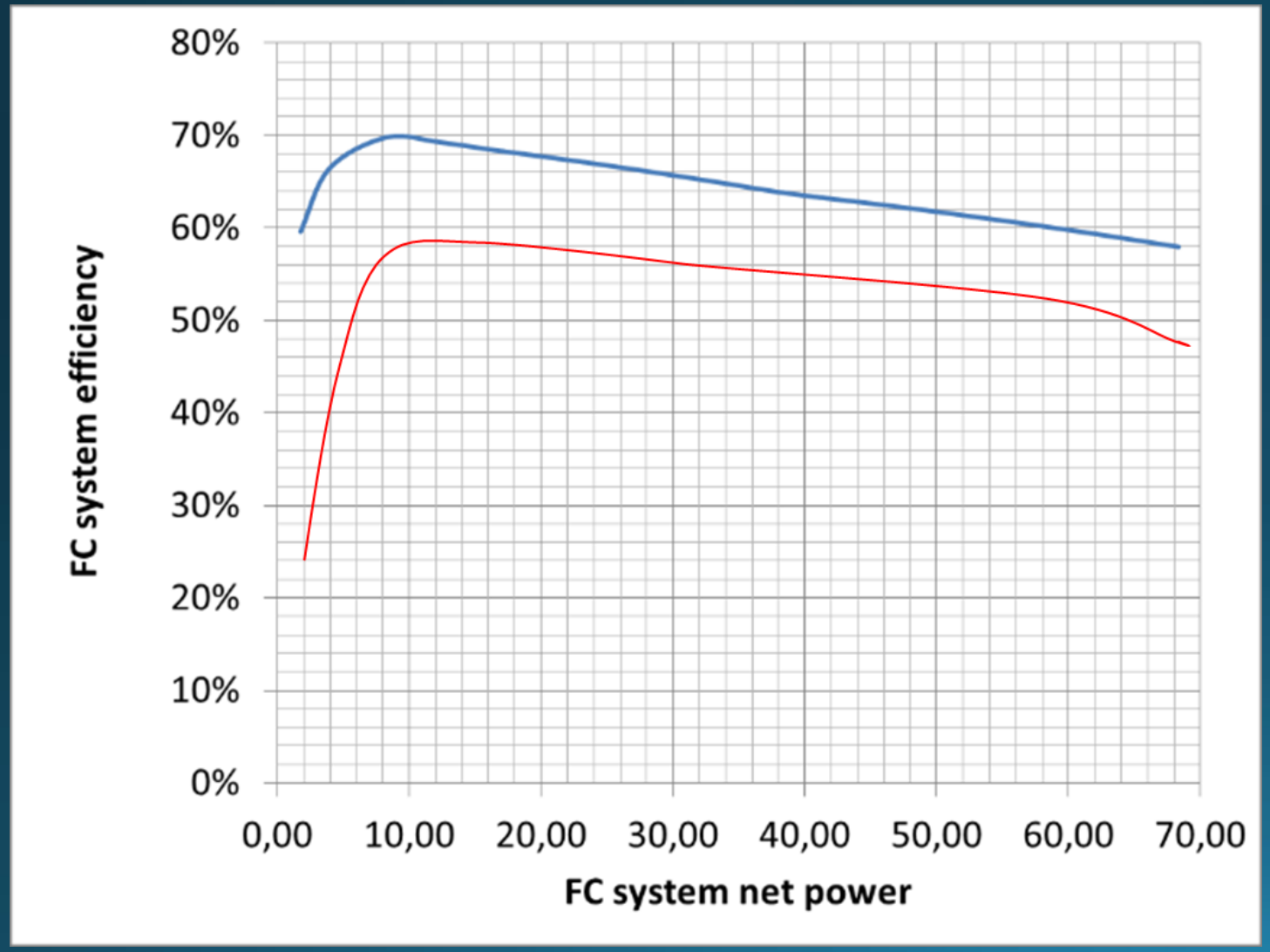
A cell consists of a Membrane Electrode Assembly (MEA) and a Bipolar Plate (BPP)

PEM FC applications



- Energiespeicherung
- Regelleistung
- Unterbrechungsfreie Stromversorgung (USV)

