Power-to-X with High Temperature Solid Oxide Cells

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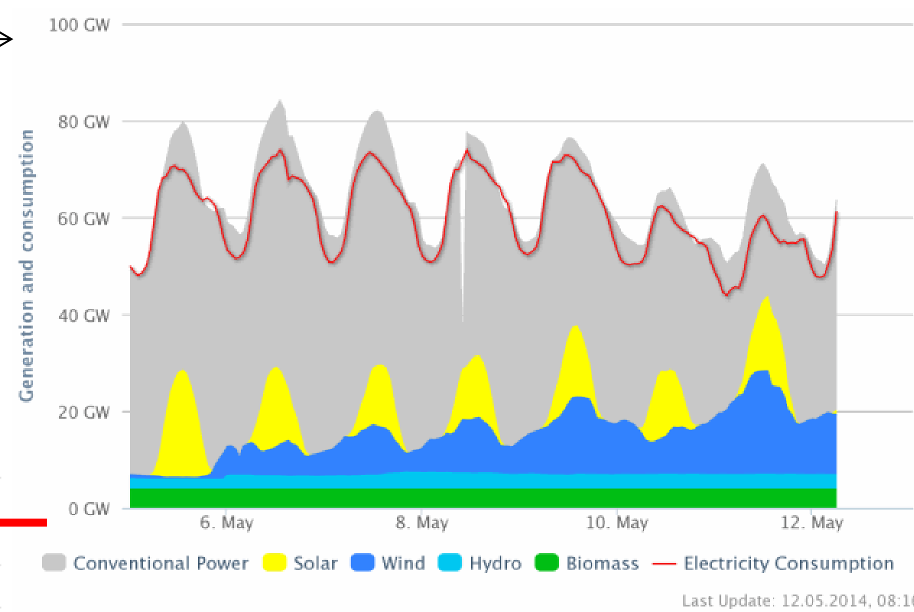
Why *Power-to-X* ?

High penetration of renewables induces mismatch between electricity generation and electricity consumption

