PAUL SCHERRER INSTITUT

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Storage
Swiss Competence Centers
for Energy Research

Thomas J. Schmidt
Swiss Competence Center for Energy Research (SCCER) Heat & Electricity Storage

Elektrochemie: Lösungen für die Langzeitspeicherung

The one-stop-shop for energy storage in Switzerland

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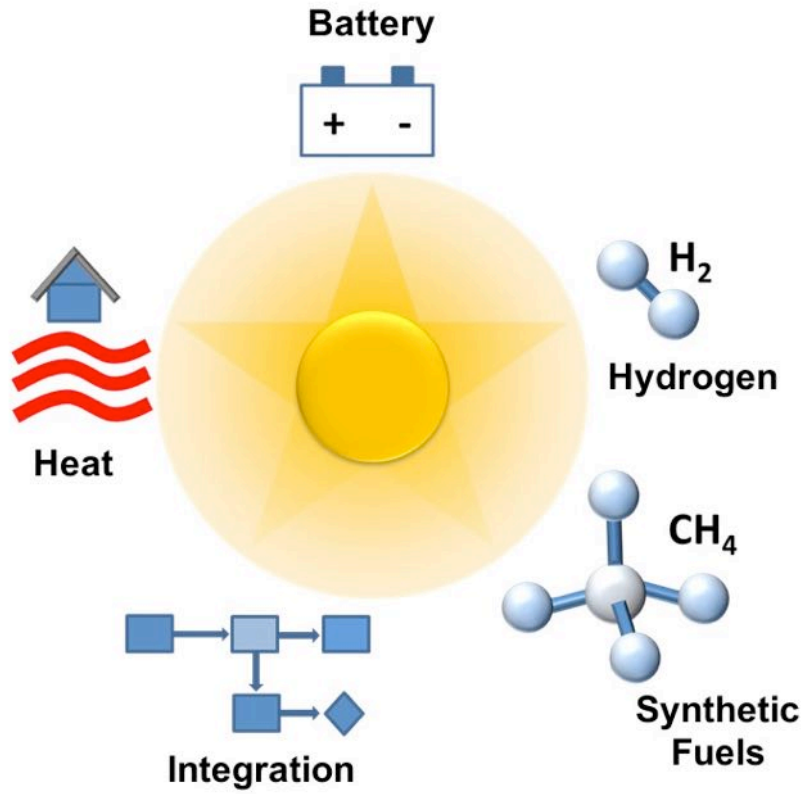
www.sccer-hae.ch



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Director

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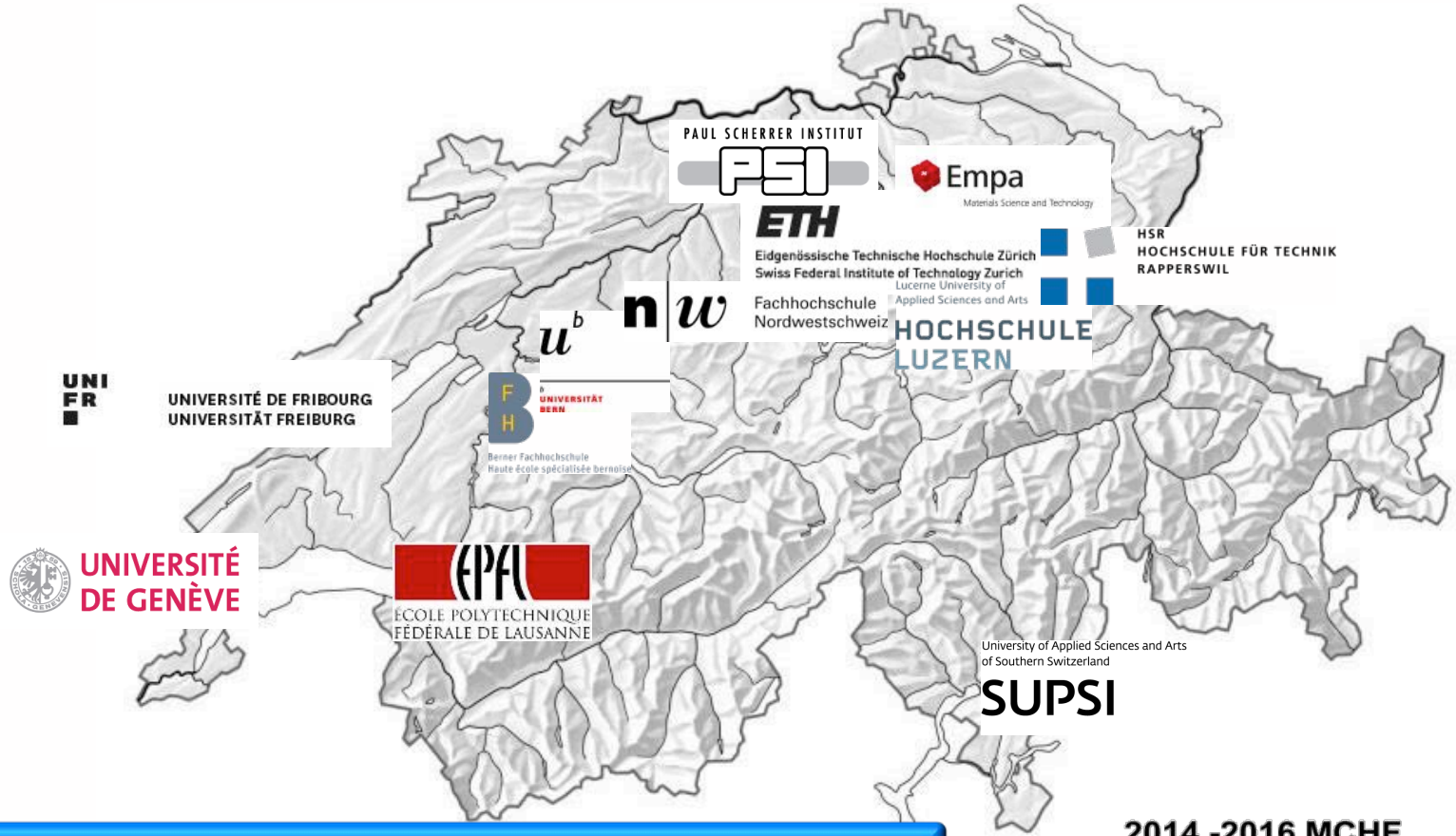
thomasjustus.schmidt@psi.ch

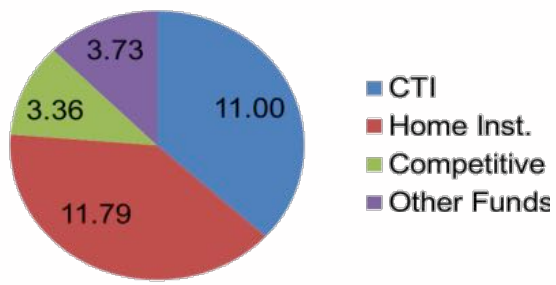
Who we are



Key Messages

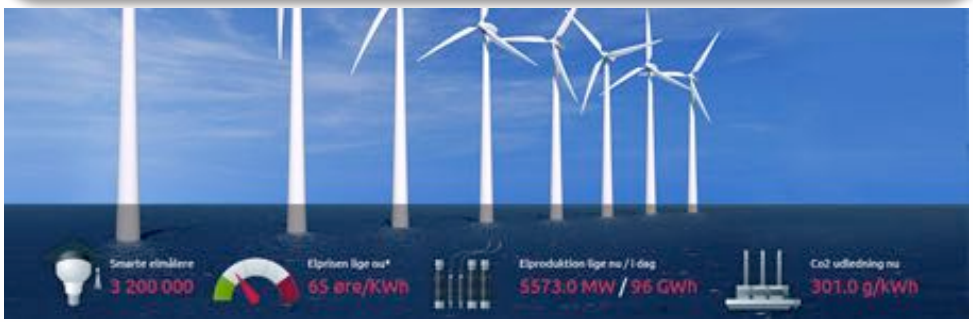
- Research network.
- Centrally organized
- 130 People ~ 70 FTE.
- 30 M CHF worth of funding.