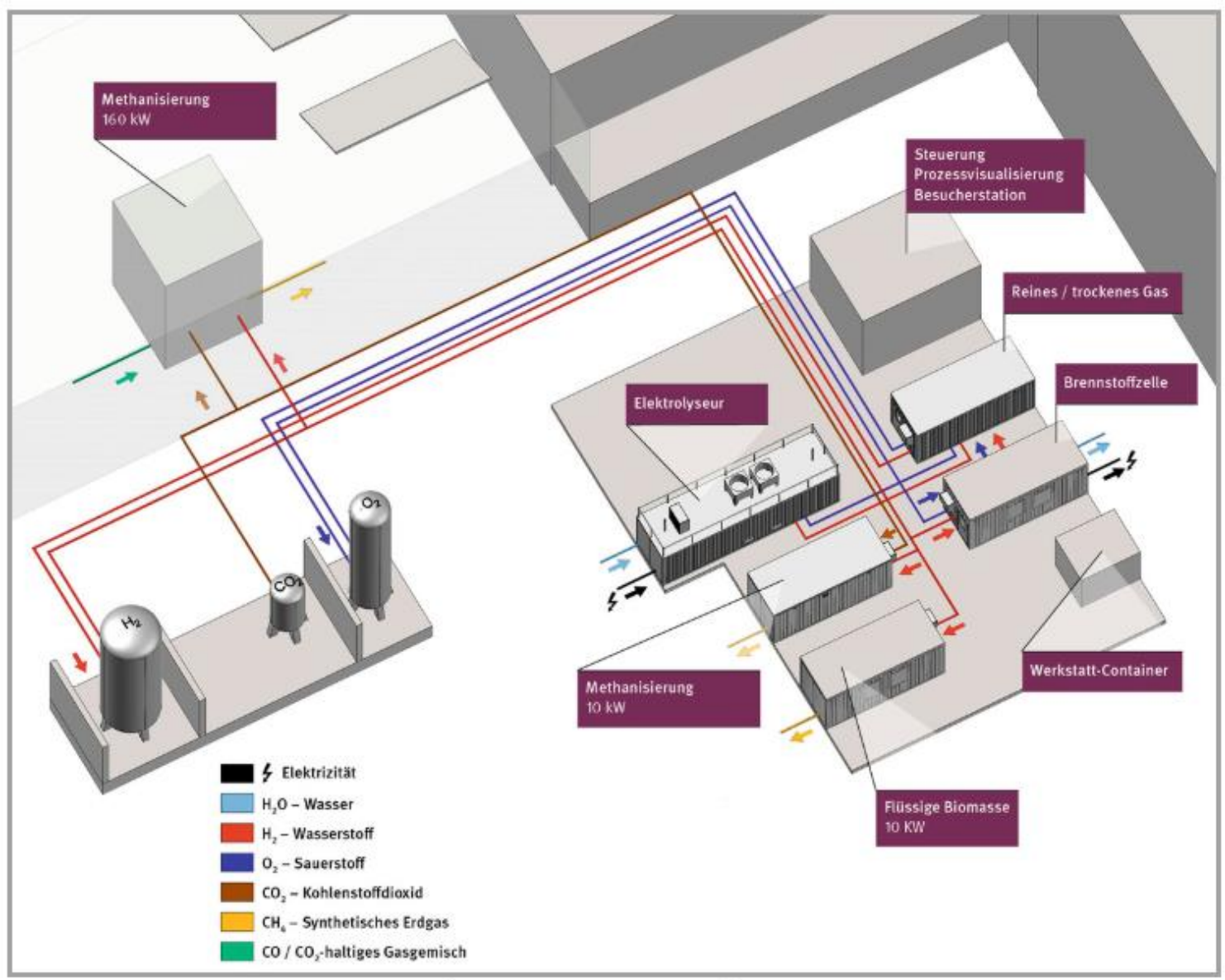
Efficiency advantage for H_2/O_2 fuel cell system



The H_2/O_2 FC system as installed in the ESI platform (blue curve) has an efficiency advantage of approx. 10% over conventional H_2/Air FC systems (red curve)

ESI platform at PSI

- Siemens Electrolyser with H_2 and O_2 supply at 48 bar
- Cleaning and drying of gases, no compression required
- H_2 and O_2 Storage in steel cylinders
- Swiss Hydrogen FC system with 4 x 60 kW

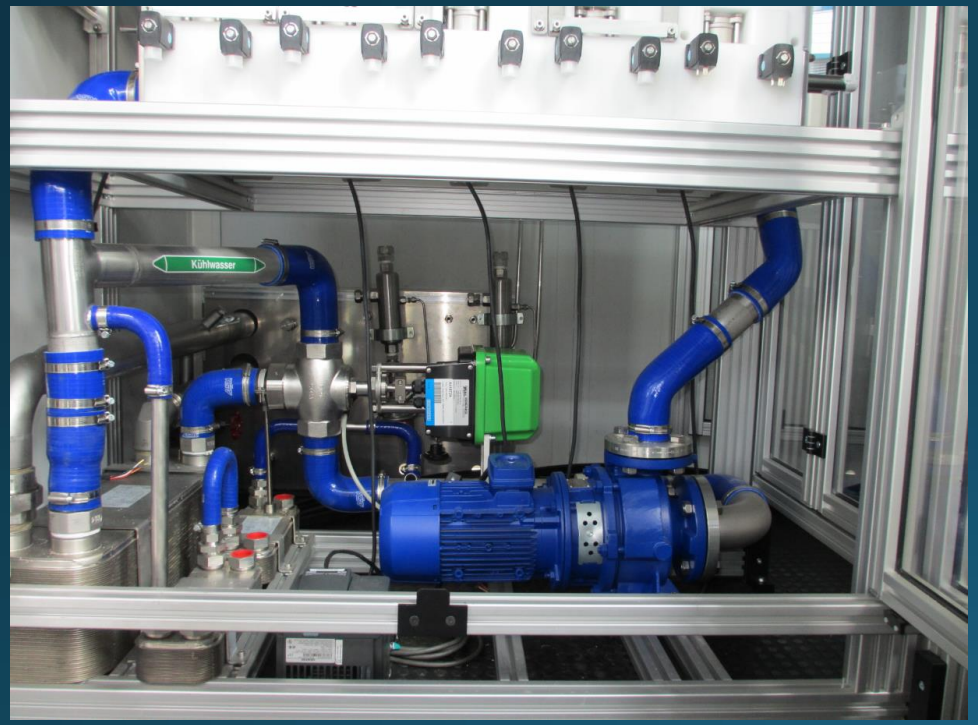


Schematische Darstellung der ESI-Plattform. (Grafik: Paul Scherrer Institut)