Generation and Consumption of electricity in Germany 5th-12th of May 2014

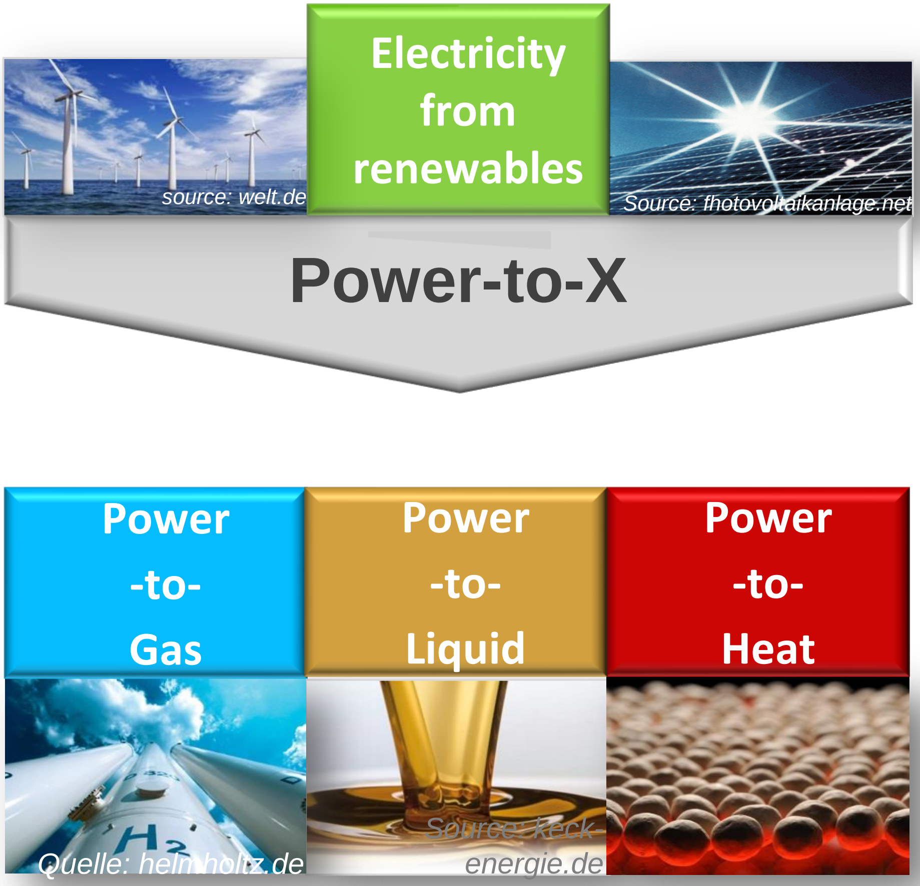


Electricity price on the DE-AT market on ***8th of June 2019*** *(Source EPEX)*

The energy transition requires large energy storage capacities

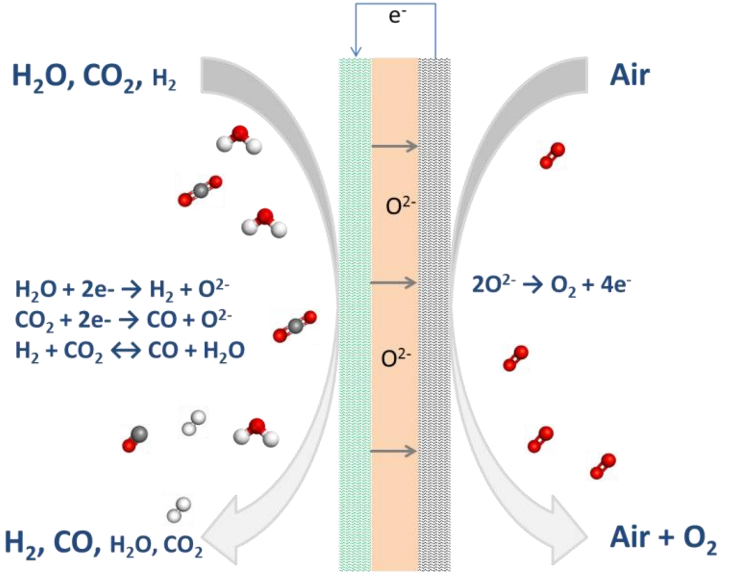
Power-to-X – What is behind the X ?

- Store the surplus of energy in alternative vectors ***(hydrogen, fuels, heat…)***
- Delocalize in the space and in the time the release of the energy surplus ***(use of other existing infrastructures)***
- Store the kWh of energy **on other markets** with higher potential of gains



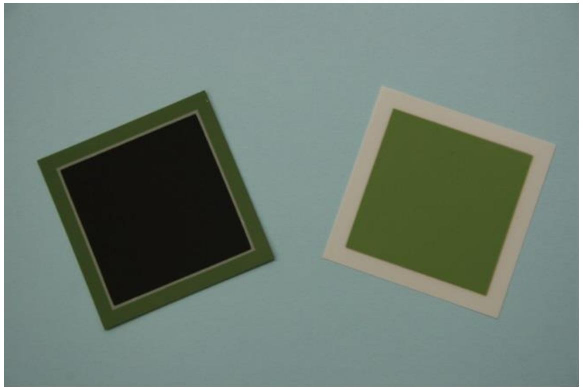
Power-to-X with High Temperature Solid Oxide Cells

- Conversion at high efficiency
- Possibility to co-electrolyse H_2O / CO_2 into syngas
- SOC are reversible
  Same materials/catalysts for SOFC & SOEC operation



Do SOFCs perform well in SOE? Specific degradation mechanisms? May optimized SOFC be further optimized for SOE operation?