2014 -2016 MCHF



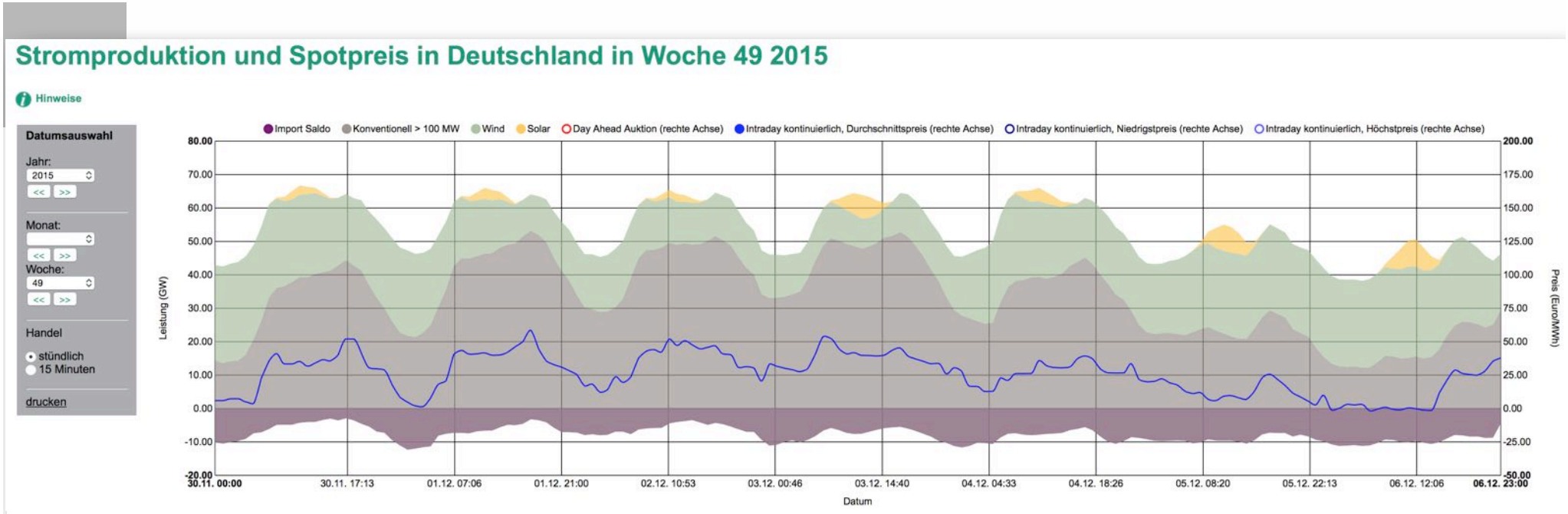
Key Role of Energy Storage

July week 2015: Denmark produces 140% of its electricity demand by wind turbines



Storage of excess electricity in pumped hydro in Norway, Germany, Switzerland

Key Role of Energy Storage
Power Generation/Cost in Germany



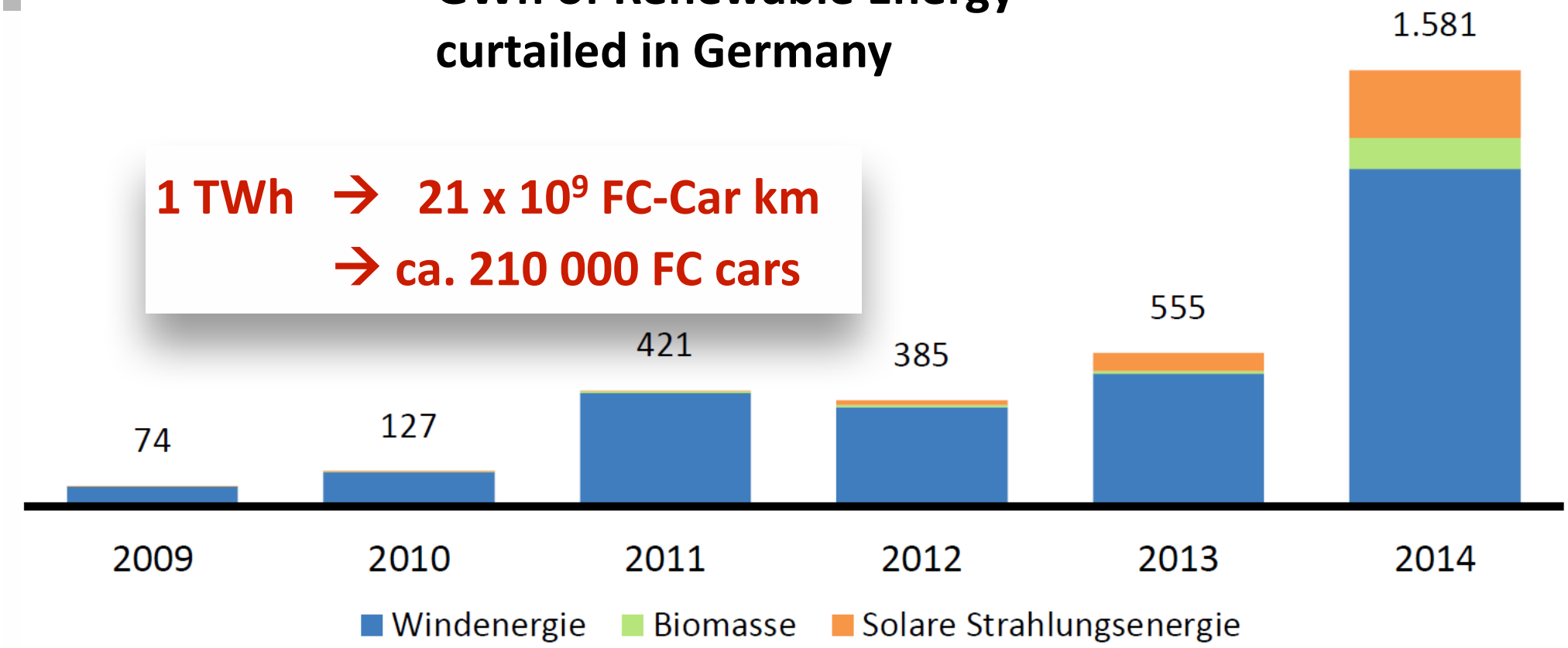
In 2020: 1000 hrs of negative electricity prizes are predicted for Germany