H_2/O_2 fuel cell system for ESI

H_2/O_2 fuel cell system for ESI

Gas supply



Cooling system and gas preheating using FC stack waste heat

4 x 60 kW FC stack

Modular interface blocks with integrated H2 and O2 recirculation

FC stack manufacturing

Cleaning of bipolar plates

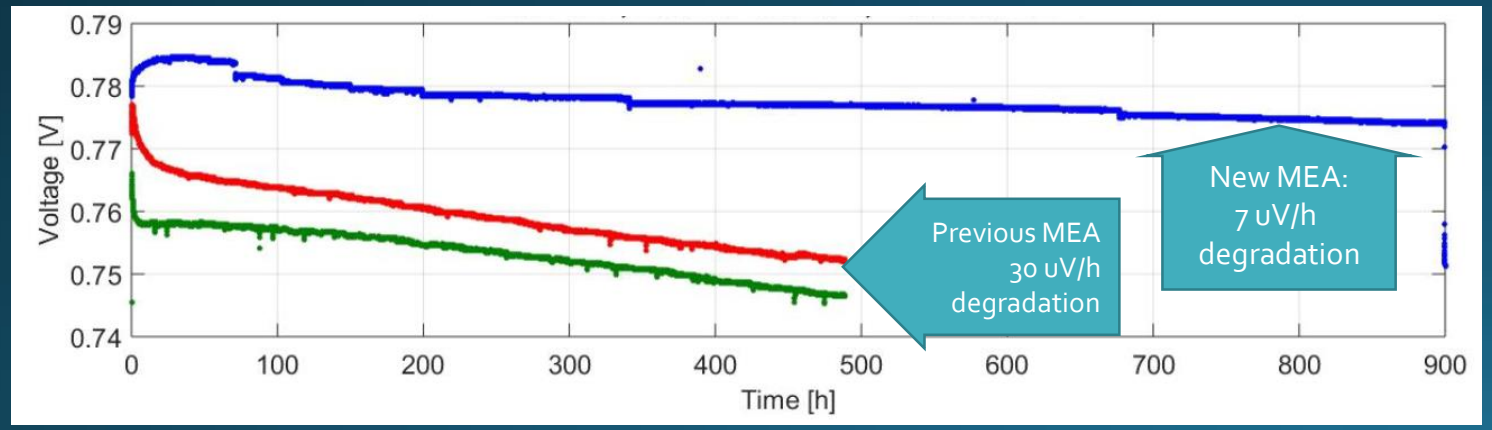
Leak test of sub-assemblies

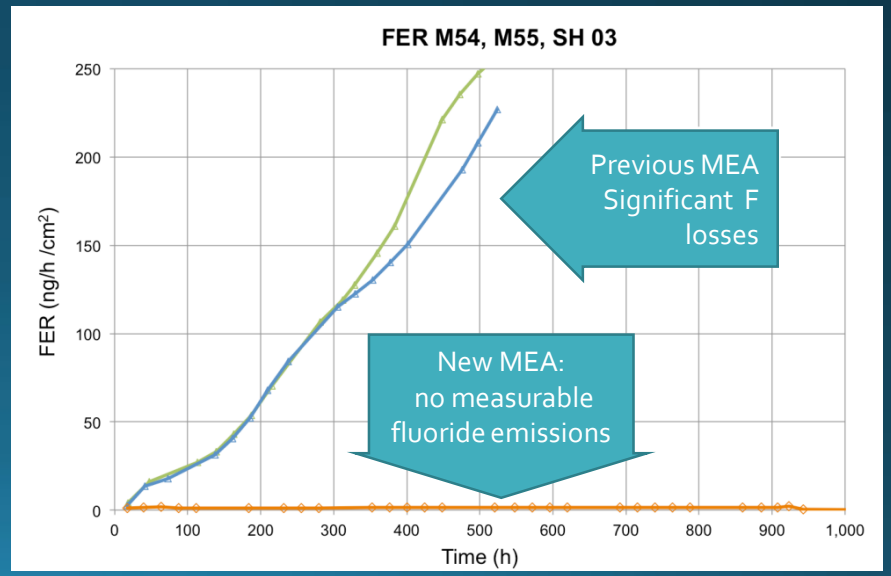
Stack assembly and compression

Assembly of FC system

FC stack durability

- Specific H_2/O_2 MEA with improved membrane and catalyst stability
- Cyclic load tests carried out at PSI indicate a lifetime of > 10.000h
- No measurable fluoride emissions in product water -> stable membrane
- No degradation of graphite bipolar plates and seals observed





