Bundesministerium
Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie

Bundesministerium
Arbeit und Wirtschaft

FFG
Forschung wirkt.

Das Land
Steiermark
Wirtschaft, Tourismus,
Wissenschaft und Forschung

SFG
NEUES DENKEN. NEUES FÖRDERN.

ober
österreich

UAR INNOVATION NETWORK

Stadt
Wien

wirtschafts
agentur
wien

LAND
TIROL

Implementierung und Verbreitung von Wasserstofftechnologie: Technologische Fortschritte und Herausforderungen

Ass.Prof. Dr.techn. Alexander Trattner

CEO and Research Director

HyCentA Research GmbH, Graz 2024

TU Graz

HyCentA
HYDROGEN CENTER AUSTRIA

HyCentA Research GmbH – COMET K1

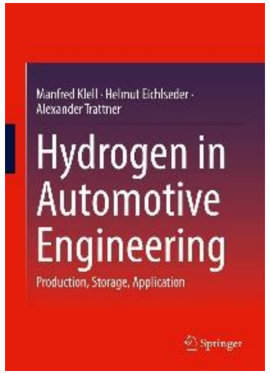
Austria's research center for hydrogen technologies

Source: Chatgpt

Non-university research organization at Graz University of Technology (TUG)

TU Graz FVT MAGNA OMV

- **100+ researchers** from mechanical engineering, physics, chemistry, process engineering, electrical engineering
- More than **600+ projects** successfully completed
- More than **20 years of expertise** State-of-the-art testing & refueling infrastructure
- Teaching at TU Graz
- International network



Manfred Klell · Helmut Eichlseder · Alexander Trattner

Hydrogen in Automotive Engineering

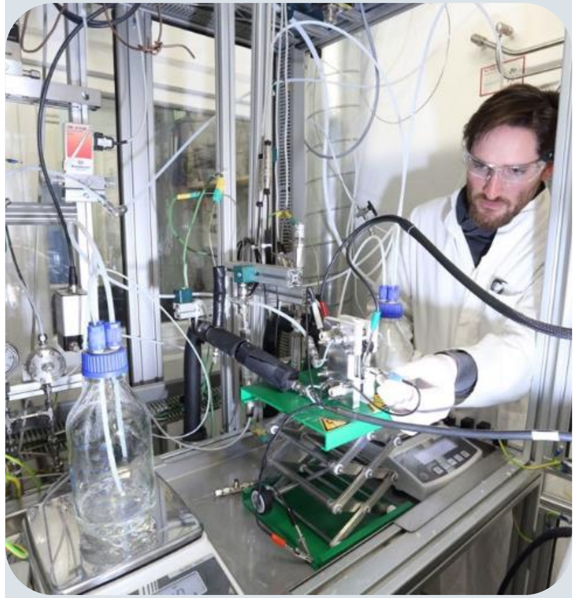
Production, Storage, Application

Springer

Research Areas along the Entire Value Chain

HyCentA
HYDROGEN CENTER AUSTRIA

Area 1 – ECT
Electrolysis and Power-to-X



Material research, new **electrolysis technologies**, alternative processes
(from materials to industrial applications)

Area 2 – INT
Green Energy and Industry

Research on **generation**, **purification**, **compression**, **storage**, **distribution** and **delivery** technologies for the industry and the energy Sector

Area 3 – MOT
Green Mobility

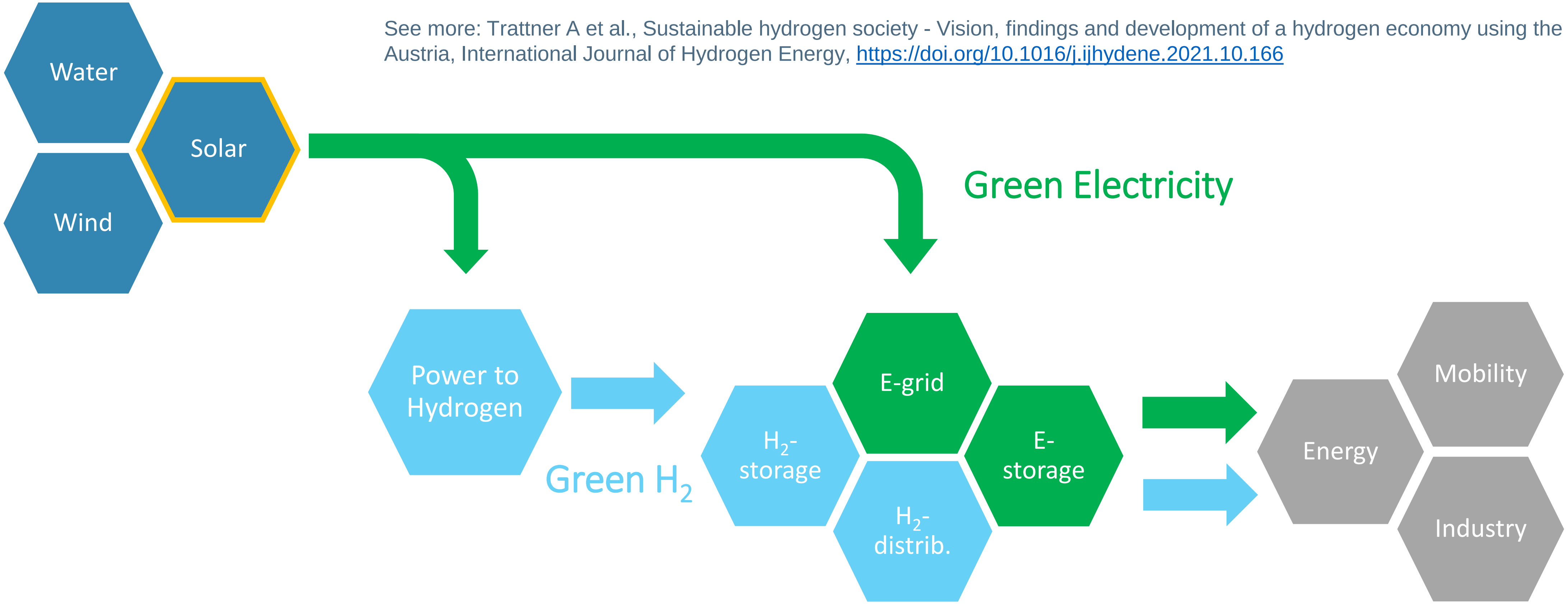
Fuel cell research on materials, cell, stack and system; optimisation of entire **powertrain** system including **hydrogen storage**

Area 4 – MET
Circularity and Sys. Optimization

Measurement and **testing** technologies, **controls**, diagnostics, **modelling** and simulation “digital twin”

Hydrogen – a Key to the Energy Transition

See more: Trattner A et al., Sustainable hydrogen society - Vision, findings and development of a hydrogen economy using the example of Austria, International Journal of Hydrogen Energy, https://doi.org/10.1016/j.ijhydene.2021.10.166



Water

Solar

Wind

Green Electricity

Power to Hydrogen

Green H_2

H_2-storage

E-grid

H_2-distrib.

E-storage

Mobility

Energy

Industry

Integration of renewables

- Integrate production surpluses
- Direct water splitting

Energy conversion

- Electrolysis - compensate temporal volatility
- H2 as secondary energy carrier – energy storage

Storage and distribution

- Centralized and decentralized storage
- Long-term storage
- Efficient transport over long distances