Solution: Curtailment

Losses of ca. €80M

GWh of Renewable Energy curtailed in Germany

1 TWh → 21 x 10^9 FC-Car km
→ ca. 210 000 FC cars



Source: German Network Agency

Storage Technologies

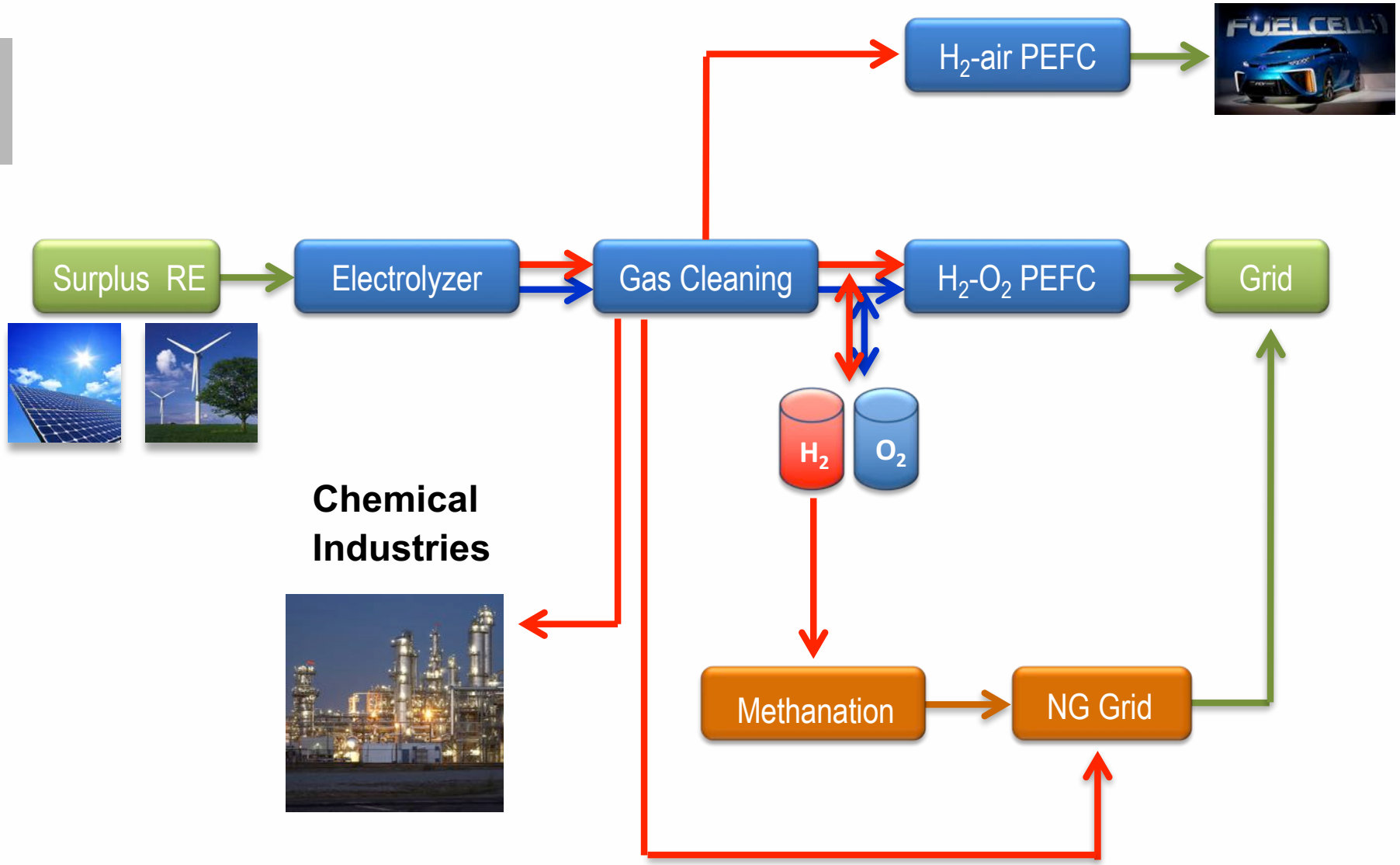
	decentralized Storage		centralized Storage	
	< 0.1 MW	0.1 - 10 MW	10 - 100 MW	100 - 1000 MW
months		Power-to-Gas	Power-to-Gas Pumped Hydro	Power-to-Gas Pumped Hydro
days --> weeks		Power-to-Gas	Pumped Hydro Power-to-Gas	Pumped Hydro Power-to-Gas
hours --> days	Lead Acid Battery Li-Ion Battery	Lead Acid Battery Sodium Sulfur Batt. Li-Ion Battery Na-NiCl2 Batt. Redox-Flow Batt.	Pumped Hydro CAES Sodium Sulfur Batt Na-NiCl2 Batt Redox Flow Batt	Pumped Hydro CAES
minutes --> hours	Lead Acid Battery Li-Ion Battery	Lead Acid Battery Sodium Sulfur Batt. Li-Ion Battery Na-NiCl2 Batt. Redox-Flow Batt.	Lead Acid Battery Sodium Sulfur Batt. Li-Ion Battery Na-NiCl2 Batt. Redox-Flow Batt.	Pumped Hydro CAES
seconds --> minutes	Super Caps	Flywheels	Batteries	Pumped Hydro CAES

Storage Technologies

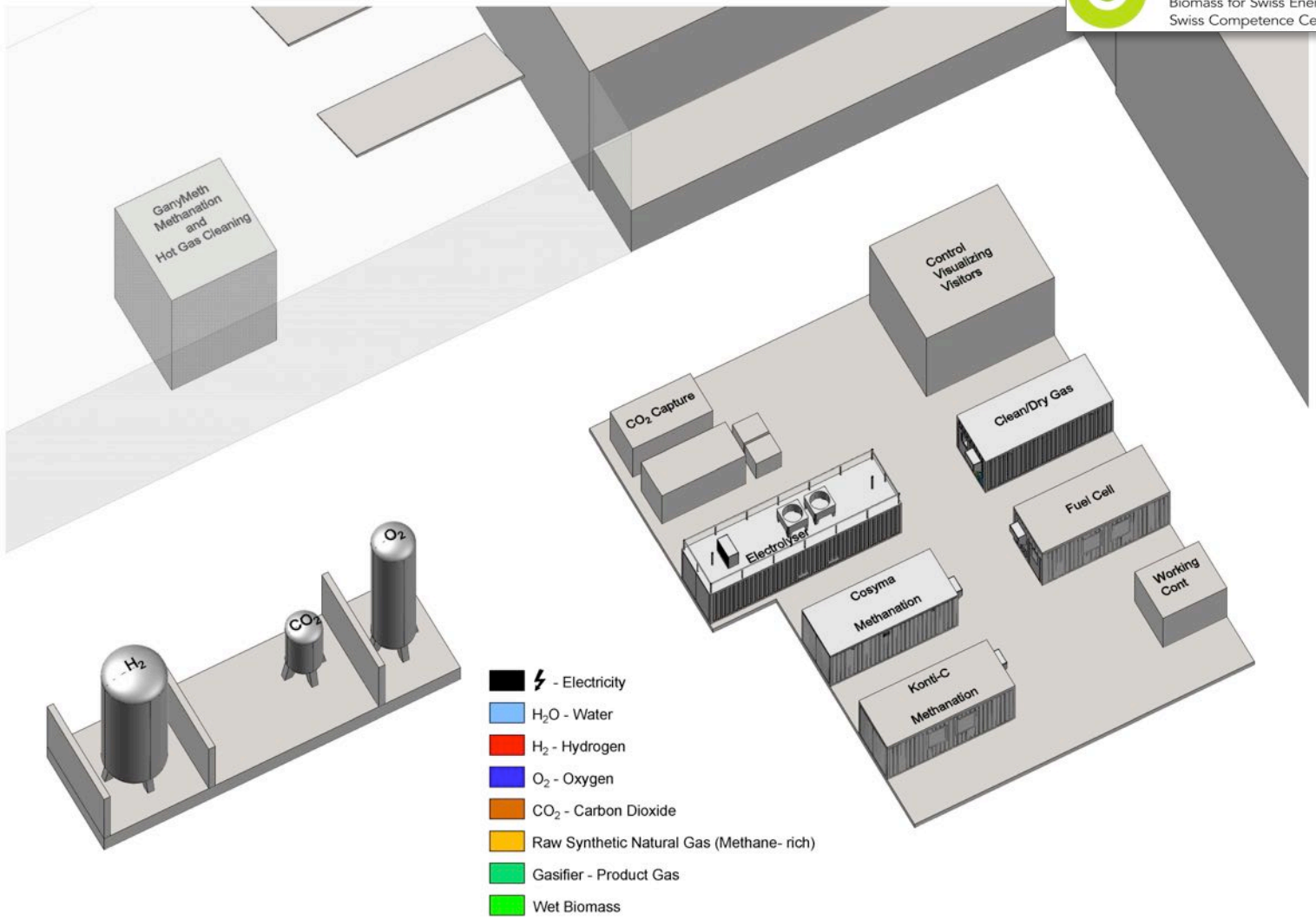
	decentralized Storage		centralized Storage	
	< 0.1 MW	0.1 - 10 MW	10 - 100 MW	100 - 1000 MW
months		seasonal balancing	seasonal balancing	seasonal balancing
days --> weeks	demand/supply optimization	demand/supply optimization	weekly load balancing	weekly load balancing
hours --> days	demand/supply optimization (4 - 8h) RE balancing (1-8h) and mobile applications	demand/supply optimization (4 - 8h) RE balancing (1-8h) and mobile applications	demand/supply optimization (4 - 8h), RE balancing (1-8h)	demand/supply optimization (4 - 8h), RE balancing (1-8h)
minutes --> hours	control power (<15min)	control power (<15min)	control power (<15min)	control power (<15min)
seconds --> minutes	frequency regulation (<30s), UPS	frequency regulation (<30s), UPS	frequency regulation (<30s)	frequency regulation (<30s)