Case study 1: Anode Supported Cells



50 mm x 50 mm / 16 cm² area

- **Commercial Anode Supported Cells (ASCs)**

NiO-YSZ I YSZ I CGO I LSCF

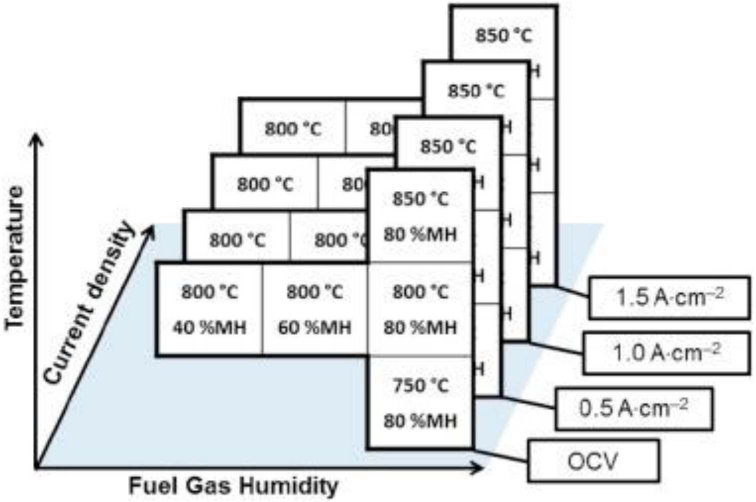
- **Commercial Electrolyte Supported Cells(ESCs)**
- NiO-CGO I CGO I YSZ I CGO I LSCF

- **Test Conditions**

Steam-electrolysis

Co-electroylsis **(57% H_2O + 36% CO_2 + 7% H_2)**

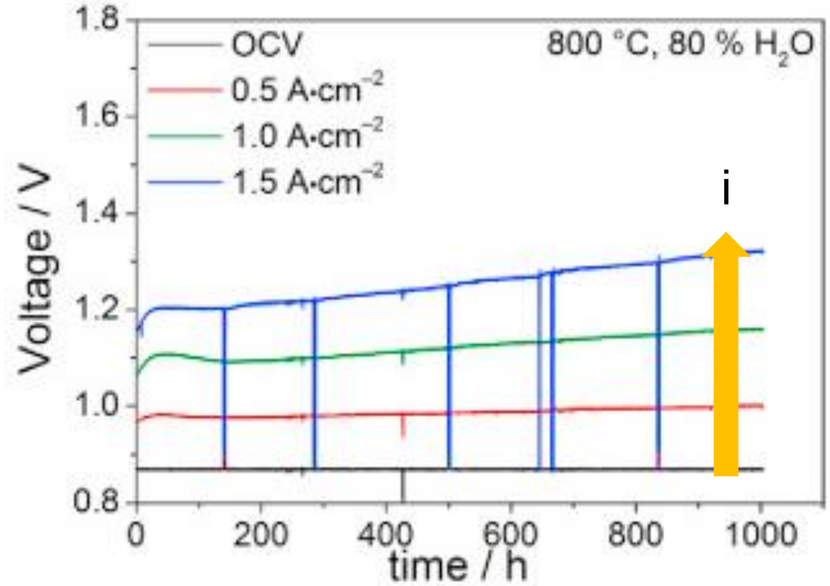
- **Post test SEM analysis**



M.P. Hoerlein, M. Riegraf, R. Costa, G. Schiller, K.A. Friedrich, *A parameter study of solid oxide electrolysis cell degradation: Microstructural changes of the fuel electrode*. Electrochimica Acta, 276, (2018), 162 - 175

Electrochemical behaviour and degradation

- ➢Degradation rate increases with the applied current density upon galvanostatic aging