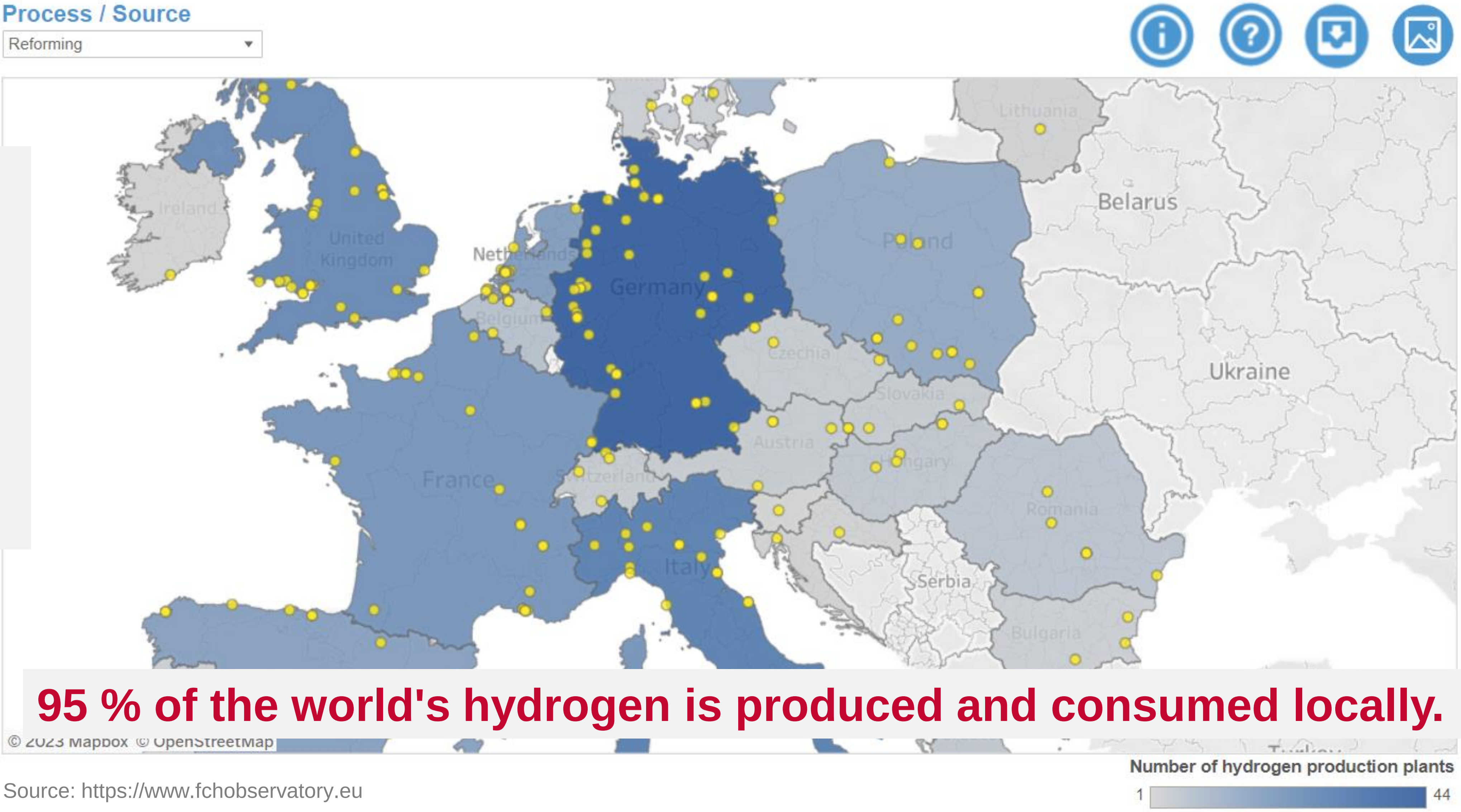
Zero Emission Usage

- Energy Services – CHP
- Mobility with Fuel cells
- Industry and high-temperature processes

Grey Hydrogen in AUT – Steam reforming

2020:
Austria
433 t/day

3 large-scale steam reformers



Process / Source
Reforming

95 % of the world's hydrogen is produced and consumed locally.

Source: https://www.fchobservatory.eu

Overview of H2 in Industry - Austria

- Currently, the annual hydrogen demand of industry in Austria (primarily in the chemical and petrochemical industry) is **around 140,000 tonnes** (source: H2 Strategy AUT), which is produced from fossil sources (natural gas).
- **140,000 tonnes = 5.6 TWh** (calorific value) → 1.4 % share in the primary energy system (approx. 400 TWh)
- Would correspond to an electrolysis capacity of **approx. 830 MW** (8000 h/a - 70% efficiency)
- **Goal = 1 GW in Austria until 2030**

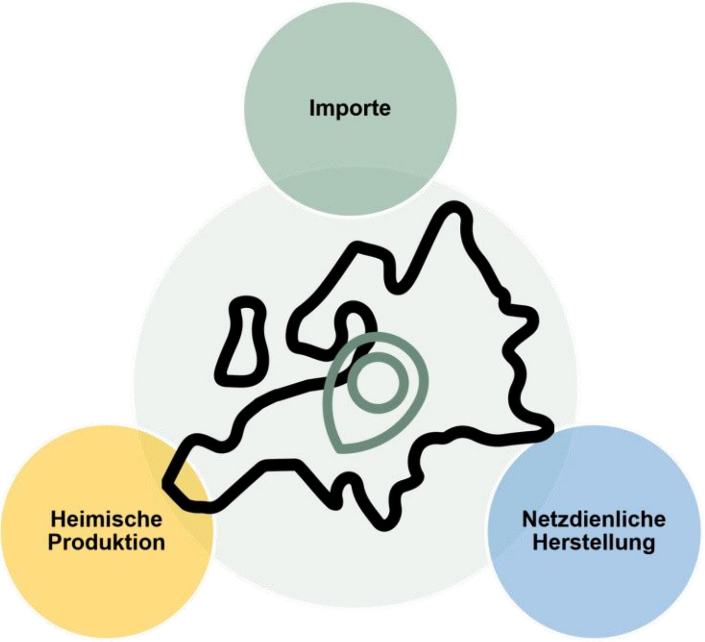
Bundesministerium
Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie

Bundesministerium
Digitalisierung und
Wirtschaftsstandort

Wasserstoffstrategie
für Österreich

Erneuerbare Wasserstoffversorgung

Wie kann sich **Europa** und **Österreich** mit **grünem Wasserstoff versorgen**?



AUT 2030: 20+ TWh

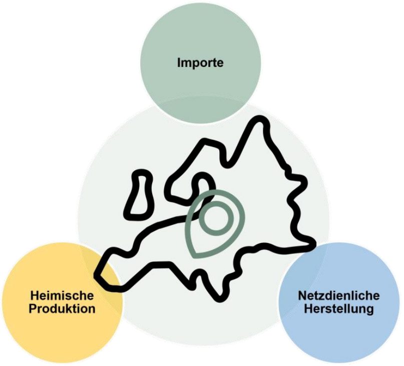
- **Importe:** (Off-Grid) H_2 Produktion im Ausland und Transport nach Europa (Pipeline/Schiff)

AUT 2030: 5 TWh

- **Netzdienliche Herstellung:** Nutzen von Überschussenergie zu Stromgestehungskosten
- **Heimische Produktion:** Nutzen von grüner Energie zur H_2 Produktion lt. RED II

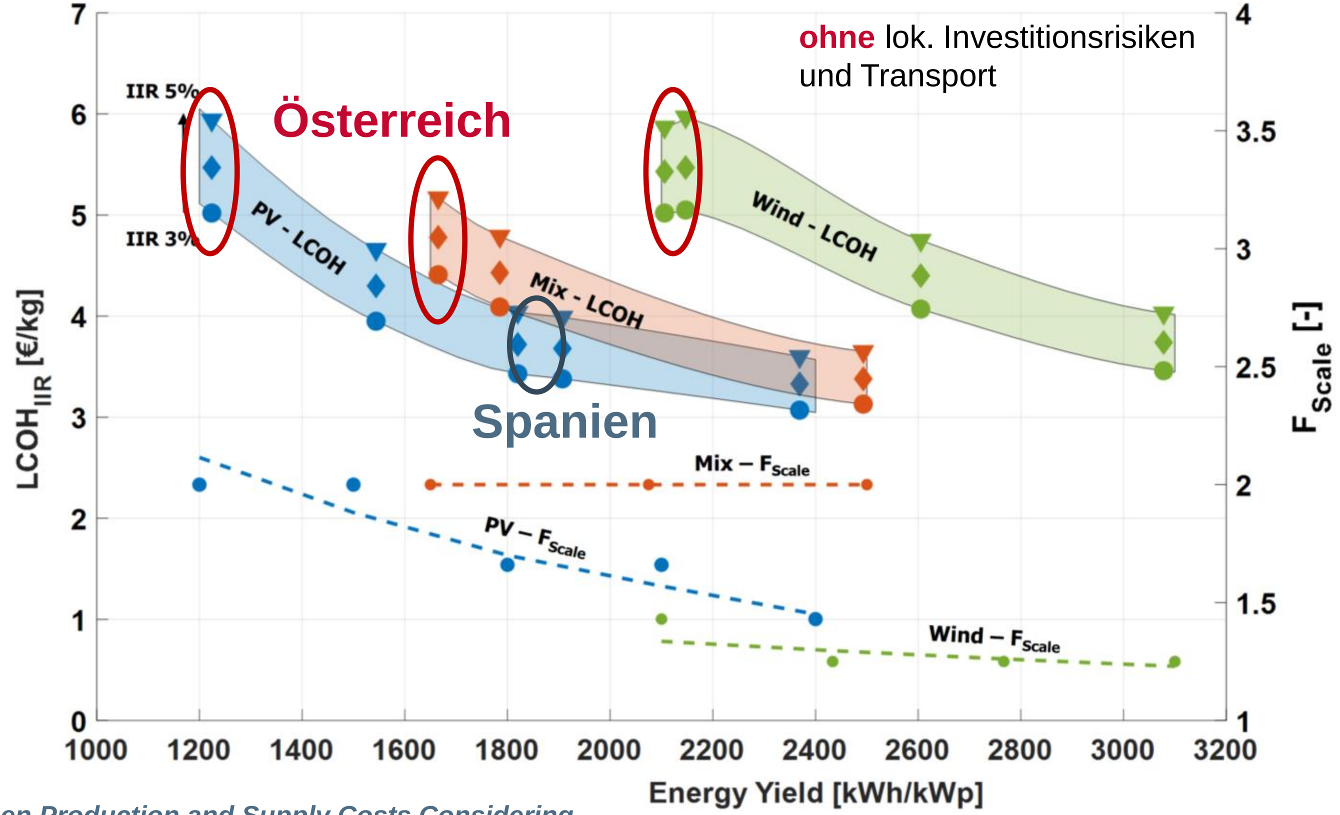
- Wieviel kostet erneuerbarer Wasserstoff?

Importierter Wasserstoff



H_2-Importe: Berücksichtigen von lokaler Energieausbeute, Investitionsrisiken und Transportkosten

- **Höhere Energieausbeute** – niedrigere LCOH
- **Gemischte Energiequellen** – niedrigere LCOH
- **Leistungspaarung** Erneuerbar-Elektrolyse **standortabhängig**



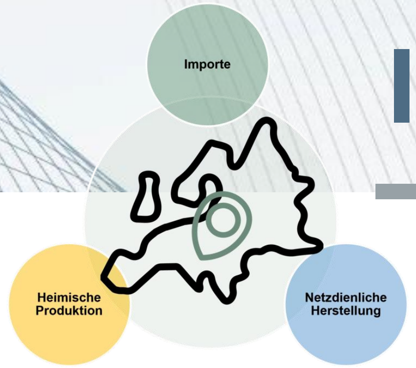
ohne lok. Investitionsrisiken und Transport

Österreich

Spanien

Österreich nicht konkurrenzfähig?