Power-to-X

Power-to-X


H2-air PEFC
Surplus RE
Electrolyzer
Gas Cleaning
H2-O2 PEFC
Grid
H2
O2
Chemical Industries
Methanation
NG Grid

PSI & SCCER Activities in P2X: The Energy System Integration Platform



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ESI Becomes Reality

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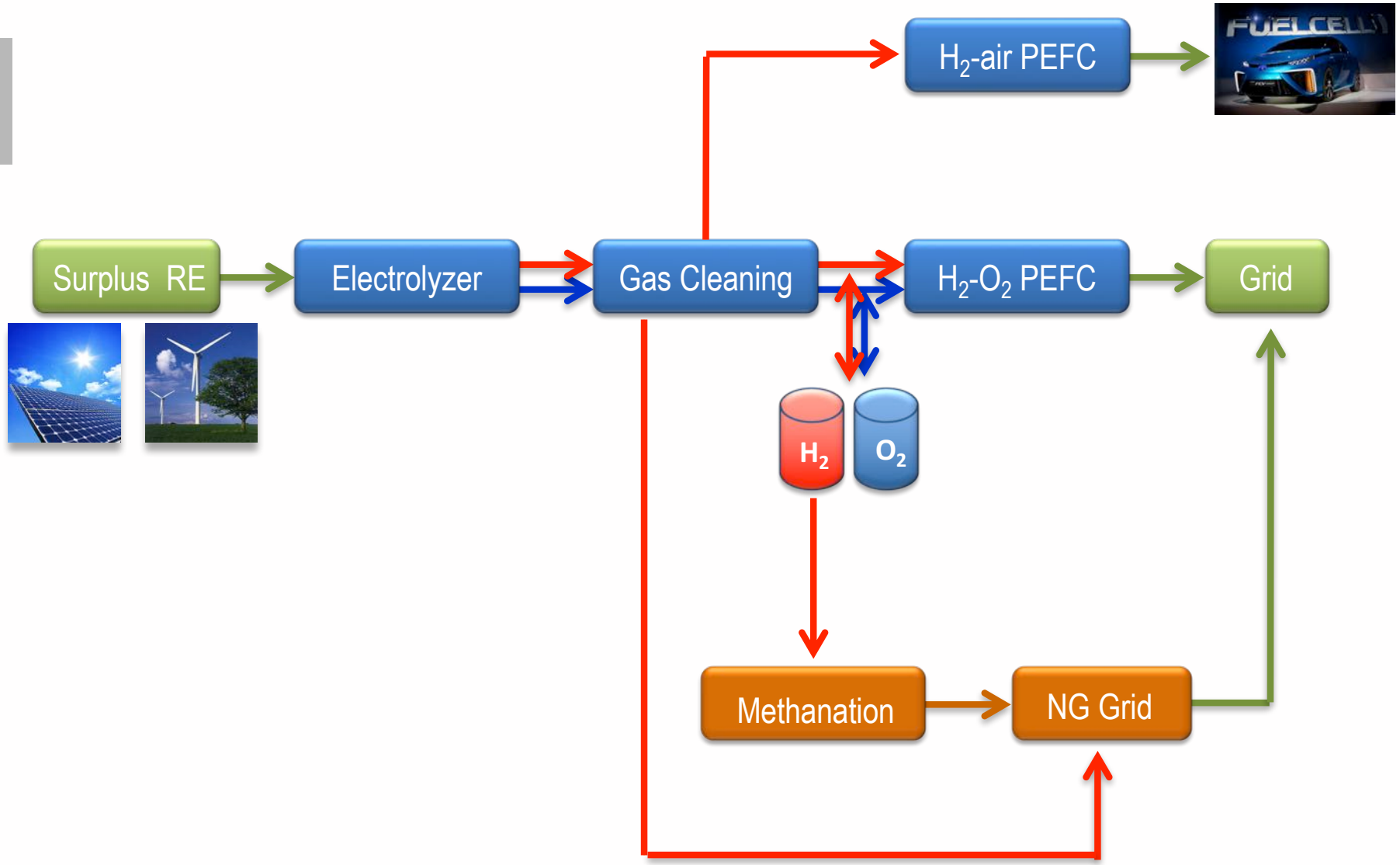
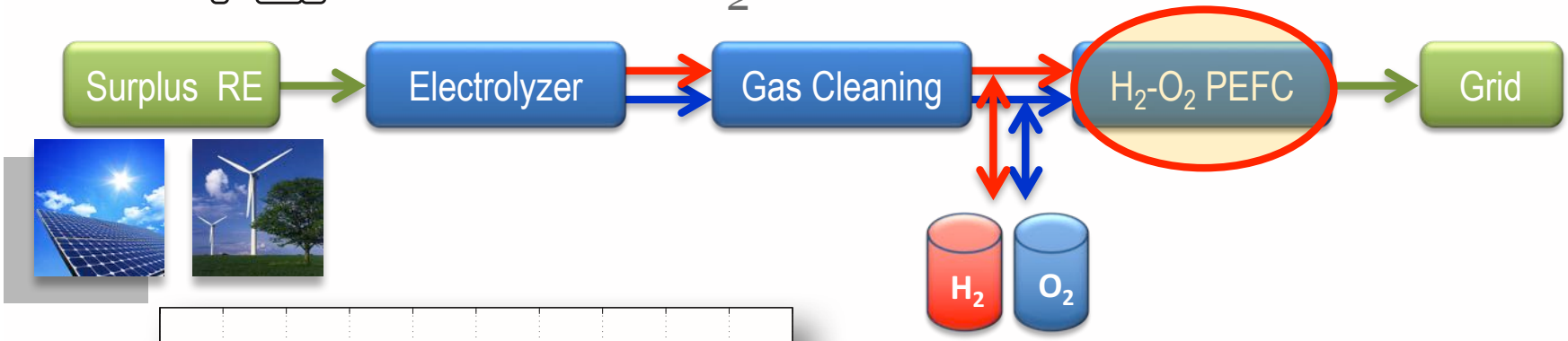
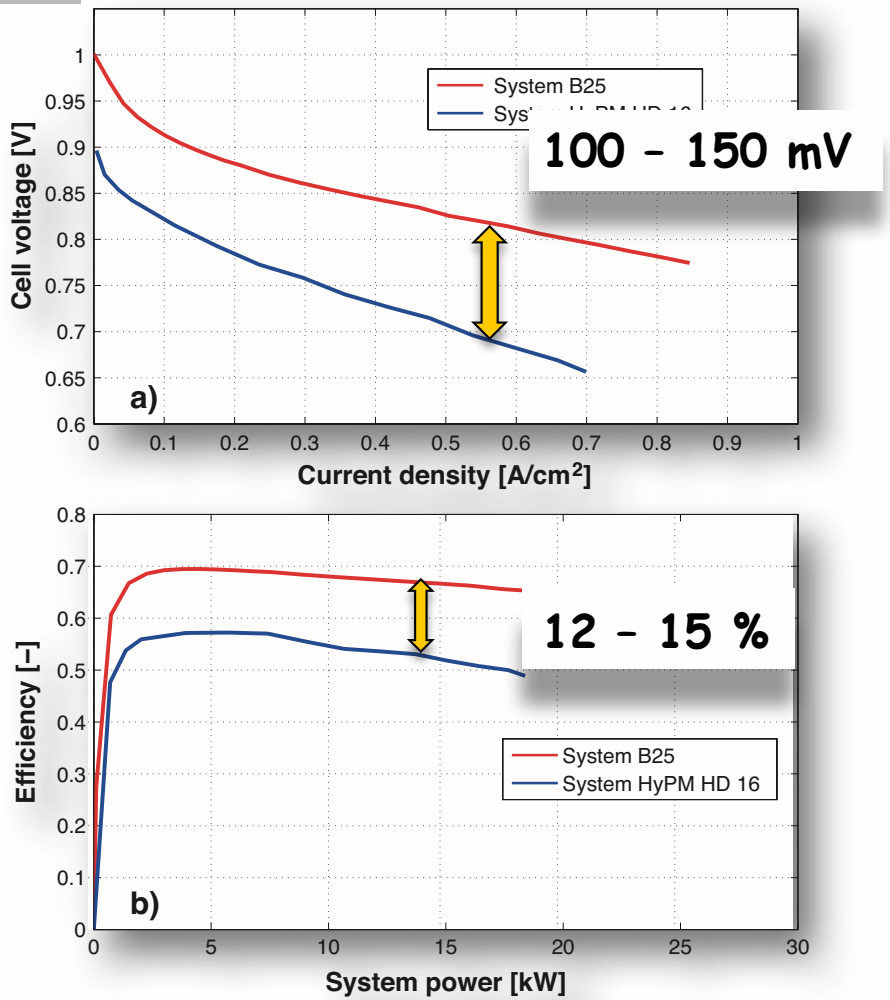
Power-to-X