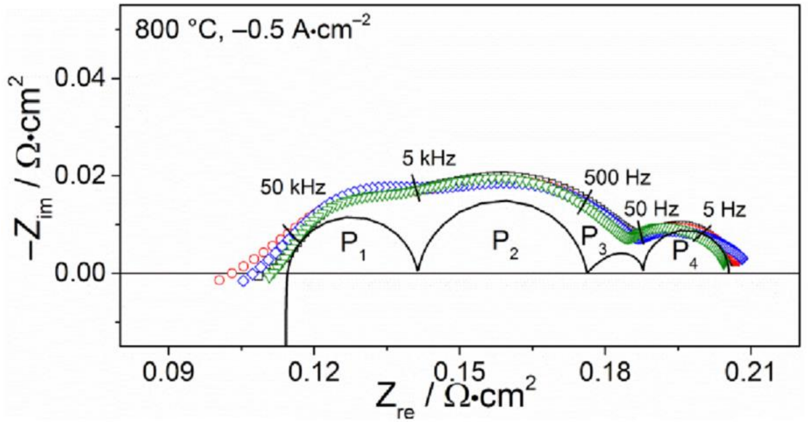
- ➢ EIS investigation

(P1: ionic transport coupled with charge transfer FE)

(P2: charge transfer FE)

(P3: Air Electrode)

(P4: FE gas transport)



- ➢Increase of R_{ohm} as f(i, T, H_2O)

At T=800°C / 80% MH

27 mΩ·cm² (OCV)

41 mΩ·cm² (0.5A.cm²)

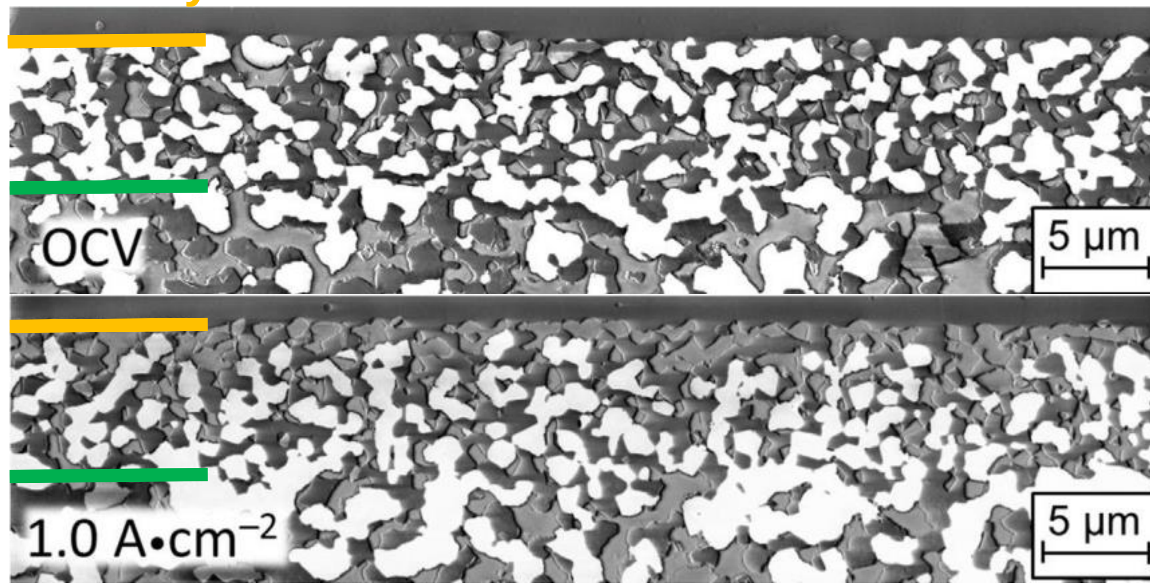
59 mΩ·cm² (1 A.cm²)

87 mΩ·cm² (1.5 A.cm²)

Microstructural investigation

- SEM investigation: Mapping of Secondary Electrons emission with inlens detector at low acceleration voltage
- Interface functional fuel electrode / electrolyte is depleted in (percolant!) Nickel
- Nickel transport away from inner interface into the substrate
- Increase of diffusion pathlength for oxygen ions responsible for apparent ohmic resistance increase