Source: Radner, F; Et al. Off-Grid Hydrogen Production: Analysing Hydrogen Production and Supply Costs Considering Country-Specifics and Transport to Europe. IJHE, 2024, https://doi.org/10.1016/j.ijhydene.2024.07.142

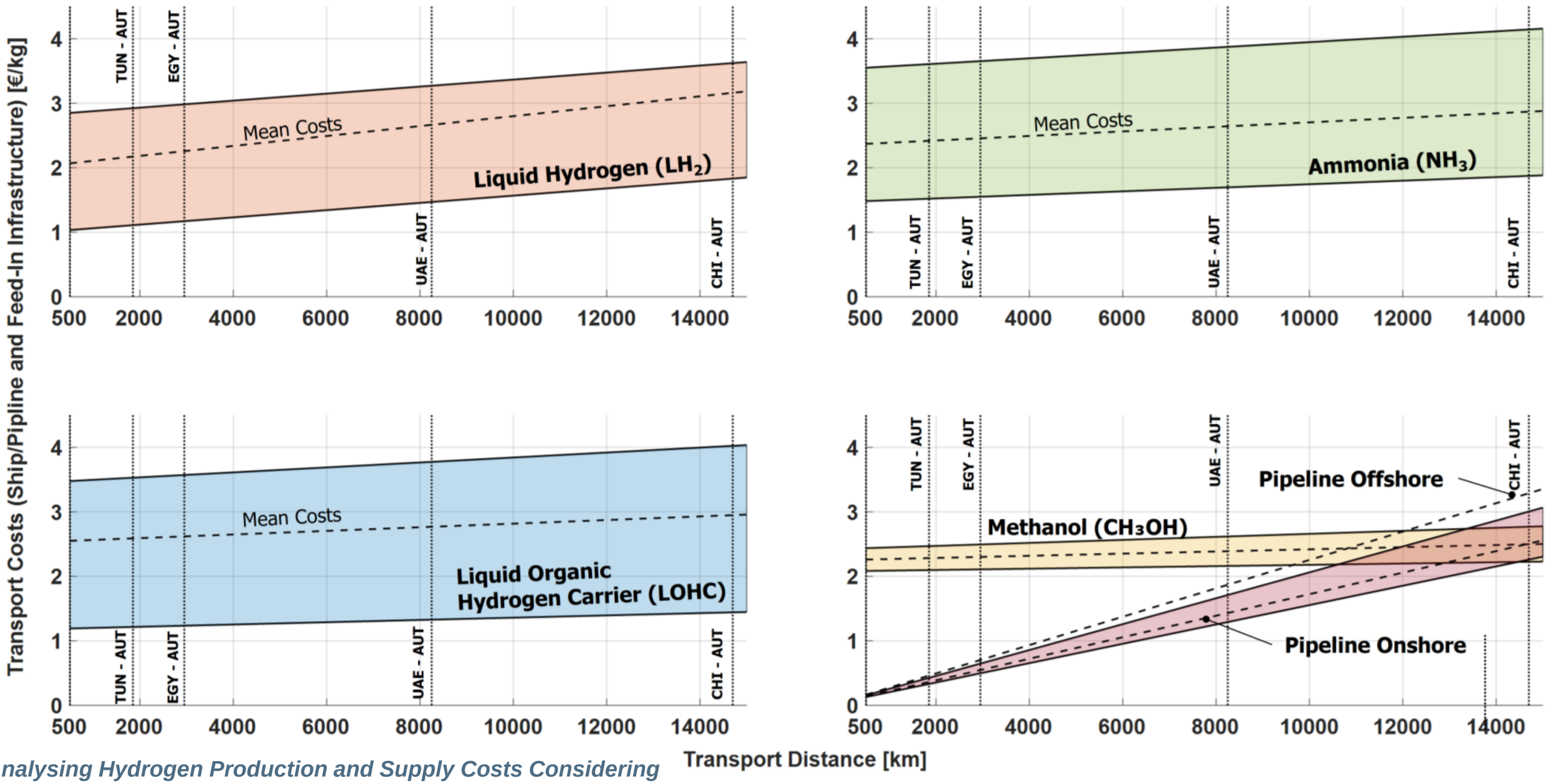


Importierter Wasserstoff

H_2-Importe: Berücksichtigen von lokaler Energieausbeute, Investitionsrisiken und Transportkosten

- CHI-AUT: 2,9 - 4,4 €/kg
- UAE-AUT: 1,5 - 4,0 €/kg
- EGY-AUT: 1,3 - 3,8 €/kg
- TUN-AUT: 0,3 - 0,4 €/kg

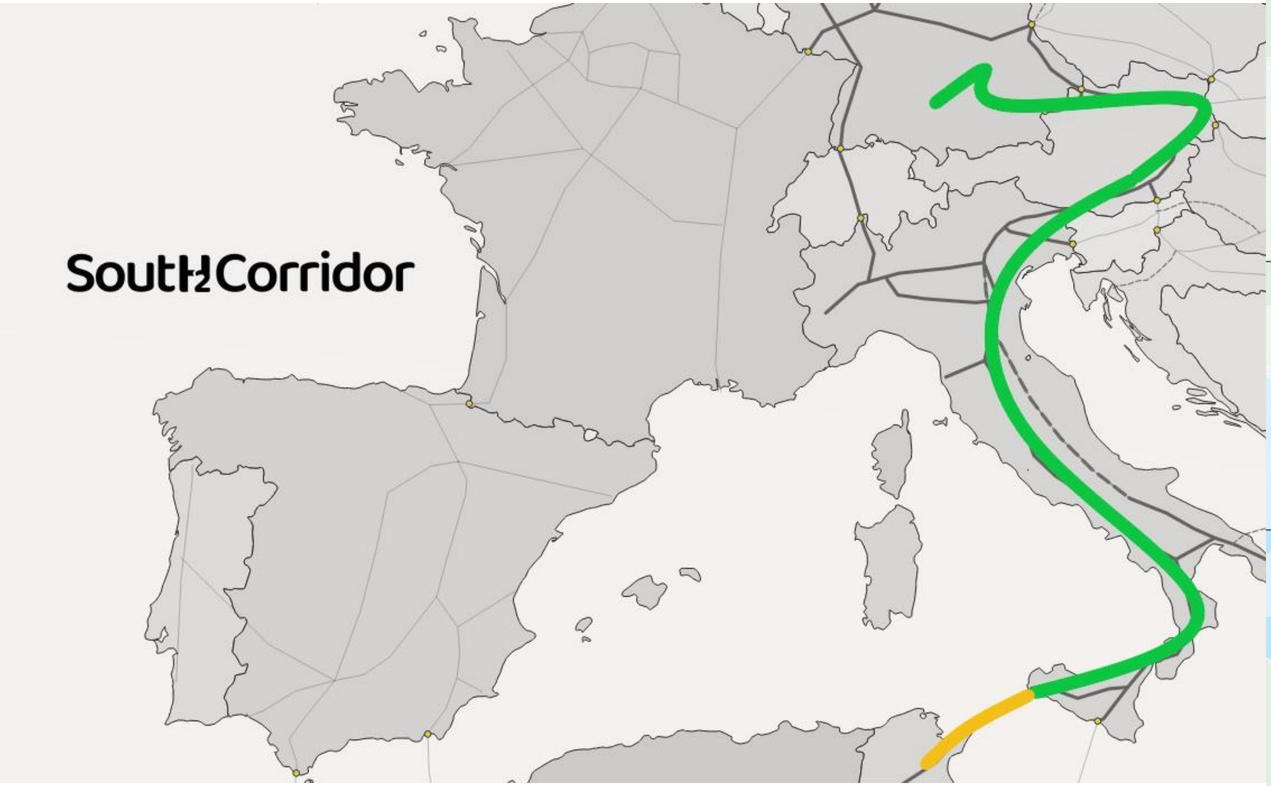
- **Transportkosten** sind **Entscheidend**
- Form und **Kosten** sind **unklar**
- **Pipeline** am **günstigsten**



Source: Radner, F; Et al. Off-Grid Hydrogen Production: Analysing Hydrogen Production and Supply Costs Considering Country-Specifics and Transport to Europe. IJHE, 2024, https://doi.org/10.1016/j.ijhydene.2024.07.142

South H2 Corridor (PCI)

Fernleitungsnetz (international)



H_2 Backbone WAG + Penta-West

This project enables bidirectional cross-border hydrogen transport possibilities between Slovakia and Austria as well as between Austria and Germany and allows for taking over hydrogen ariving via the TAG-hydrogen pipeline systems in the Baumgarten node to the extent of 150 GWh/day.

HyPipe Bavaria – The Hydrogen Hub

The project will be laying the foundation for the indispensable Bavarian hydrogen network, to be completed by 2030. Implementing the Bavarian hydrogen network is an essential prerequisite for establishing import routes from Southern and Eastern Europe for the German hydrogen market.

H_2 Readiness of the TAG pipeline system

The Trans Austria Gasleitung GmbH project enables the transport of hydrogen through one of three existing pipelines from the Italian-Austrian border to the Austrian-Slovakian border, where the future connection to the H_2-WAG pipeline is also located. The repurpose of one existing pipeline and the construction of the necessary compressor capacities will enable the bidirectional transport of H_2. At the same time, the H_2 pipeline serves as the basis for the Austrian distribution grid.

Italian H_2 Backbone

The Italian H_2 Backbone is composed of around 2300 km of pipelines (73 % repurposed and 27 % new built) and several hundred MW of compressor stations, expected to become dedicated hydrogen assets by 2030. With an import capacity of 448 GWh/day from North Africa, this project is a major European renewable hydrogen import artery, serving Italian demand clusters and with a capacity to export 168 GWh/day to Austria and beyond.