H_2-air PEFC
Surplus RE
Electrolyzer
Gas Cleaning
H_2-O_2 PEFC
Grid
H_2
O_2
Methanation
NG Grid

Efficient H_2-to-e^- conversion for ESI

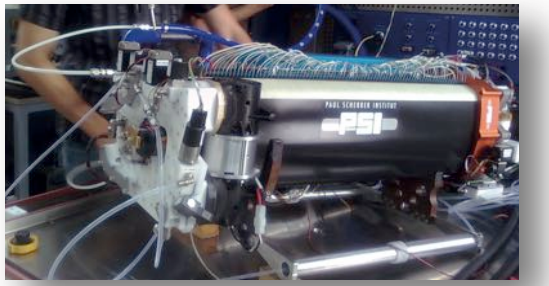




Büchi et al., *RSC Advances 4 (2014) 56139-56146*

H_2/O_2 30 kW

PSI B25/Belenos

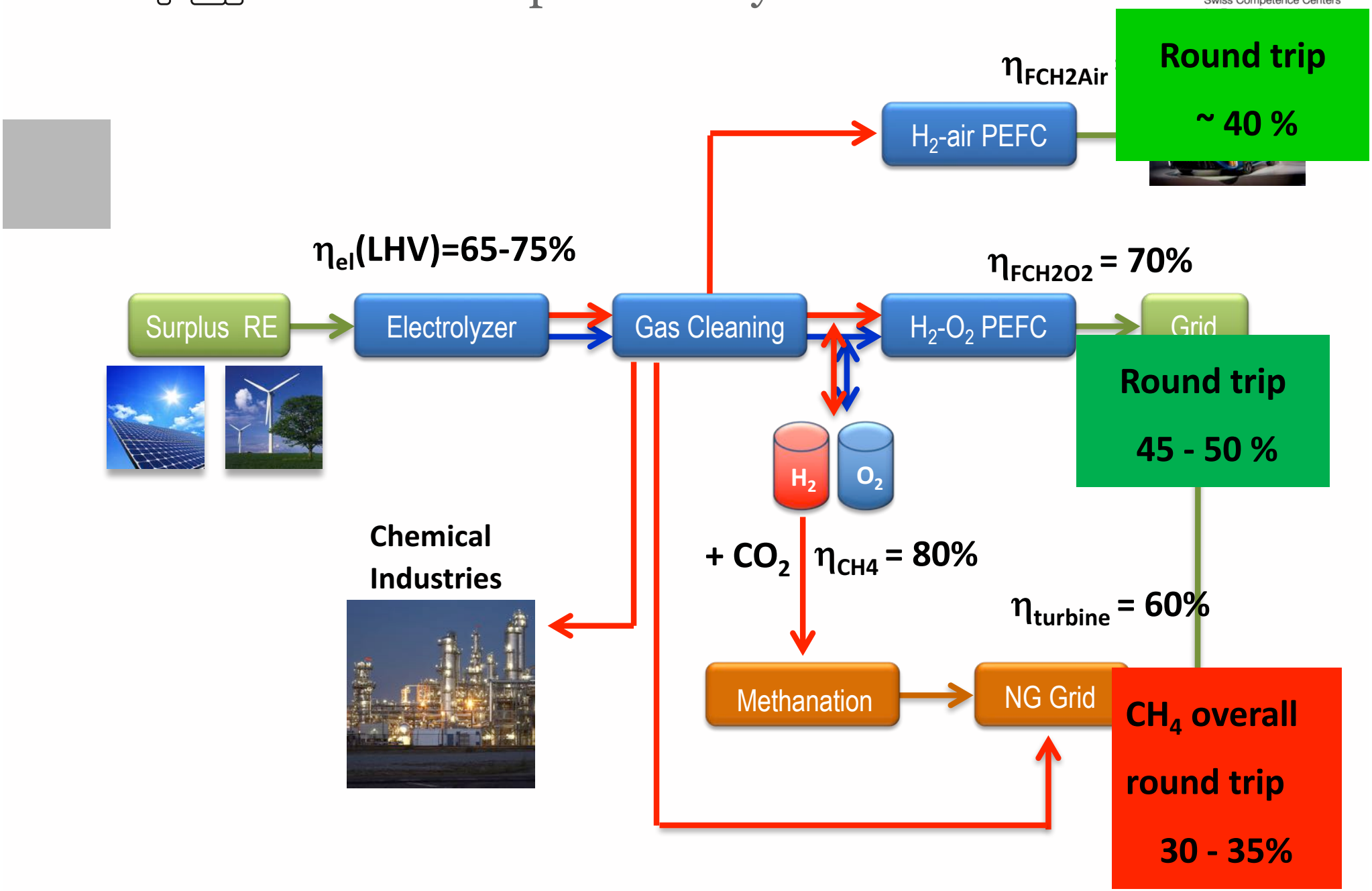


H_2/air

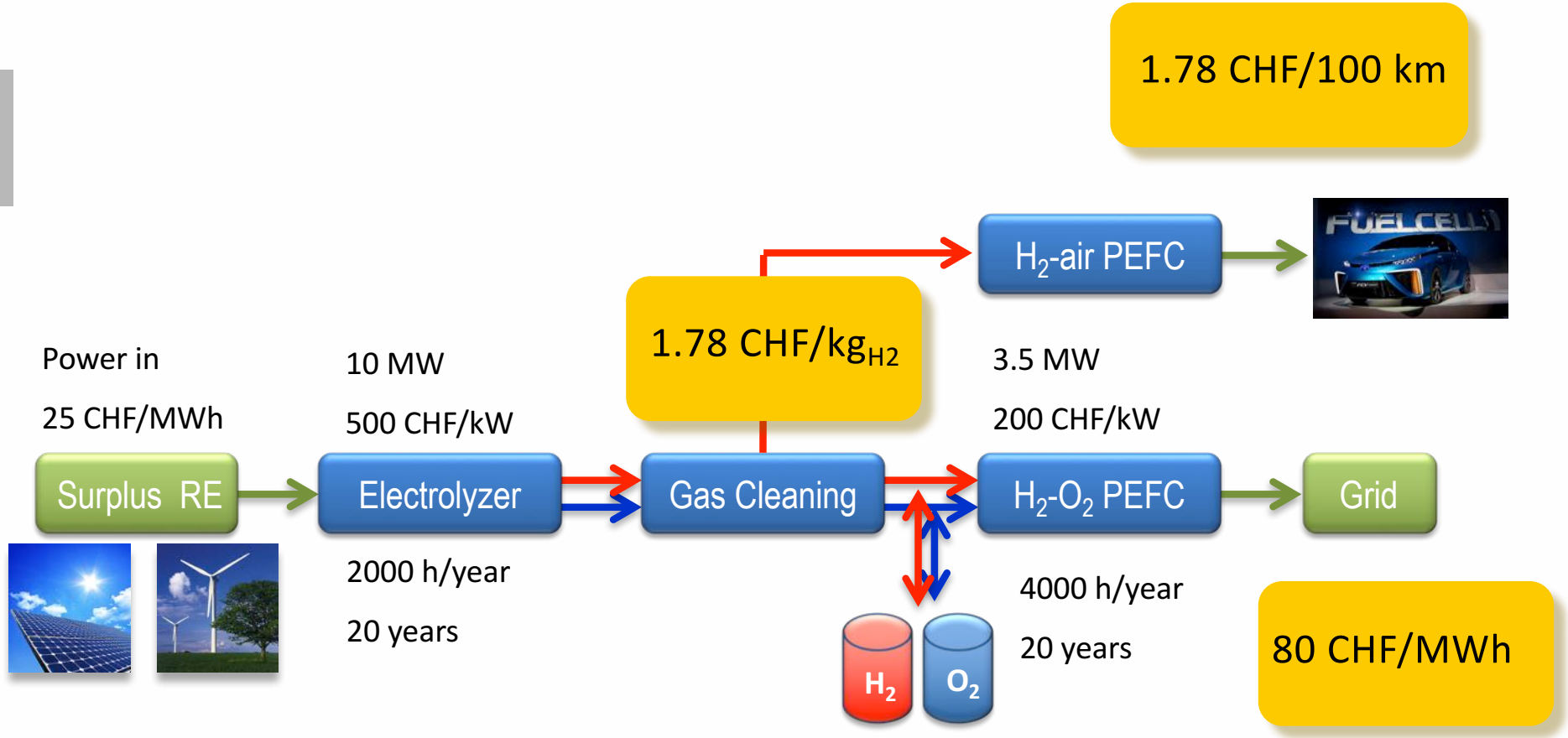
Hydrogenics HD16

New 60 kW stationary system for ESI

Round Trip Efficiency Estimations