Challenges encountered during ESI project

- Insufficient recirculation of Hydrogen

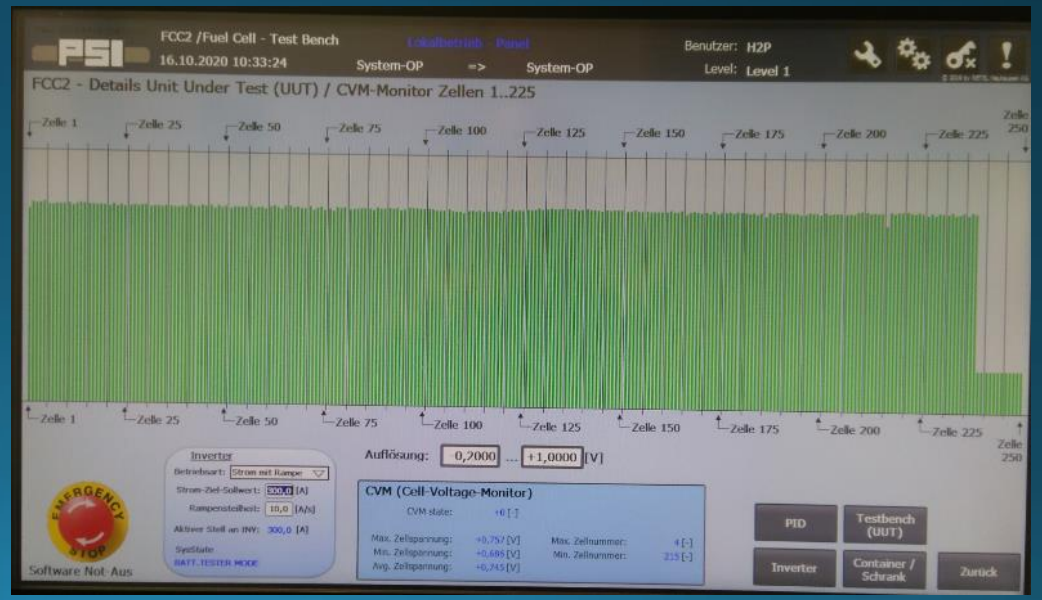
  -> new ejector design developped

- Separation and elimination of liquid water

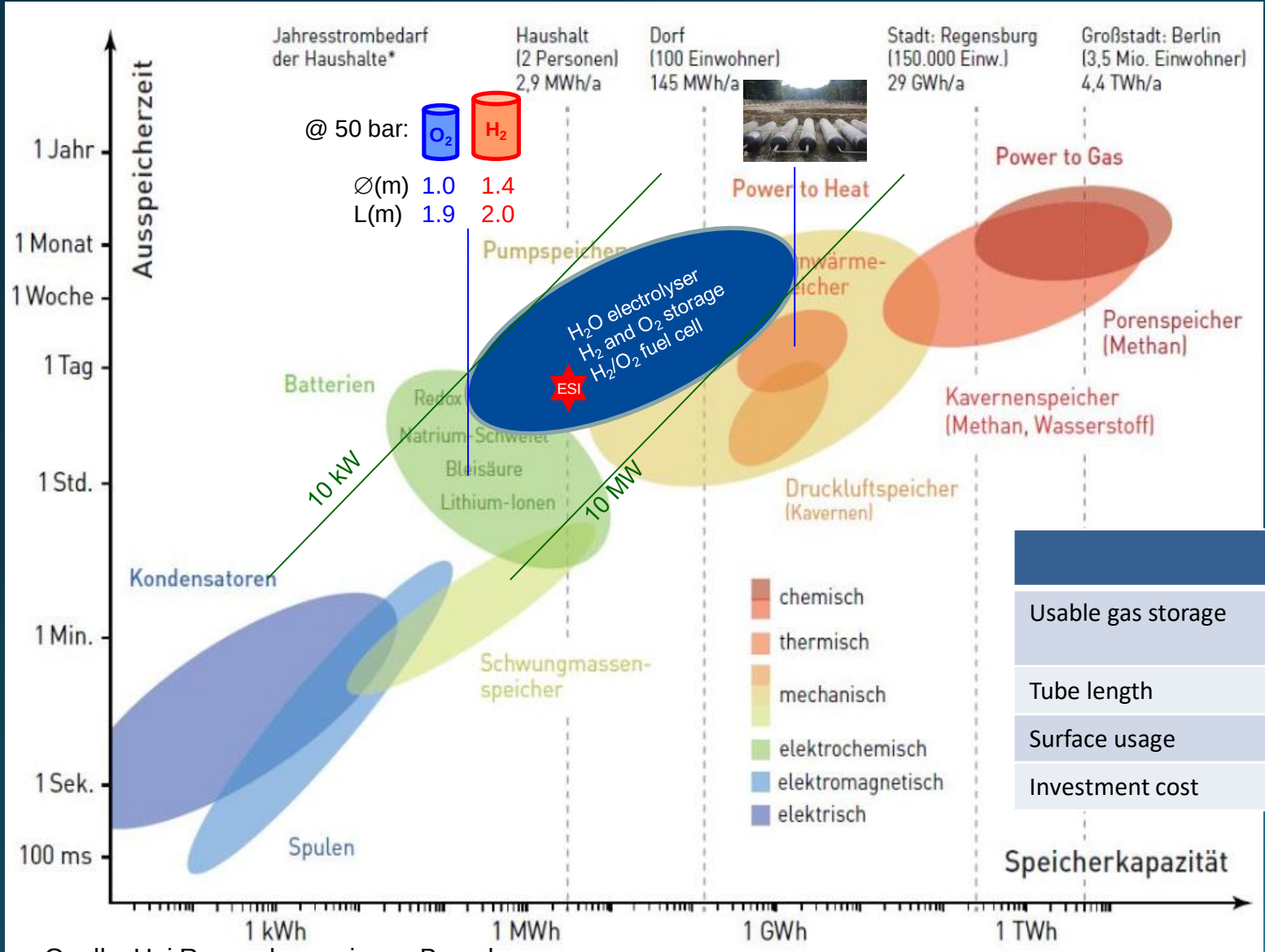
  -> water separator at cathode and anode outlet added