- ● Demand Centre (region)
- ● Demand Centre (town)
- ● Potential Storage
- ○ Production Centre

SouthH2Corridor

More information and further links about the individual projects, the TSOs, supporting partners and contact informations can be found on our joint website:

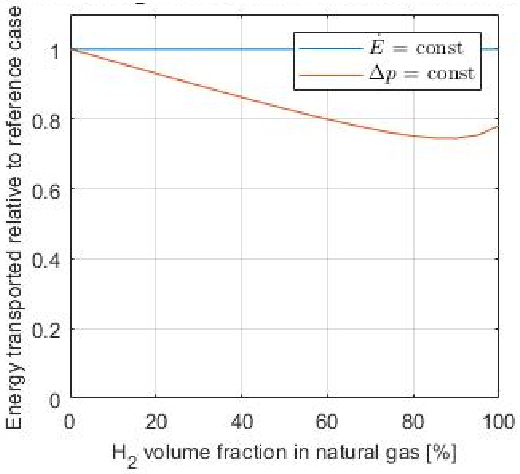
www.south2corridor.net

- **SothH2Corridor** is a **PCI Status (Project of Common Interest),** Funding allowed
- Insgesamt **3.300 km** Pipeline von Tunesien bis Bayern
- **70% Umwidmung und 30% Neubau** steigt um **Faktor 3-4**
- Potential **4 Mtpa ab 2030**
- Beabsichtigte **Produktionsmenge** in Nord Afrika **2030 2.5 Mtpa**

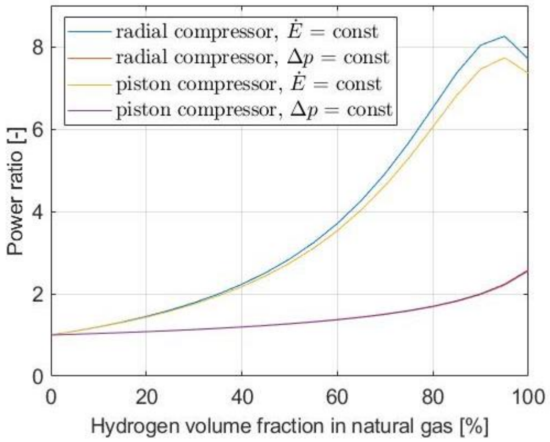
Source: SoutH2 - Home (south2corridor.net)

H_2 Charakteristik in Pipelines

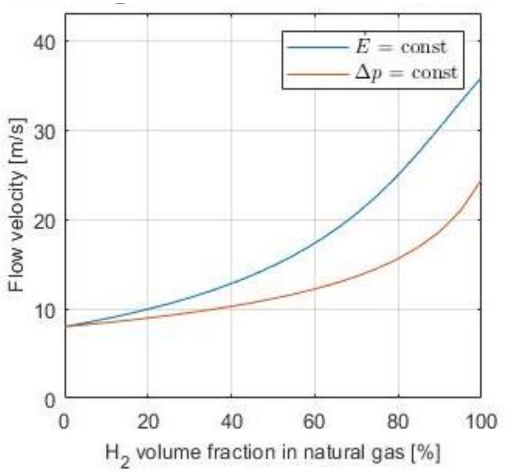
Transportable Energy



Compressor Power Ratio



Flow Velocity



Source: Klopčič, N.; Stöhr, T.; Grimmer, I.; Sartory, M.; Trattner, A. Refurbishment of Natural Gas Pipelines towards 100% Hydrogen -A Thermodynamic-Based Analysis. Energies 2022, 15, 9370

- ~80% der Energie von Erdgas kann mit H_2 übertragen werden (bei gleichem Δp)
- Strömungsgeschwindigkeit steigt um Faktor 3-4
- Höhere Strömungsgeschwindigkeit kompensiert die geringere Vol. Energiedichte von H_2
- Verdichterleistung steigt um Faktor >2 (bei gleichem Δp)
- H_2 Beimischung bis ~25% gangbar
- Verringertes Line Pack führt zu größerer Bedeutung von dezentralen Speicherungen

H_2 Gas quality: HyGrid Pilot Study

1995, MOP70

1972, MOP70

1965, MOP6

1980 , 2018 MOP70

H2 Quality in used Pipelines

Experimental determination of H2 quality in the Boltzmann Lab

What H2 quality can be achieved during transport in used high-pressure pipes?

- Strong influence of age, gas history, preparation
- Odorants are visible (ppb level!)
- Natural gas residues
- Higher HCs from solid deposits
- Grade A can easily be achieved

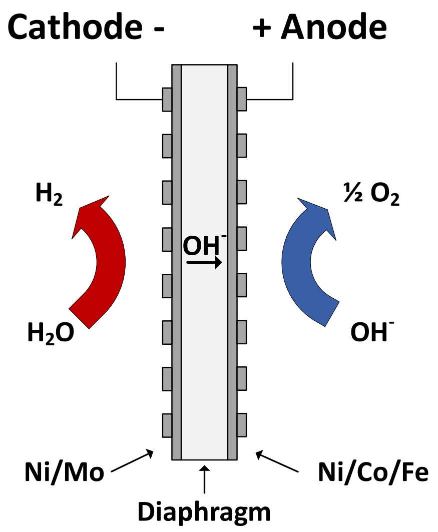
Investigated Pipeline Element No. 5

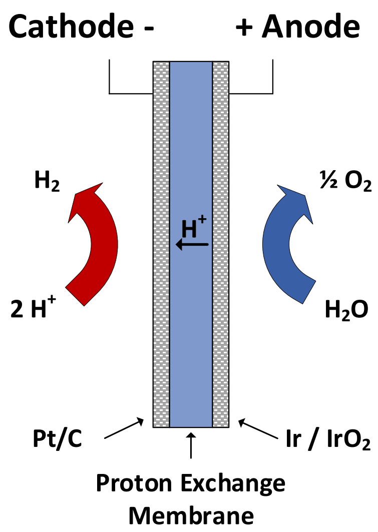
Measurement Setup at HyCentA Boltzmann Lab (IMR-MS, bottom right; FTIR, up right)

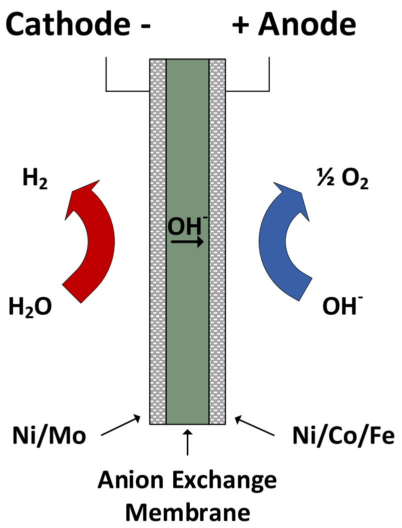
Source: Stöhr et. alt, Hydrogen Quality in used Natural Gas Pipelines, 2023, https://doi.org/10.1016/j.ijhydene.2023.09.305

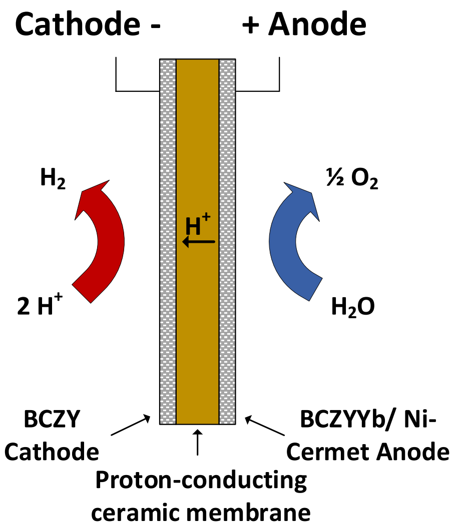
Electrolysis technologies

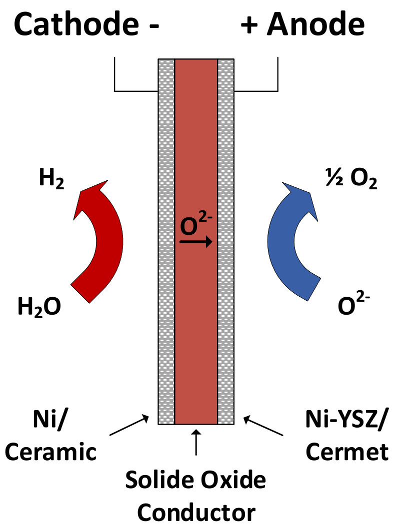
	AEL	PEM-EL	AEM-EL	PCC-EL	SO-EL
	Alkaline Electrolysis	Proton Exchange Membrane Electrolysis	Anion Exchange Membrane Electrolysis	Proton-Conducting Ceramics Electrolysis	Solid Oxide Electrolysis
Electrolyte	alkaline liquid	acidic solid	alkaline solid & liquid	H$^+$-conducting ceramic	O^{2-}-conducting ceramic











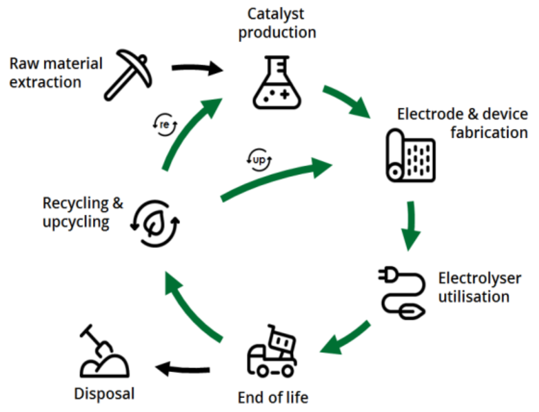
AEL	PEM-EL	AEM-EL	PCC-EL	SO-EL
70 - 95 °C	60 - 80 °C	40 - 80 °C	400 - 700 °C	700 - 1000 °C

PEMEC: Iridium - Project Recycalyse

RECYCALYSE aims to develop new electrocatalysts for PEM electrolyser systems with increased performance, reduced critical raw material usage, red. environmental footprint and red. total costs.