Cost Estimates Power-to-H2-to-Power


1.78 CHF/100 km
H2-air PEFC
FUELCELL
1.78 CHF/kgH2
Power in
25 CHF/MWh
10 MW
500 CHF/kW
3.5 MW
200 CHF/kW
Surplus RE
Electrolyzer
Gas Cleaning
H2-O2 PEFC
Grid
2000 h/year
20 years
4000 h/year
20 years
H2
O2
80 CHF/MWh

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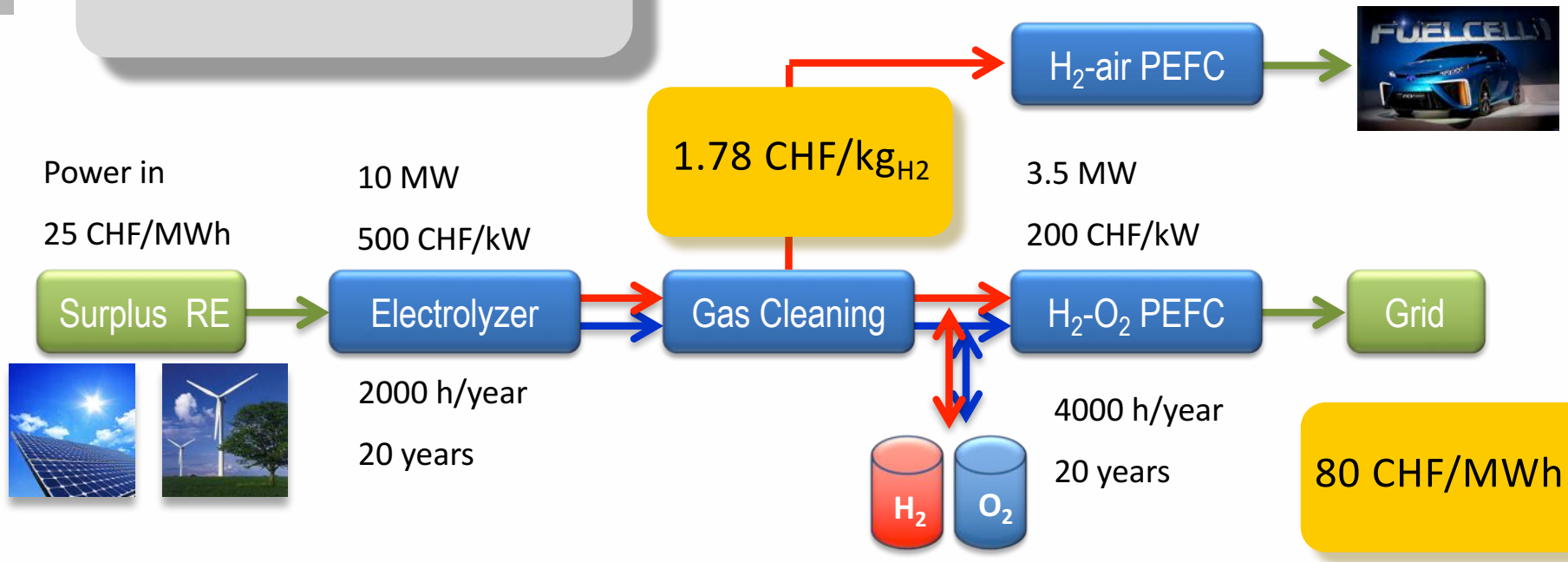
Determining Parameters:
- Cost power in (strong)
- ELY efficiency (strong)
- Invest Ely (medium)