- Measurement of cell voltages

  -> measurement of blocks of 2 cells replaced by single cell measurement



H_2/O_2 fuel cell system for energy storage



Quelle: Uni Regensburg; eigene Berechnungen

Comparison with CNG storage in Urdorf

	CNG Urdorf	H_2 for 1 GWh_{el}	O_2 for 1 GWh_{el}
Usable gas storage	700 000 Nm^3 ca. 7 GWh_{th}	510 000 Nm^3	255 000 Nm^3
Tube length	4100 m [1)]	4200 m	1800 m
Surface usage	210 x 50 m [1)]	e.g. 220 m x 50 m	e.g. 220 m x 20 m
Investment cost	16 - 25 MCHF [2), 3)]	if overall cost 30 MCHF -> 30 CHF/kWh_{el}	

[1)] www.erdgaszuerich-transport.ch/de/medien/mm-1142012-baustart-des-erdgas-roehrenspeichers-in-urdorf.html
[2)] www.schiess-iti.ch/references.aspx?pid=82&rid=526
[3)] www.jauslinstebler.ch/VGA/VEM/projekte/erdgas-roehrenspeicher-urdorf.html
All other values: own calculation

Grid balancing service

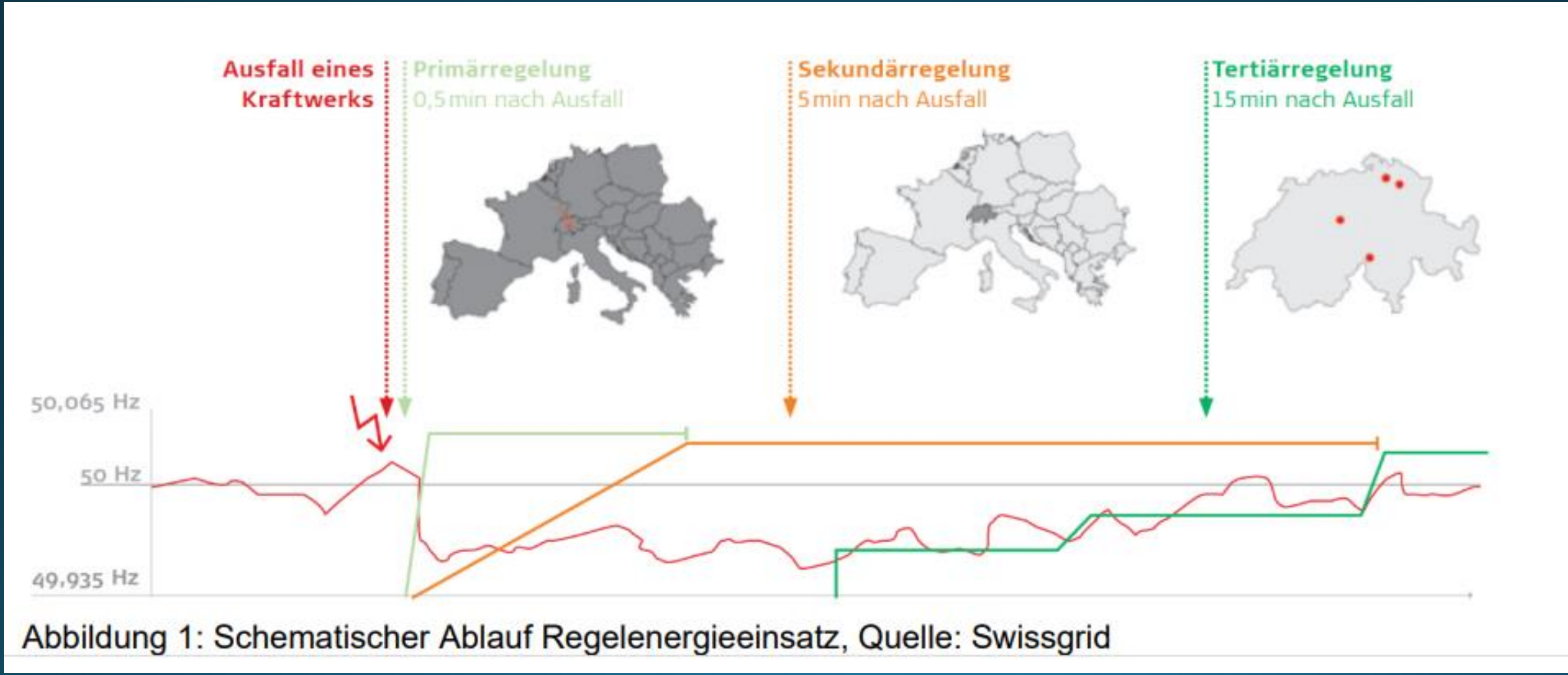
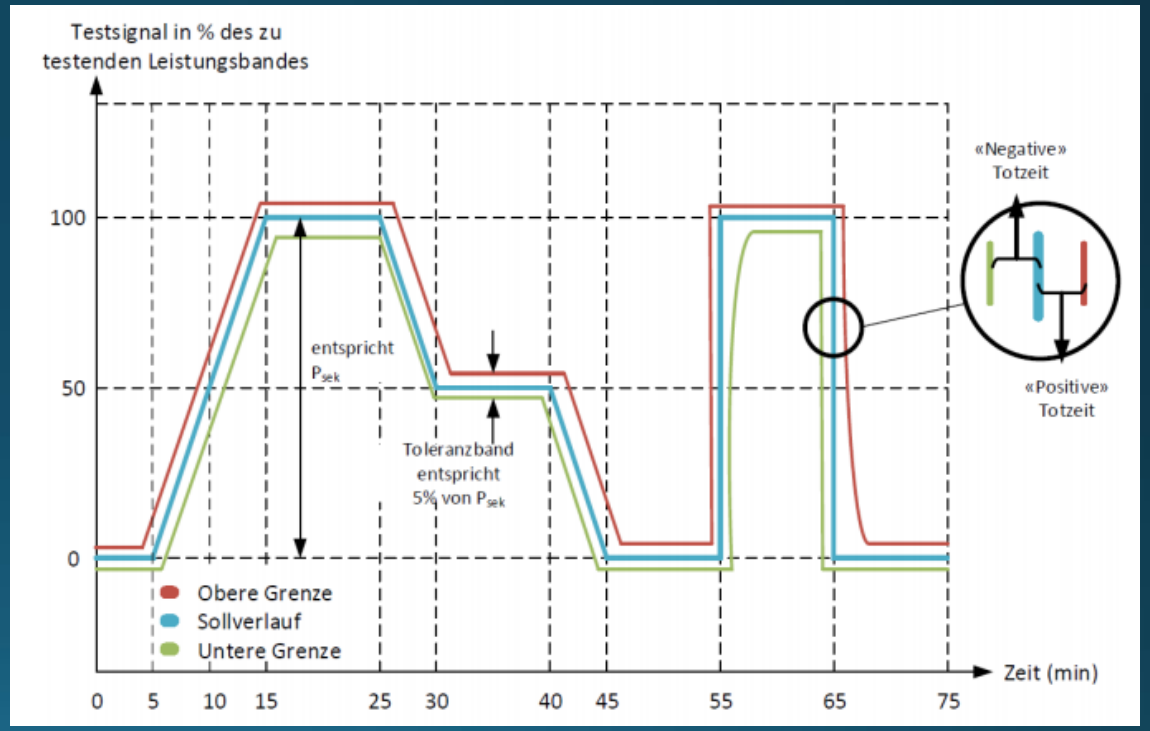


Abbildung 1: Schematischer Ablauf Regelenergieeinsatz, Quelle: Swissgrid

Source: Regelleistung und Regelenergie 2019, Bericht der ElCom

H_2/O_2 FC for balancing service

- FC stack allows high dynamic behaviour (0 to 100% within a few seconds) as long as the gas pressure on anode **and** cathode side can be assured
- Nominal power can be supplied as soon as the coolant temperature is adequate (60°C < T < 80°C). This can be reached within a few minutes.