See more: Dr. Julia Melke et al., Recycalyse – New Sustainable and Recyclable Catalytic Materials for Proton Exchange Membrane Electrolysers, https://doi.org/10.1002/cite.202300143

- Process development for large scale recycling of the critical raw materials
- Application of sustainable materials derived from earth abundant elements
- Implementation of a circular economy in which the CRM will be recovered and regenerated
- Analysis of the entire value chain from catalyst manufacturing to system integration and demonstration, end-of-life recycling and supply of raw materials for the catalyst manufacturing



Raw material extraction

Catalyst production

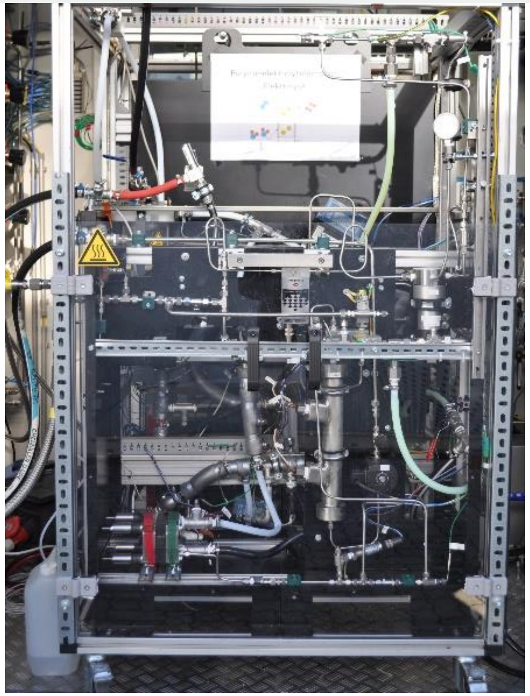
Electrode & device fabrication

Electrolyser utilisation

End of life

Disposal

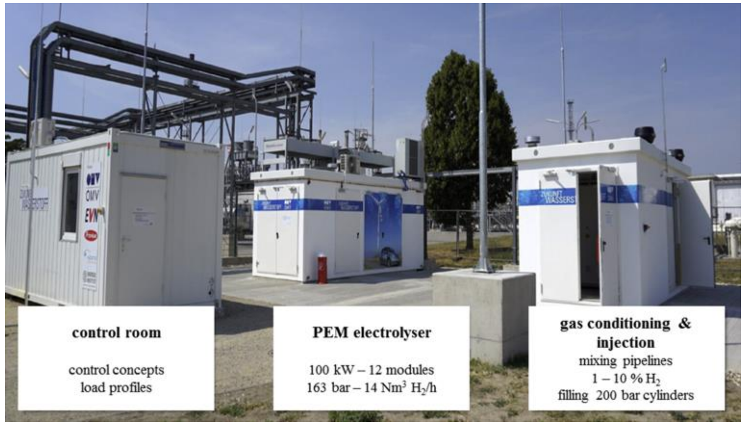
Recycling & upcycling

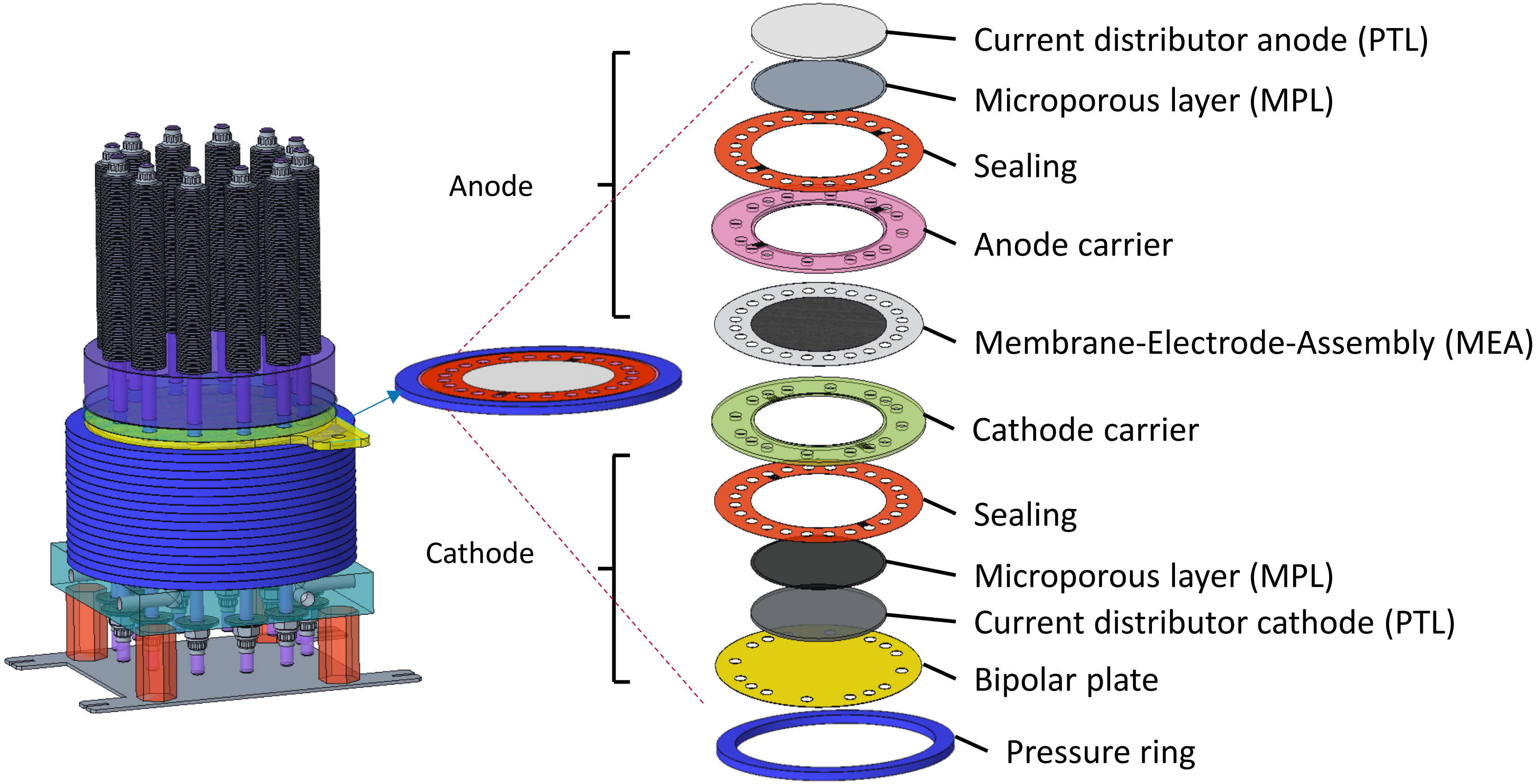


PEMEC: High Pressure

Wind2Hydrogen

163 bar HP-PEMEC





New Stack Development in COMET Programm

See more: Sartory, M., Wallnöfer-Ogris, E., Salman, P., Fellinger, T., Justl, M., Trattner, A., Klell, M.: “Theoretical and Experimental Analysis of an Asymmetric High Pressure PEM Water Electrolyser up to 155 bar”, International Journal of Hydrogen Energy, 2017. https://doi.org/10.1016/j.ijhydene.2017.10.112

AEMEC: low cost

1. Kosteneffizienz & Materialien

- Einsatz günstigerer Katalysatoren möglich (z. B. Nickel statt Platin)
  - ➢ Langlebige, stabile Membranen ohne teure Rohstoffe noch in Entwicklung

2. Skalierbarkeit & Integration

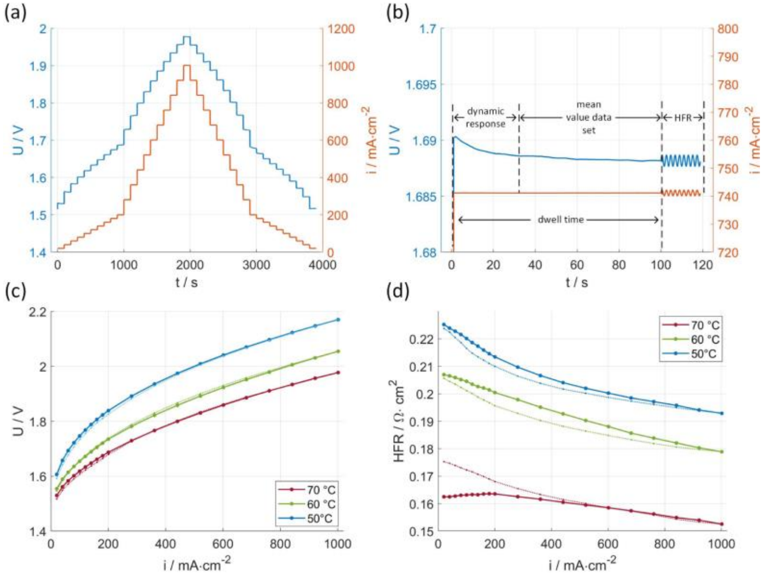
- Gute Eignung für dezentrale Anwendungen
  - ➢ Technische Standardisierung & Systemintegration noch ausbaufähig