Electrolyte



$D_{eff}=d_{Ni,dep}\ \tau/\varepsilon$ with $\varepsilon \sim 0.37$, $\tau \sim 2$

>> 10,8µm YSZ

At 800 °C $R_{eff} \sim R_{YSZ} \sim 59\ m\Omega.cm^2$

Prospects (2): Renewable heat integration in SOE

- High Temperature Solid Oxide Electrolysis allows the lower electricity demand which is very important for storage

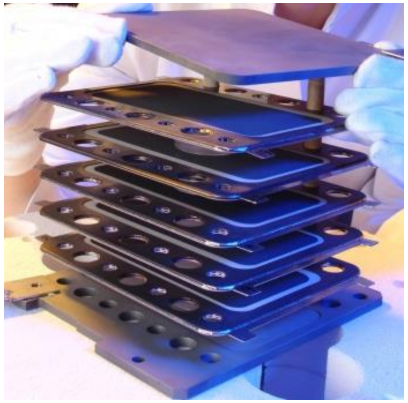
- Integration of renewable heat source / steam source into electrolysis process may allow to produce hydrogen and synthetic fuels at very high efficiency

- DLR project „future fuels“ – subproject „solar fuels“

Collaboration between 2 DLR institutes

(Solar Research in Cologne

Engineering Thermodynamics in Stuttgart)



Prospects (2): Renewable heat integration in SOE

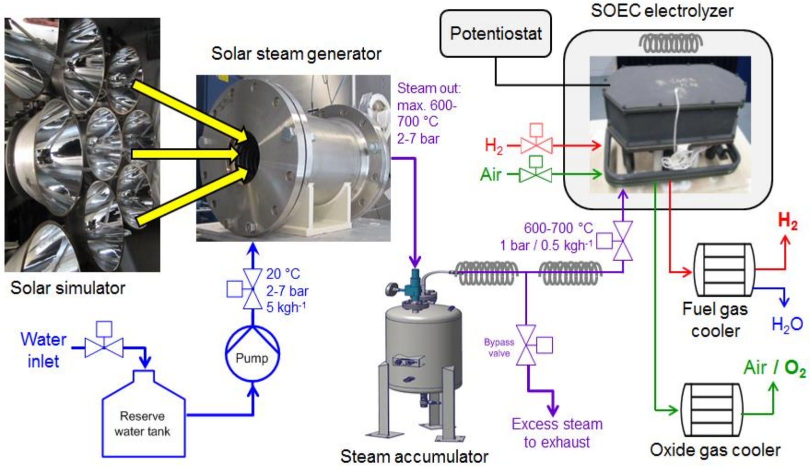
- Experimental coupling using a solar simulator (Xe lamps), solar steam generator and a 12 cells SOE stack

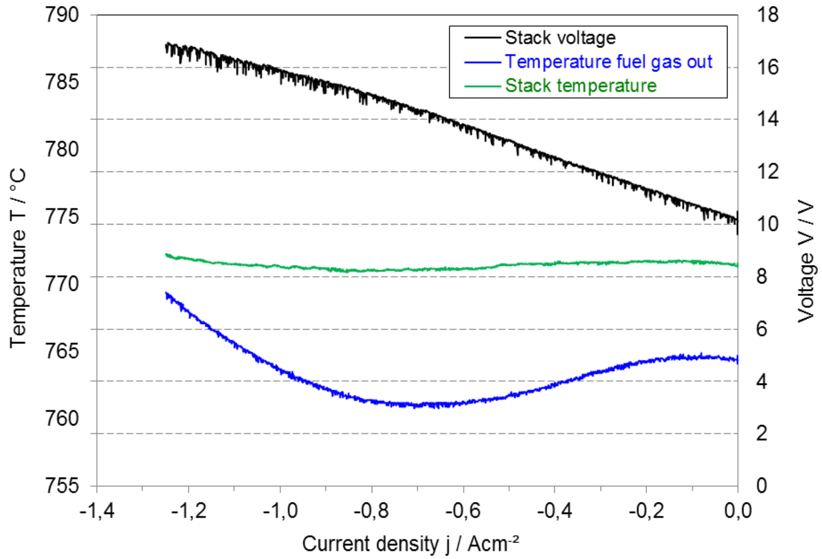
- Integration of steam storage

- At 770°C, -1.25 A.cm^{-2}, 70% conversion electrical efficiency of 93% was achieved.