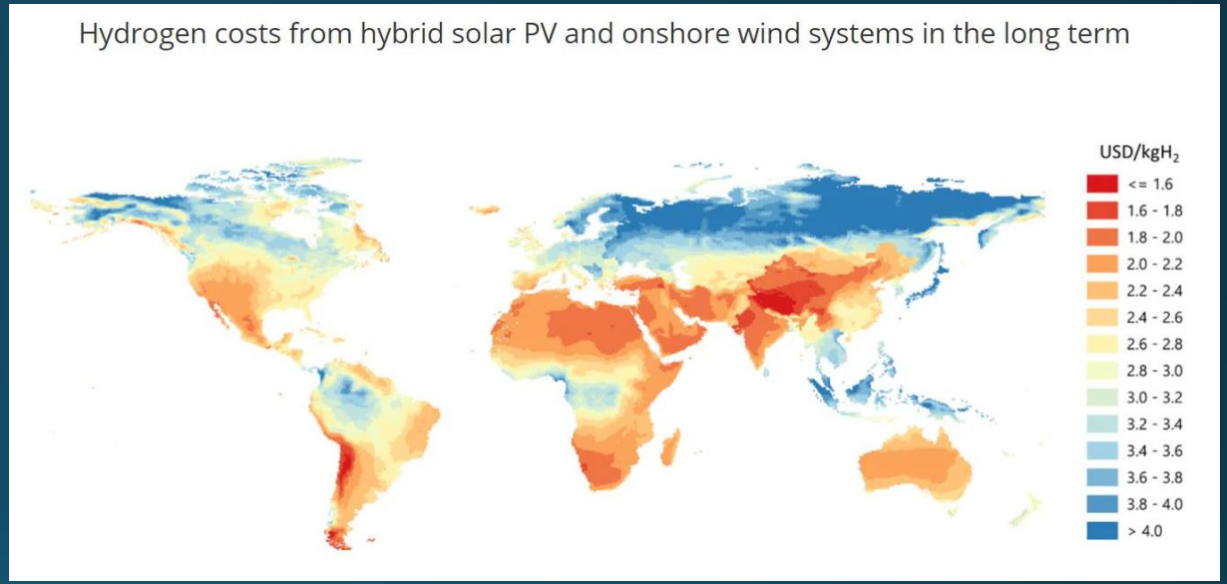


Tolerance band for secondary reserve according to Swissgrid

Cost estimation

Assumptions:

- System cost 200 € / kW
- Hydrogen cost 3 €/kg
- FC efficiency 60% (including electric conversion)
- Lifetime 20 years
- System size 5 MW
- Interest rate 3%
- Service cost 2% per year



Source: IEA
https://www.iea.org/reports/the-future-of-hydrogen

Cost per MWh

The achievable cost per MWh is above the prices which have been achieved over the last years

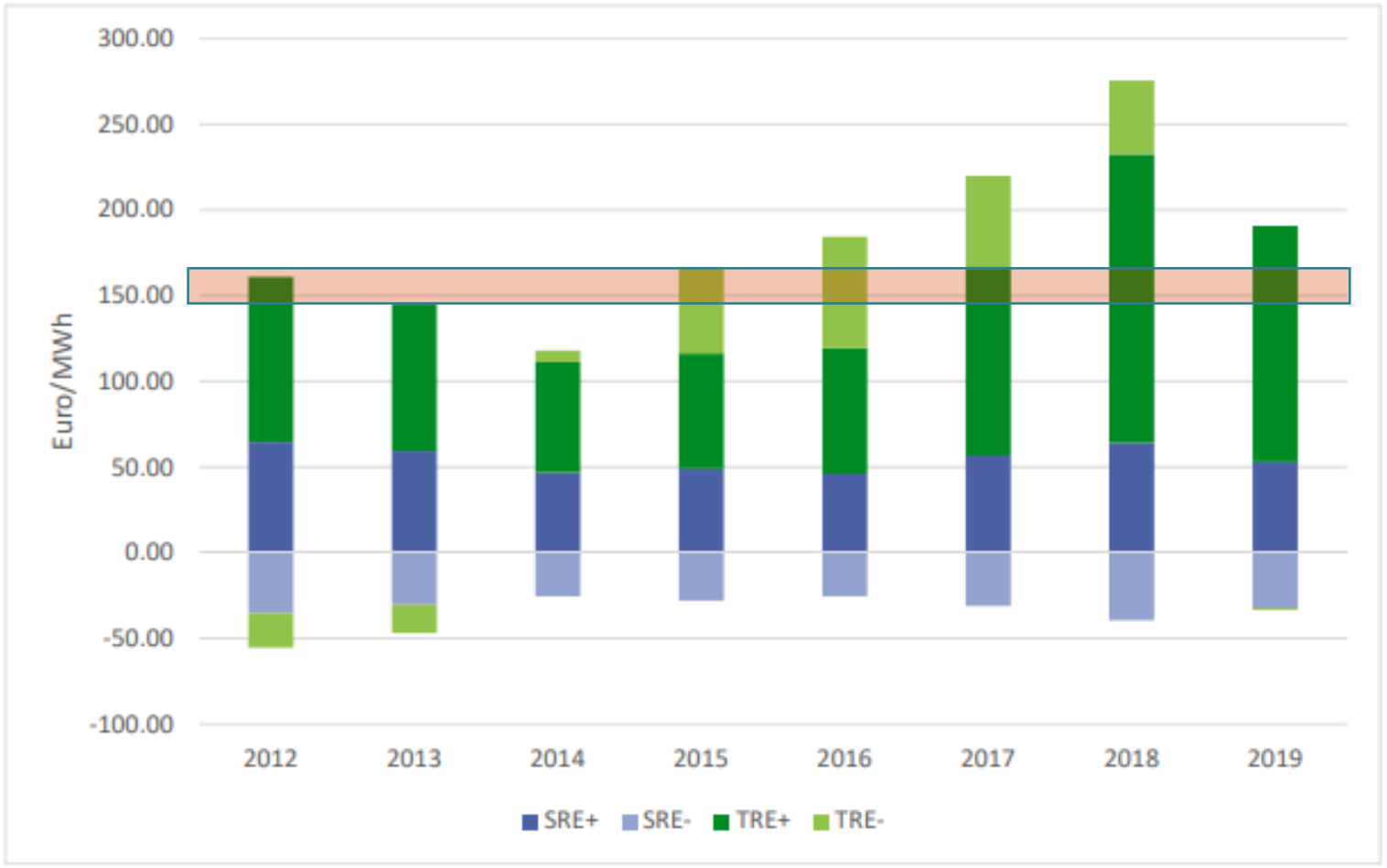


Abbildung 11: Kosten pro MWh SRE und TRE nach Produkt 2012 bis 2019, Quelle: Swissgrid, Berechnung ElCom