3. Membranstabilität & Lebensdauer

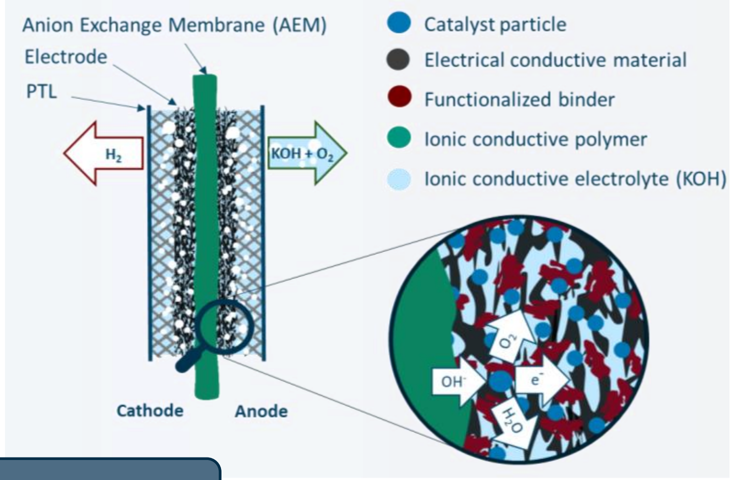
- Fortschritte bei chemisch beständigeren Polymeren
  - ➢ Aktuell geringere Lebensdauer im Vergleich zu etablierten Technologien

4. Wirkungsgrad & Betriebsführung

- Kombination der Vorteile von PEM und alkalischer Elektrolyse
  - ➢ Betriebsparameter noch nicht optimal für Langzeitanwendung



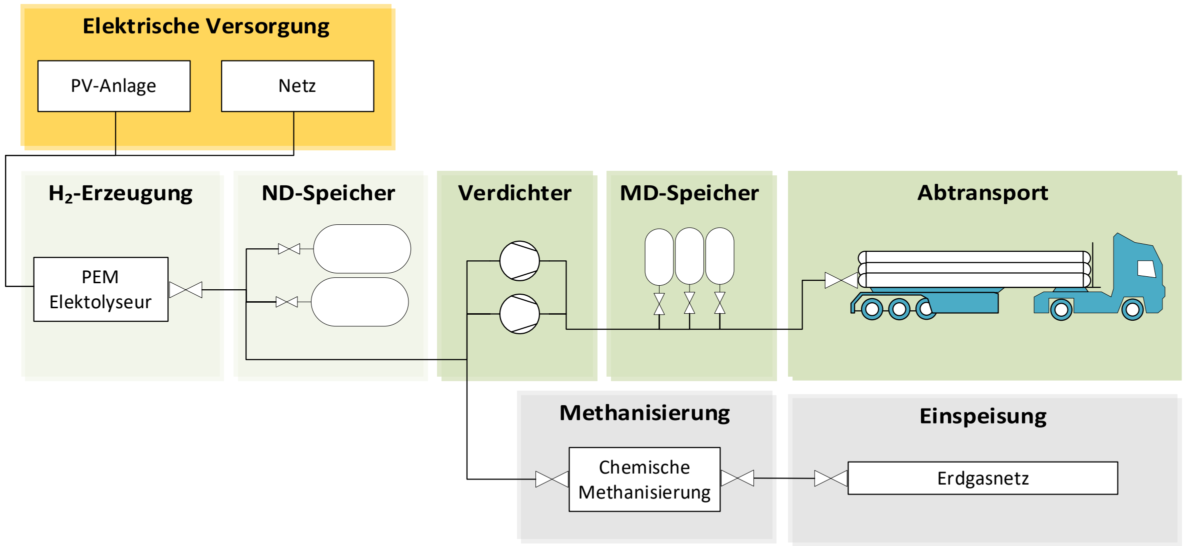
M. Ranz, B. Grabner, B. Schweighofer, H. Wegleiter, A. Trattner; Journal of Power Sources, 2024, https://doi.org/10.1016/j.jpowsour.2024.234455



New Development in COMET Programm

Decentral Production - Renewable Gasfield

- Production of green hydrogen by using electricity from a local photovoltaic plant
- 1 MW Power-to-Gas Plant (PEM-Electrolysis)
- Filling the produced hydrogen into trailer (on site) and transferred to Wolfram Bergbau und Hütten AG
- Demonstration of the load-flexible methanation process
- Production of green biomethane and storage in the existing natural gas grid



Elektrische Versorgung

PV-Anlage

Netz

H_2-Erzeugung

PEM Elektolyseur

ND-Speicher

Verdichter

MD-Speicher

Abtransport

Methanisierung

Chemische Methanisierung

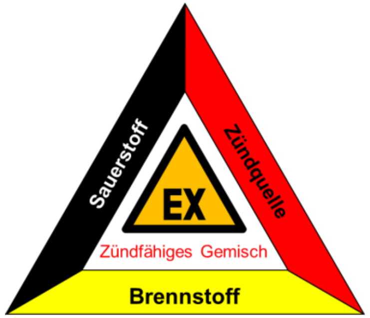
Einspeisung

Erdgasnetz

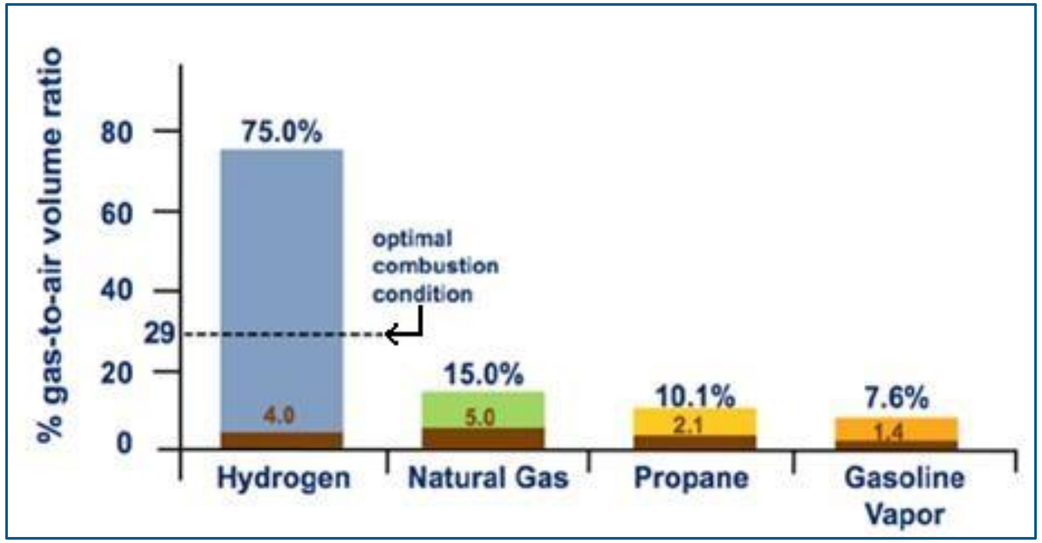
Ausgangssituation

Sicherheitsrelevante Eigenschaften Wasserstoff:

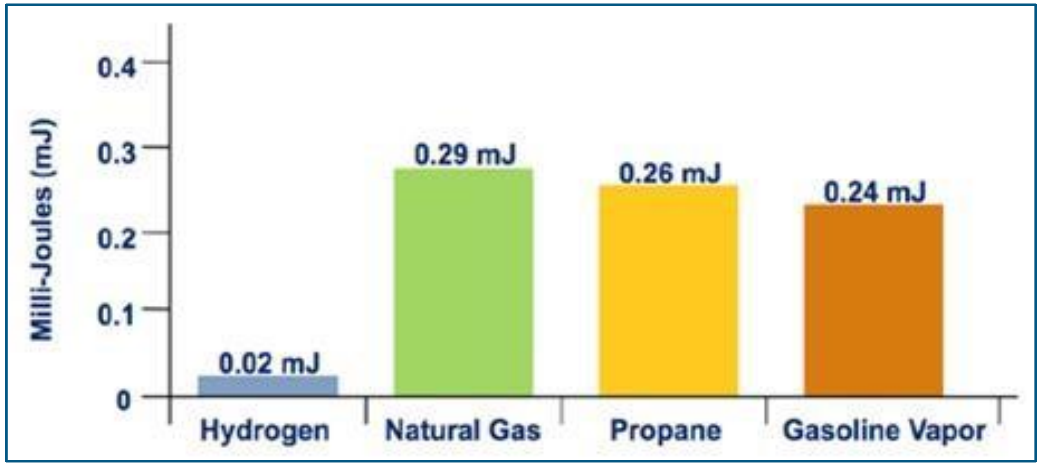
- Farbloses, geruchloses Gas
- Keine toxischen Effekte
- Geringste Dichte aller Gase
  (14-mal leichter als Luft)
- Hohe Diffusionsneigung
- Niedrige Schmelz- und Siedetemperatur
- Leicht entzündbar
- Bildet mit Luft in einem weitem Mischungsbereich zündfähige Gemische mit hoher Flammengeschwindigkeit und hoher Verbrennungstemperatur



- Kennzeichnung/Gefahrenhinweise Wasserstoff, verdichtet
  - H220: Extrem entzündbares Gas
  - H280: Enthält Gas unter Druck; kann bei Erwärmung explodieren



Explosionsfähige Atmosphären im Vergleich [1]



Zündenergien [2]

Quelle: [1] https://h2tools.org/hydrogen-compared-other-fuels
[2] Klell, Eichlseder, Trattner – Hydrogen in Automotive Engineering, 2023