1.78 CHF/100 km

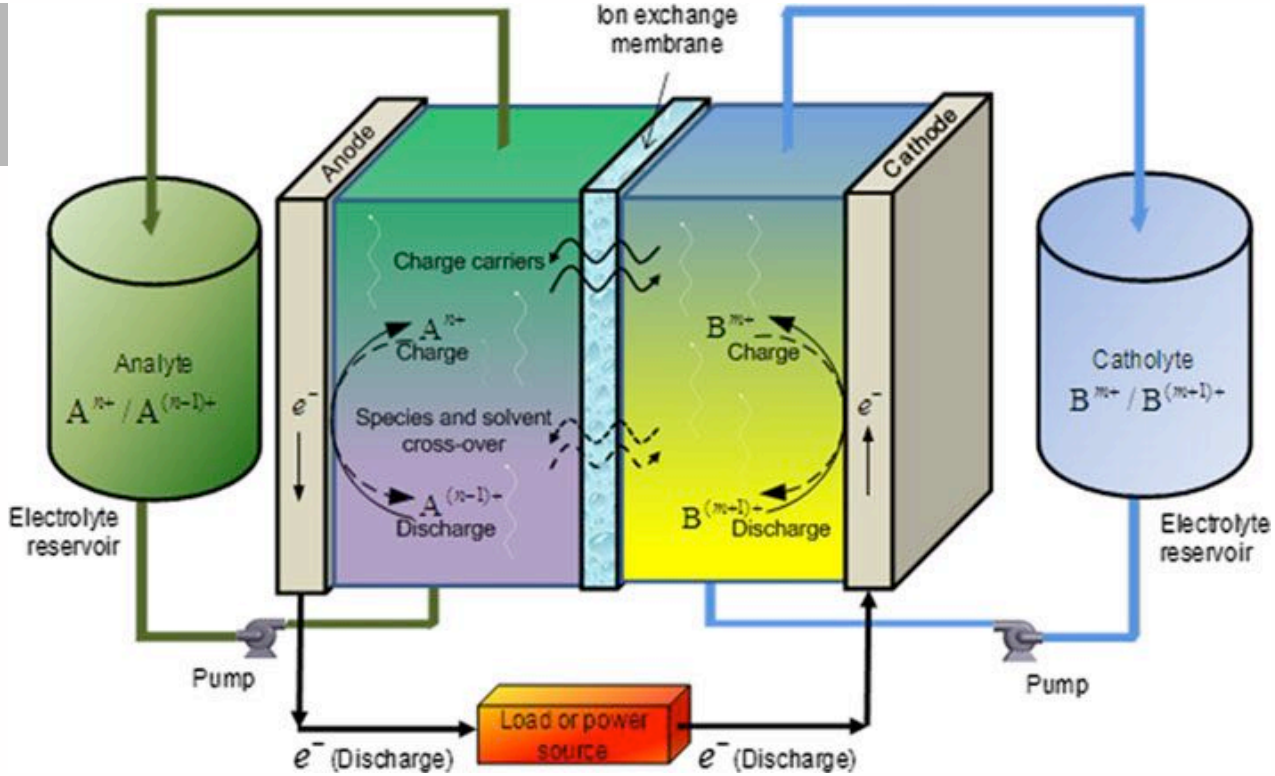


80 CHF/MWh

'Unimportant' Parameters:
- Invest Fuel Cell (small)
- Efficiency FC (small to medium)

Redox-Flow Batteries

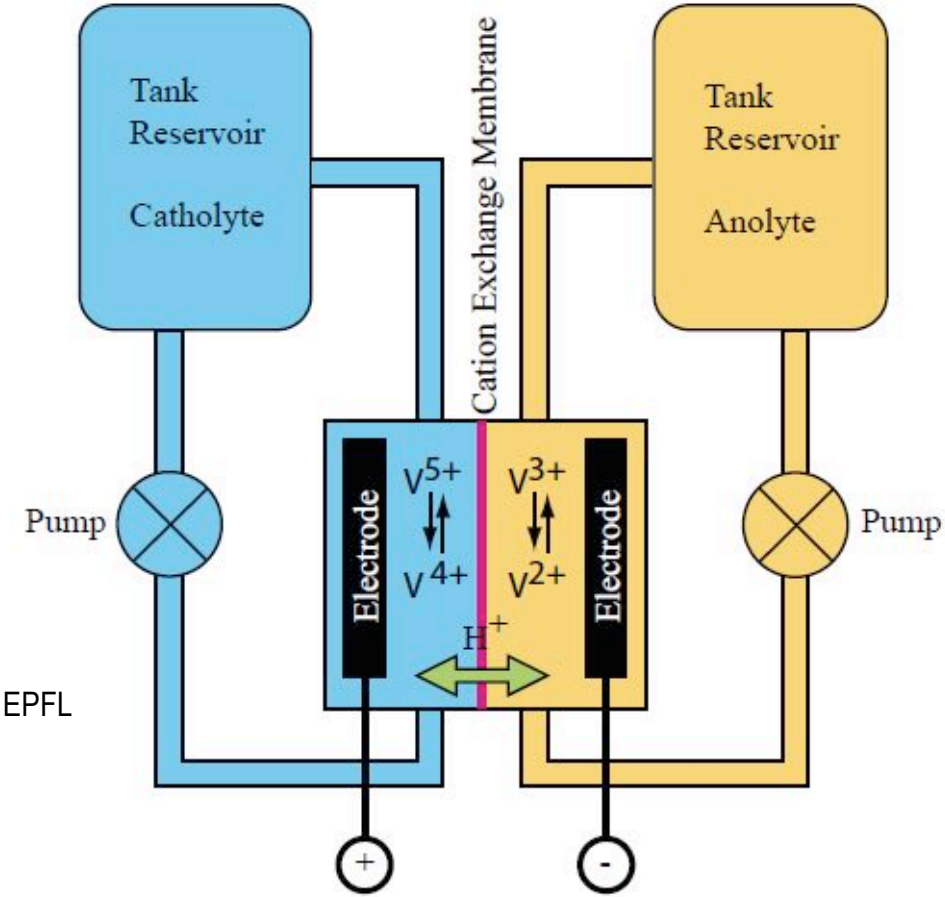
Redox Flow Battery Principle



- **all-V**
  single element
- **Fe/Cr**
  NASA 1970's
- **H_2/Br_2**
  gas half-cell
- **Zn/Br_2**
  hybrid (Zn plating)
- **all-Fe**
  slurry electrode
- **aqueous quinone**
  research stage

A.Z. Weber et al., *J. Appl. Electrochem.* **41** (2011) 1137

All-Vanadium Redox Flow Battery (VRB)