- Challenges Steam & Temperature management

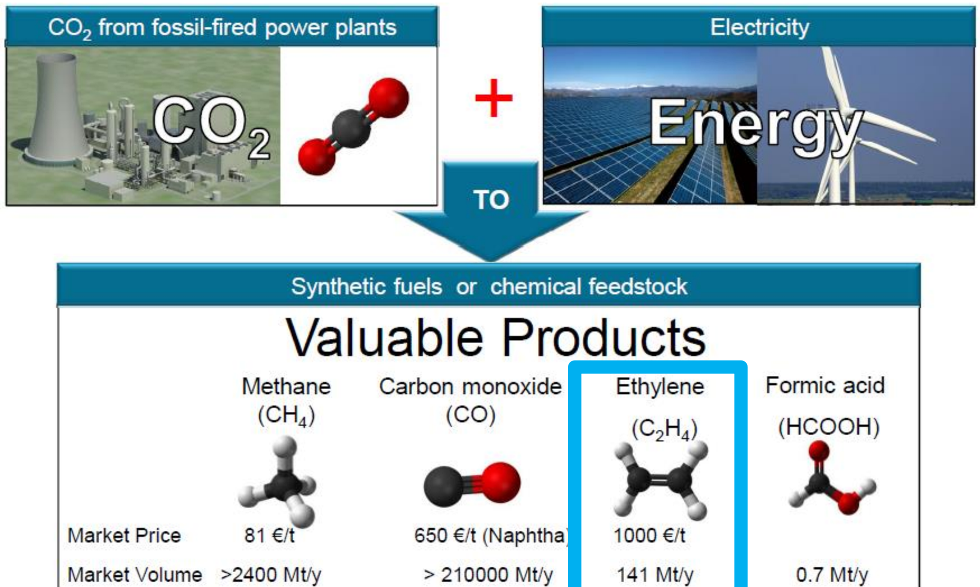
- Ongoing activities are dedicated towards solar heat integration into co-electrolysis



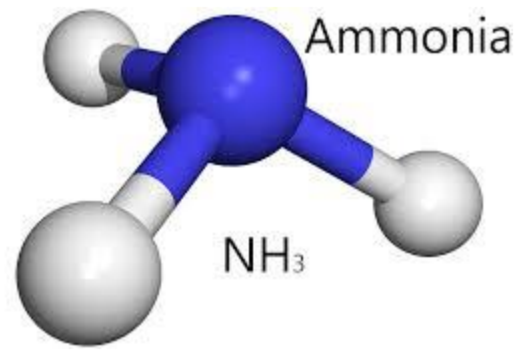


Prospects (3): Electrify Chemistry

Production from base chemicals out of CO_2, H_2O, air and electricity



Source Siemens 2014



Market Price	650€/t
Market Volume	> 180 Mt/y

„play“ with protons not with oxygen
PCCs

ARCADE

Conclusion

- Similar behaviours are observed in steam electrolysis and co-electrolysis

  A unique SOC technology

- Main degradation mechanism is assigned to nickel transport away from the interface Fuel Electrode / Electrolyte. Mechanisms not well understood

- Materials and Microstructure optimization required for durable operation in SOE, as well as definition

  Perovskite exsolution catalysts are a promising alternative to cermets (ESCs)

- Solar Heat integration into SOE is a promising route for producing synthetic fuels at high efficiency

- Electrochemical Reactors with Proton Conductings Ceramics are promising for application in the chemical industry

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

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DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service

Thank You!