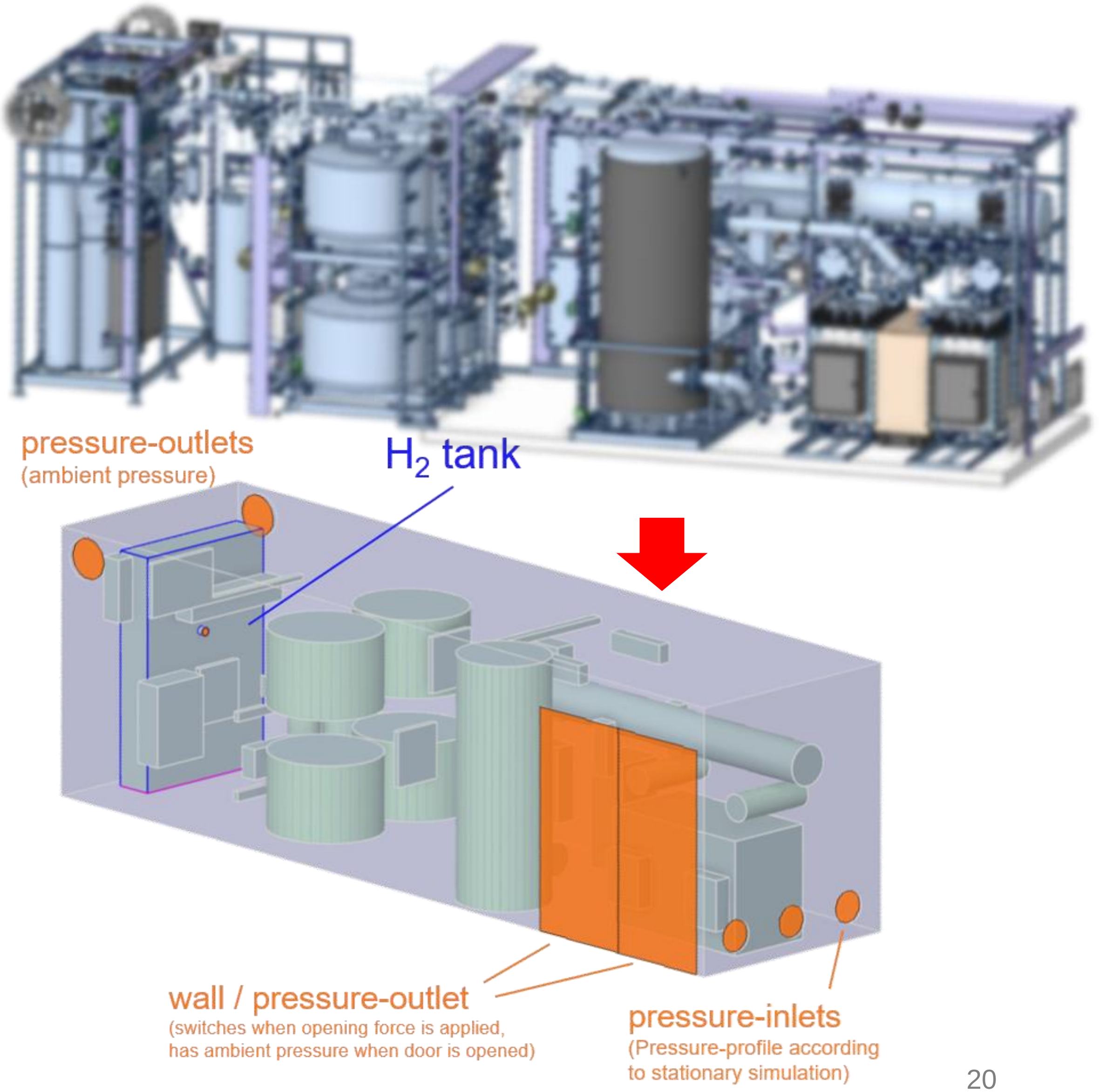
H_2-Austritt im Störfall

Evaluierung des Gefahrenpotentials eines 2,5MW Elektrolyseurs im Regelbetrieb

- Bewertung des Gefährdungspotentials aufgrund plötzlicher Wasserstoffleckage im Elektrolysebehälter
- Verteilung von Wasserstoff im Falle eines Rohrbruchs
- Wirksamkeit der Sicherheitsausrüstung und Überwachung
- Auswirkungen der Druckwelle
- Abschätzung der Explosionsintensität (TNT-Äquivalent)

Worst-Case-Scenario:

- System im Regelbetrieb, H2- Sensorik und Belüftung aktiv
- 35 bar aufgrund eines plötzlichen Wasserstofflecks (Rohrbruch ohne Rissbildung) mit 80 mm kreisrunder Bruchfläche
- 3kg H_2 max. Freisetzungspotential treten aus



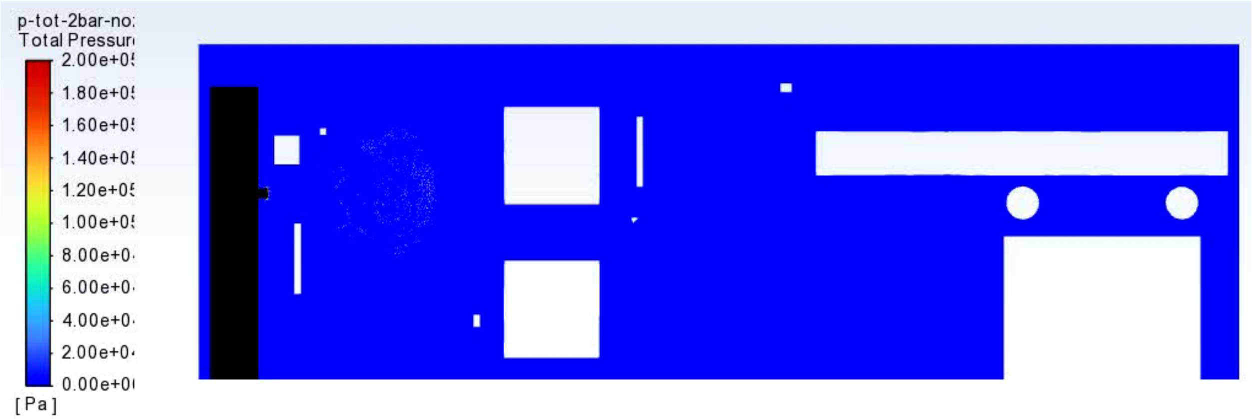
H_2-Austritt im Störfall

- Stationäre Belüftung kann die Bildung eines Ex-Gemischs nicht verhindern
- 65% des gesamten H_2-Freisetzungspotentials als Ex-Gemisch im Raum
- Explosion höchst wahrscheinlich
- Dabei wird Container deformiert aber nicht zerstört
- Druckwelle öffnet Explosionsklappen am Elektrolyse-Container und tritt durch diesen hindurch
- Druckwelle schleudert die Türen auf und kann Personen verletzen

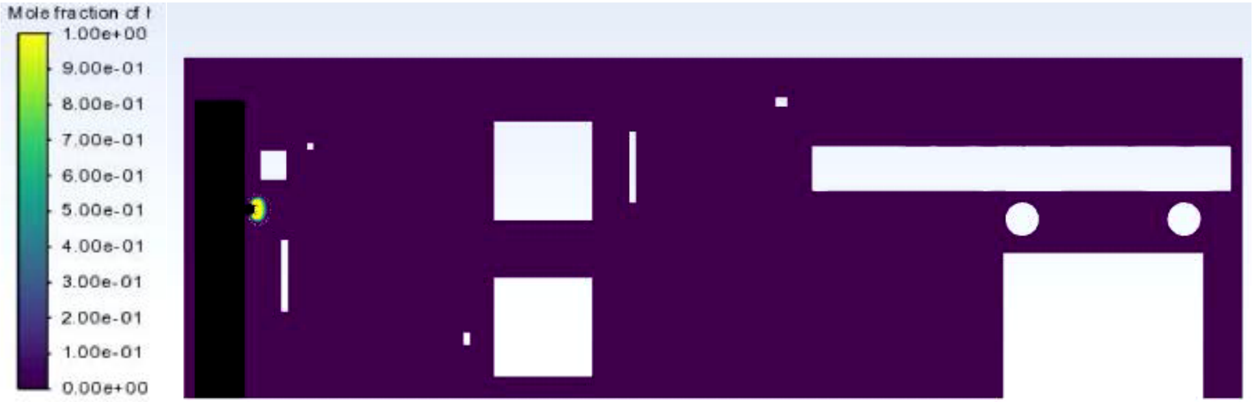
Kernergebnisse:

- Mindestabstände zwischen Elektrolyseuren angepasst
- Zugangsbeschränkung bei Produktion