source: EPFL

$$VO^{2+} + H_2O \Leftrightarrow VO_2^+ + 2H^+ + e^-$$

E^0=1.0V

$$V^{2+} \Leftrightarrow V^{3+} + e^-$$

E^0=-0.26V

Gildemeister Energy Solutions

Completed: 2013

Location: Pellworm, Germany

PV: 1071 kW

Wind: 300 kW

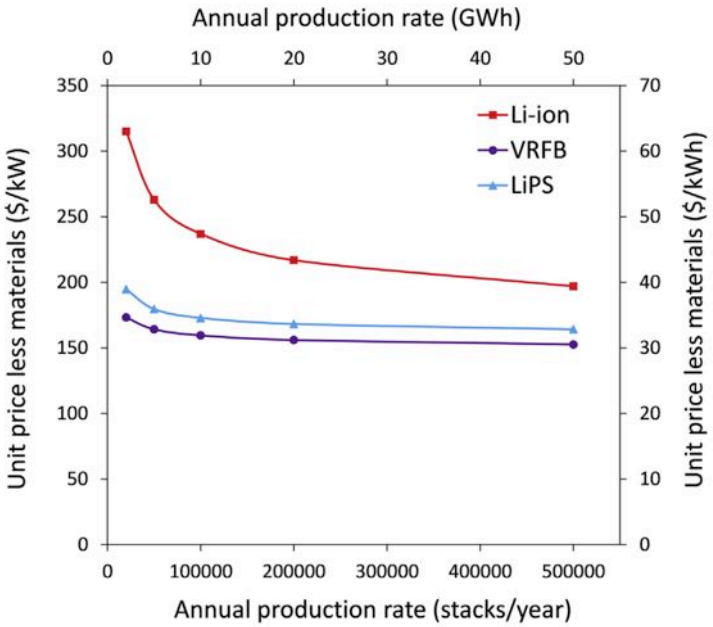
VRFB: 0.2 MW / 1.6 MWh

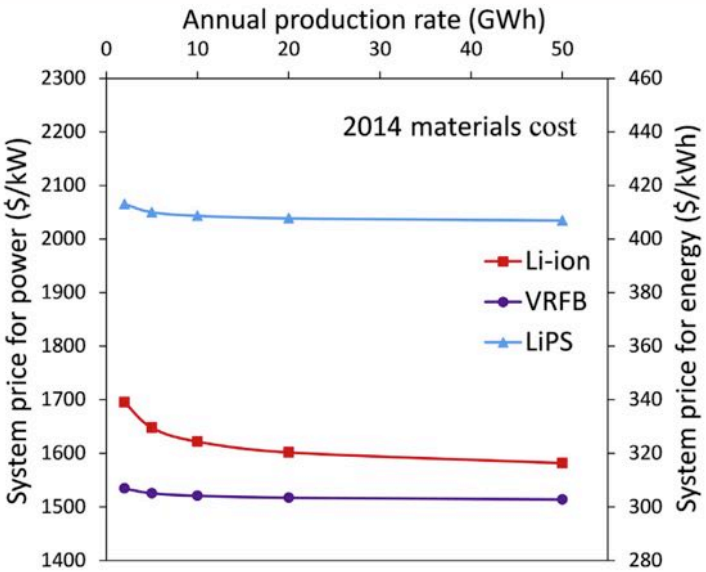
Li-Batt.: 1.1 MW / 0.56 MWh

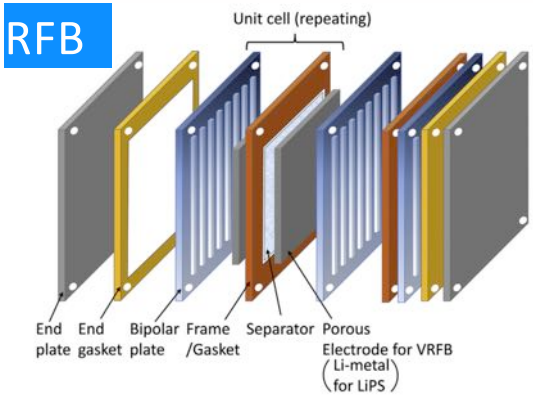
Objectives:

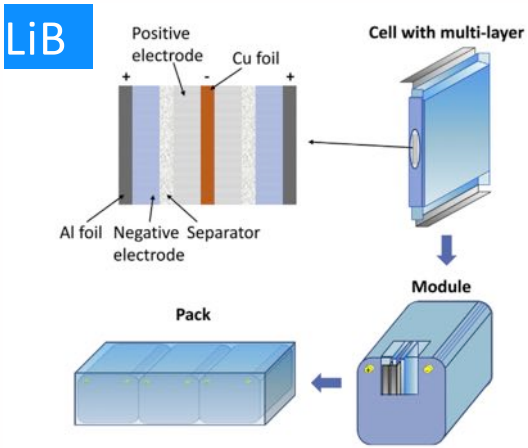
•Harmonize power generation and consumption

•Increase self-supply









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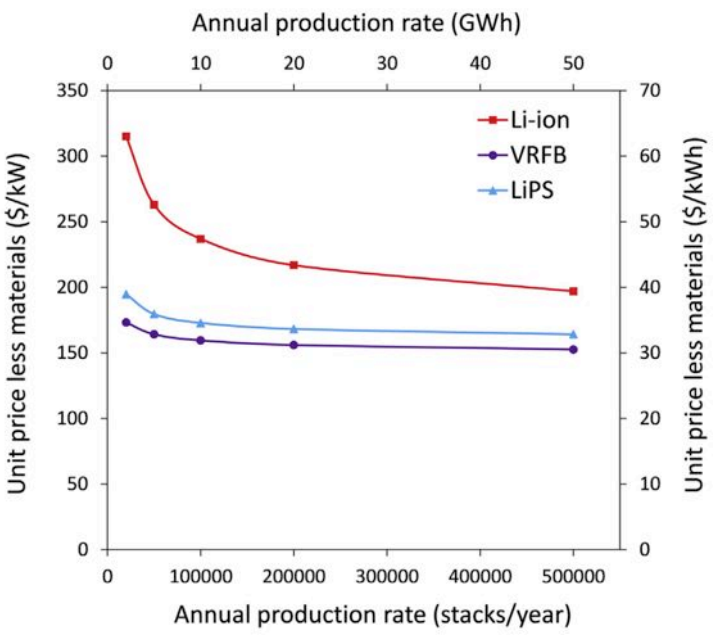

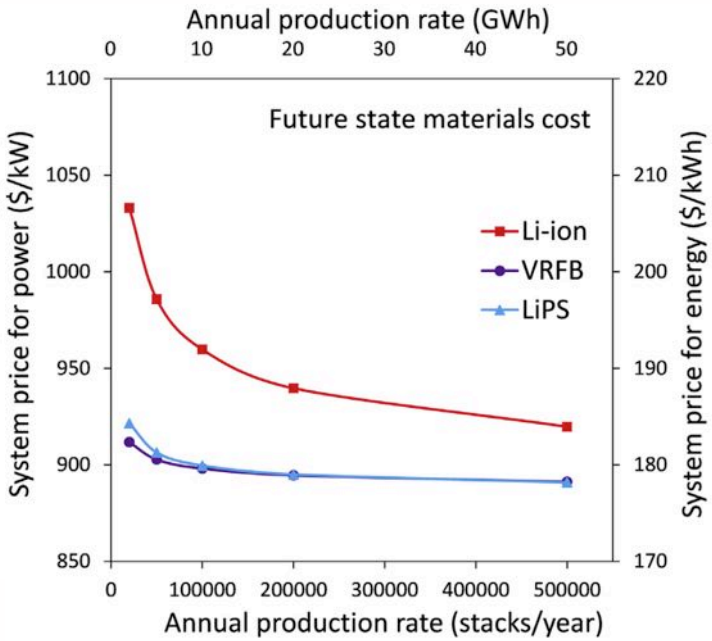

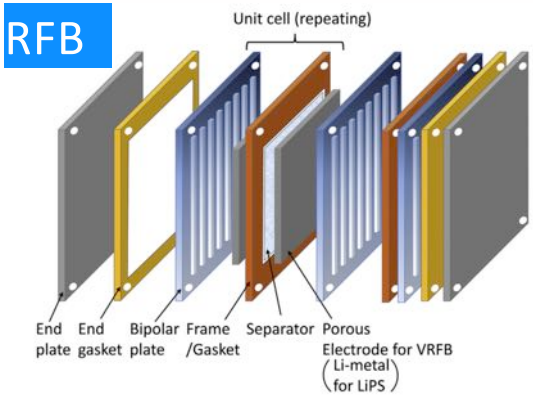

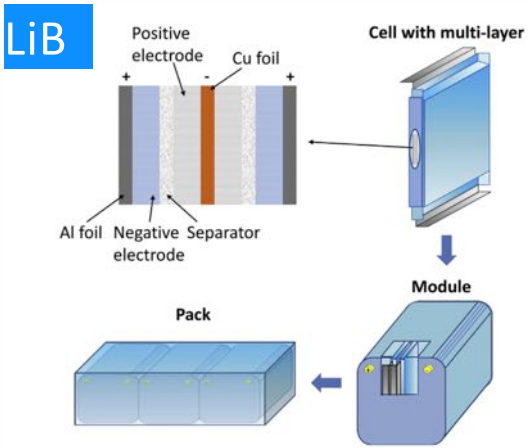

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Summary

- SCCER Heat & Electricity Storage: The one-stop-shop for energy storage in Switzerland
- Storage requirements are presently there and will increase in the future
- Energy Storage helps to flexibilize energy system
- Power-to-X will play significant role on different power, energy and time scales
- Redox flow batteries are attractive storage solution for broad size and time range