Source: Regelleistung und Regelenergie 2019, Bericht der ElCom
Cost span: own calculation

Cost per MW

The achievable cost per MW can be competetive for positive secondary reserve

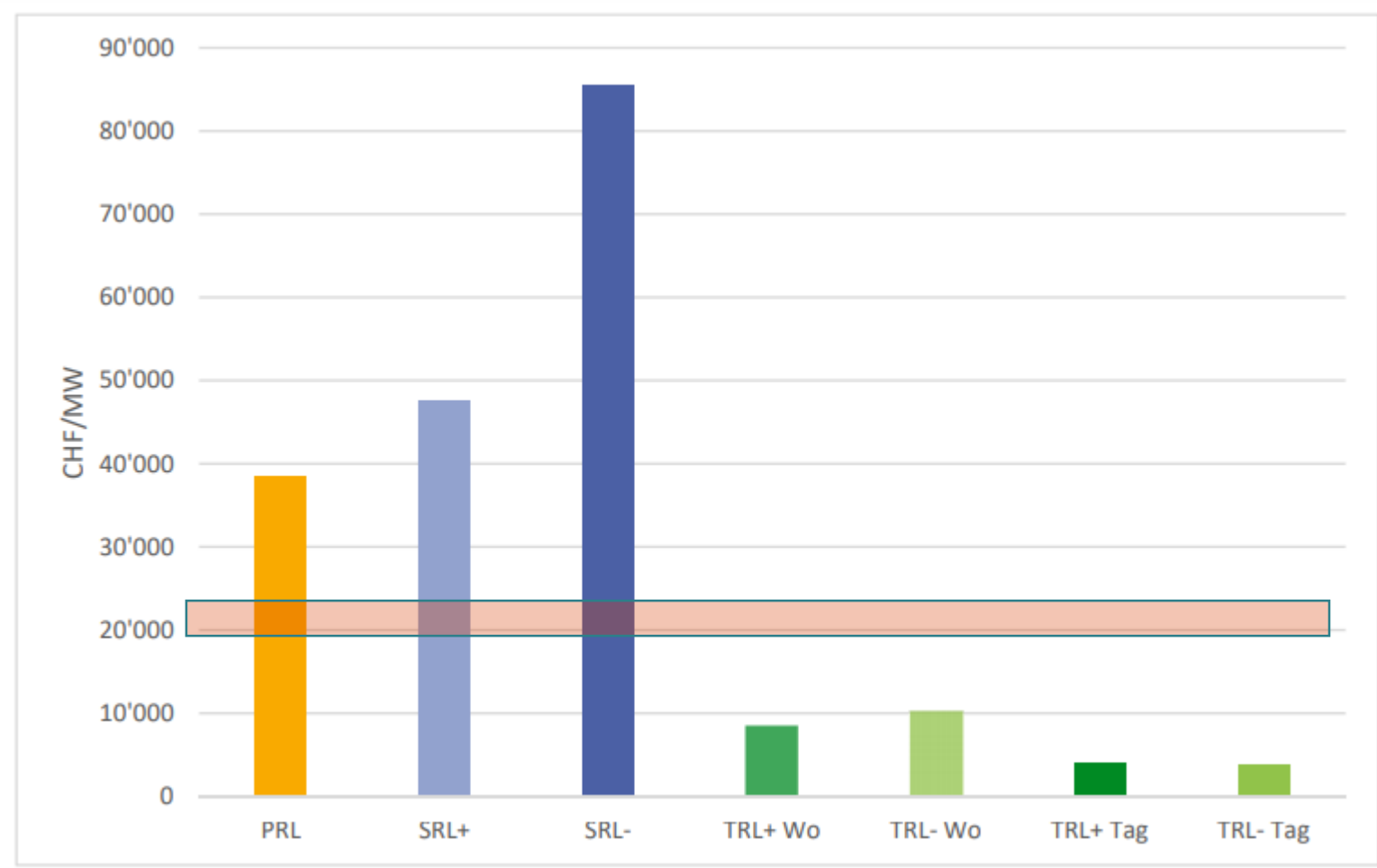


Abbildung 3: Kosten pro MW der Regelleistungsprodukte 2019, Quelle: Swissgrid, Berechnung ElCom

Source: Regelleistung und Regelenergie 2019, Bericht der ElCom
Cost span: own calculation

Summary

- PEM fuel cell systems with H_2/O_2 operation offer higher efficiency, reduced system complexity and a high lifetime potential
- A system with 4 x 60 kW is installed at the ESI platform at the Paul Scherrer Institute
- Long term energy storage and grid balancing with H_2/O_2 fuel cell systems is technically feasible
- Further cost reduction will be required to be competitive