Druckwelle

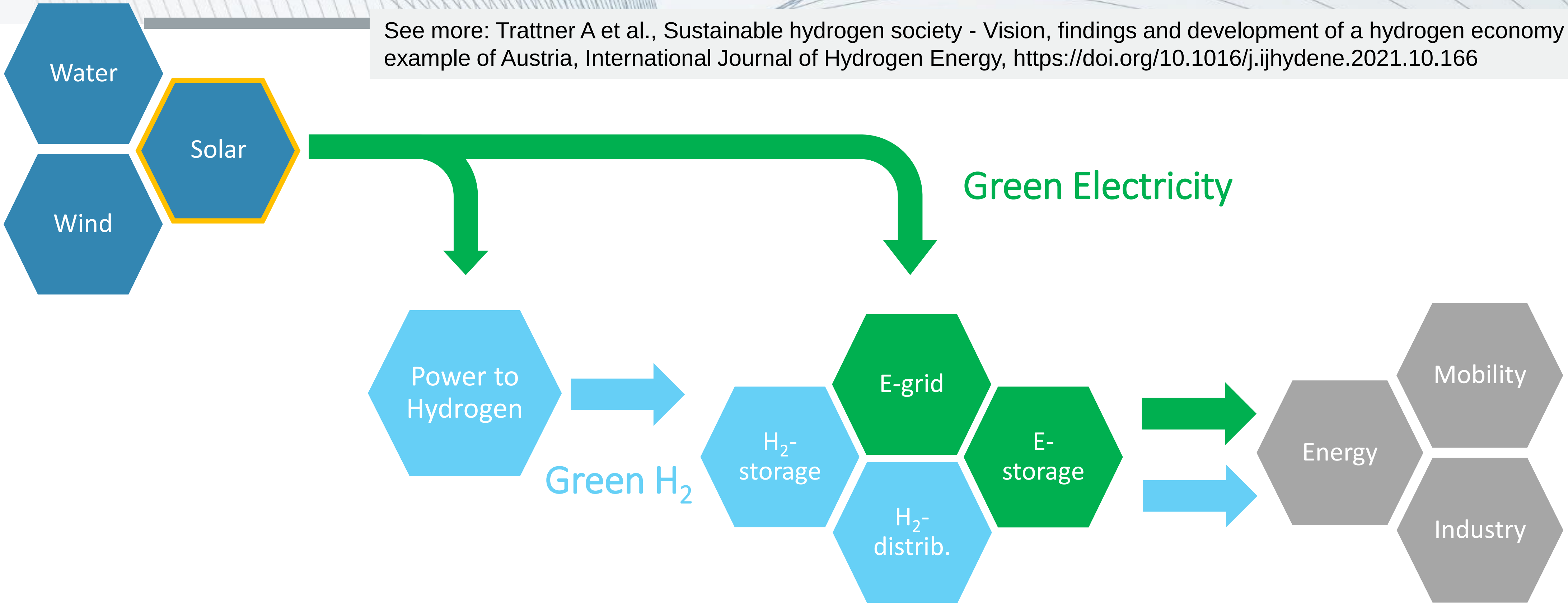


H_2 Ausbreitung im Raum



Hydrogen – a Key to the Energy Transition

See more: Trattner A et al., Sustainable hydrogen society - Vision, findings and development of a hydrogen economy using the example of Austria, International Journal of Hydrogen Energy, https://doi.org/10.1016/j.ijhydene.2021.10.166



Integration of renewables
- Integrate production surpluses
- Direct water splitting

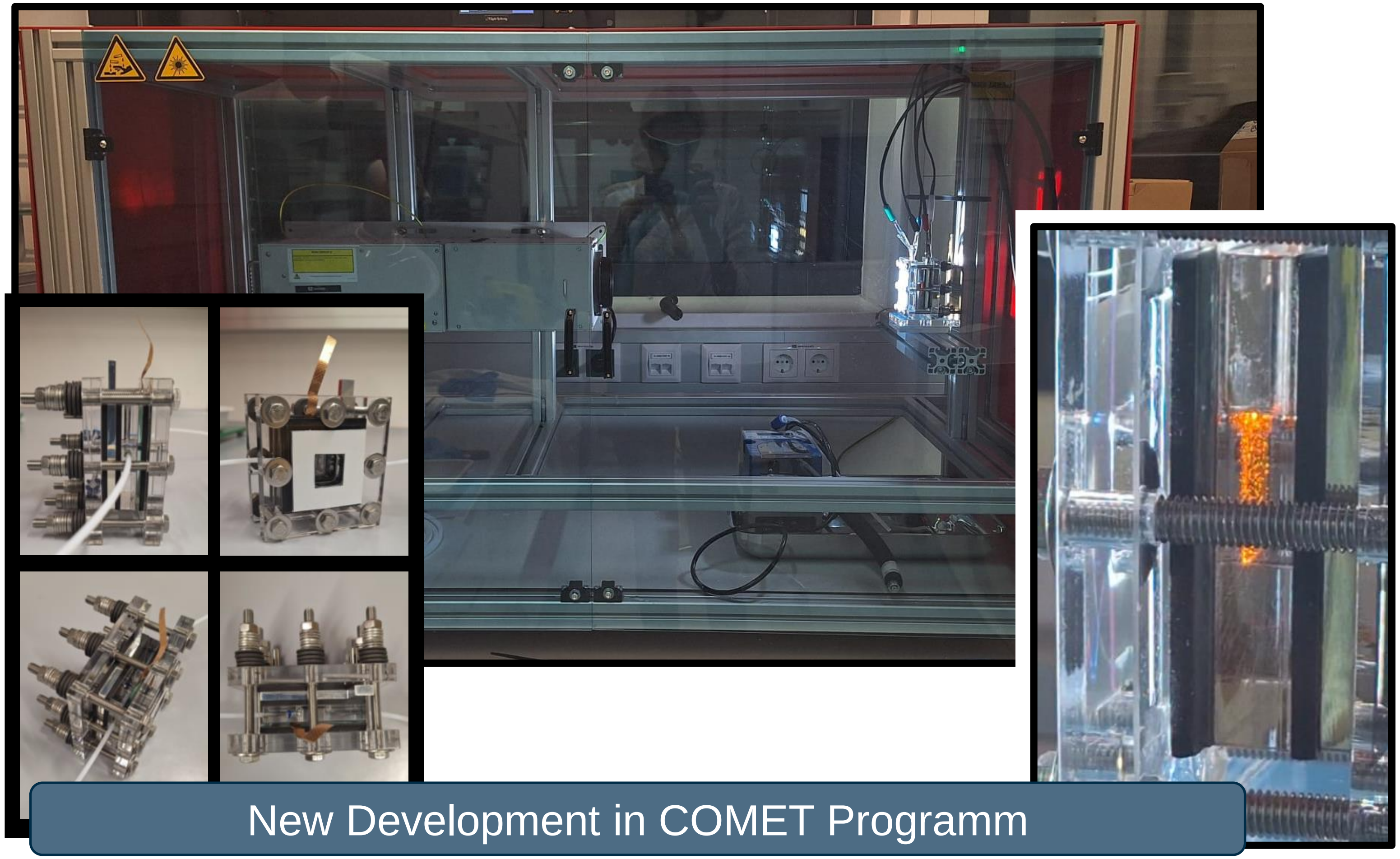
Energy conversion
- Electrolysis - compensate temporal volatility
- H2 as secondary energy carrier – energy storage

Storage and distribution
- Centralized and decentralized storage
- Long-term storage
- Efficient transport over long distances

Zero Emission Usage
- Energy Services – CHP
- Mobility with Fuel cells
- Industry and high-temperature processes

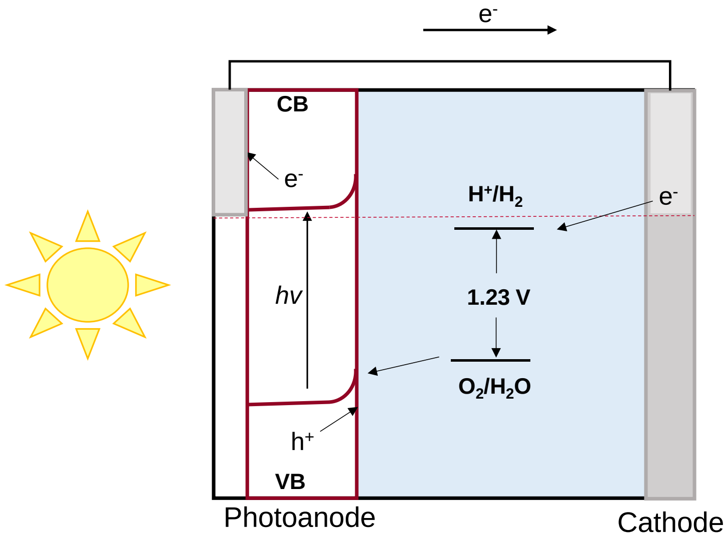
PEC – photoelectrochemical water splitting

PEC prototype and test rig



New Development in COMET Programm

Jonas Wolfsberger, Sarah Holler, Sarah Kurakin, Illena Grimmer and Marie Macherhammer



Hisatomi, T.; Kubota, J.; Kazunari Domen, K.; Recent advances in semiconductors for photocatalytic and photoelectrochemical water splitting. *Chem. Soc. Rev.*, **2014**, 43, 7520-7535; DOI: 10.1039/c3cs60378d
Lin, Y.-C.; Wyżga, P.; Macyk, J.; Macyk, W.; Guzik, M. N. Solar-driven (photo)electrochemical devices for green hydrogen production and storage: Working principles and design. *Journal of Energy Storage* **2024,** *82*, 110484. DOI: 10.1016/j.est.2024.110484.
Jiang, C.; Moniz, S. J. A.; Wang, A.; Zhang, T.; Tang, J. Photoelectrochemical devices for solar water splitting - materials and challenges. Chemical Society reviews 2017, 46 (15), 4645–4660. DOI: 10.1039/c6cs00306k.

Bundesministerium
Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie

Bundesministerium
Arbeit und Wirtschaft

FFG
Forschung wirkt.

Das Land
Steiermark
Wirtschaft, Tourismus,
Wissenschaft und Forschung

SFG
NEUES DENKEN. NEUES FÖRDERN.

ober
österreich

UAR INNOVATION NETWORK

Stadt
Wien

wirtschafts
agentur
wien

LAND
TIROL

Contact

HyCentA Research GmbH

Inffeldgasse 15

A-8010 Graz

Phone: +43 316 873 9500

office@hycenta.at

www.hycenta.at

TU
Graz

HyCentA
HYDROGEN CENTER AUSTRIA

HyCentA
HYDROGEN CENTER AUSTRIA

TU Graz

Bundesministerium
Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie

Bundesministerium
Arbeit und Wirtschaft

Das Land
Steiermark
Wirtschaft, Tourismus,
Wissenschaft und Forschung

Stadt
Wien

wirtschafts
agentur
wien

UAR INNOVATION
NETWORK

SFG
NEUES DENKEN. NEUES FÖRDERN.

FFG
Forschung wirkt.

ober
österreich

LAND
TIROL