Electrolysis / eFuels

Pathways to synthetic eFuels

Karl-Josef Kuhn, Siemens Energy

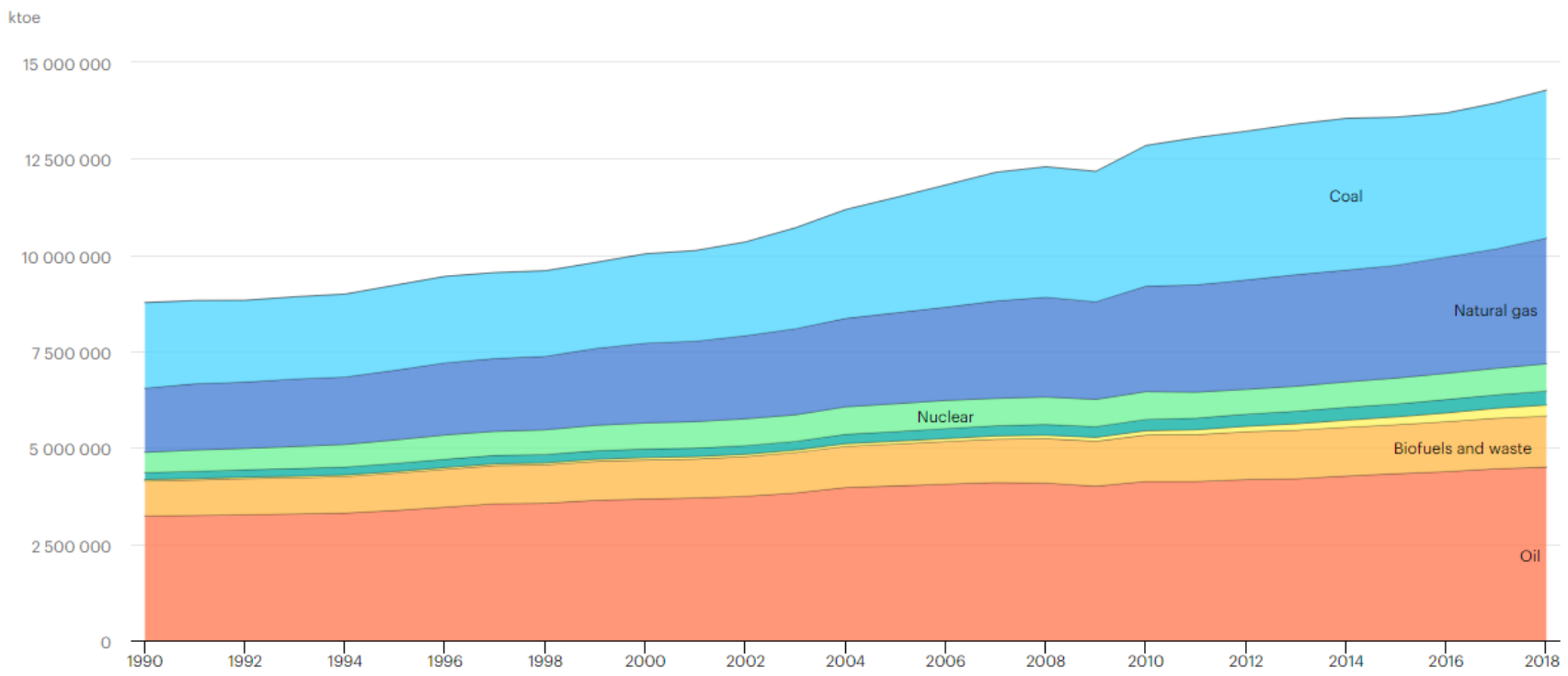
Renewables are playing a minor role in the global energy supply

Energy topic ⓘ
Energy supply

Indicator ⓘ
Total energy supply (TES) by source

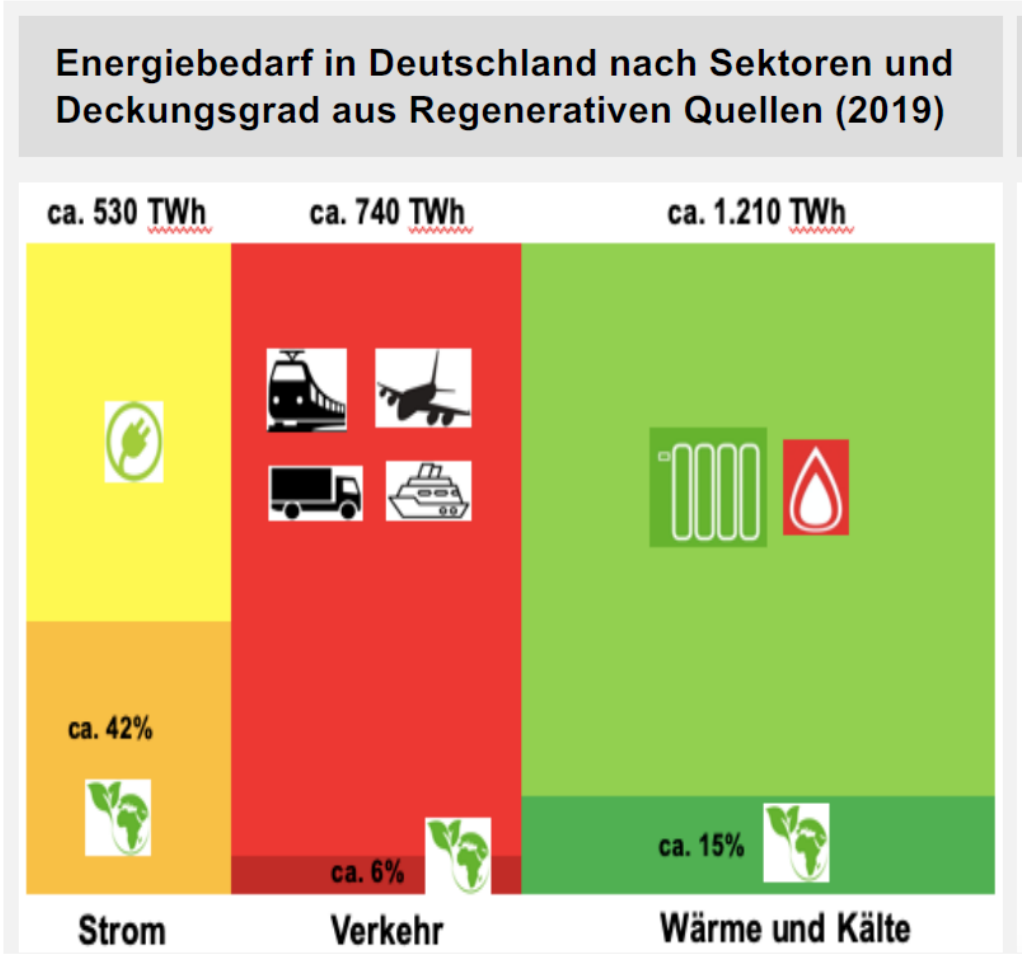
Country or region
World

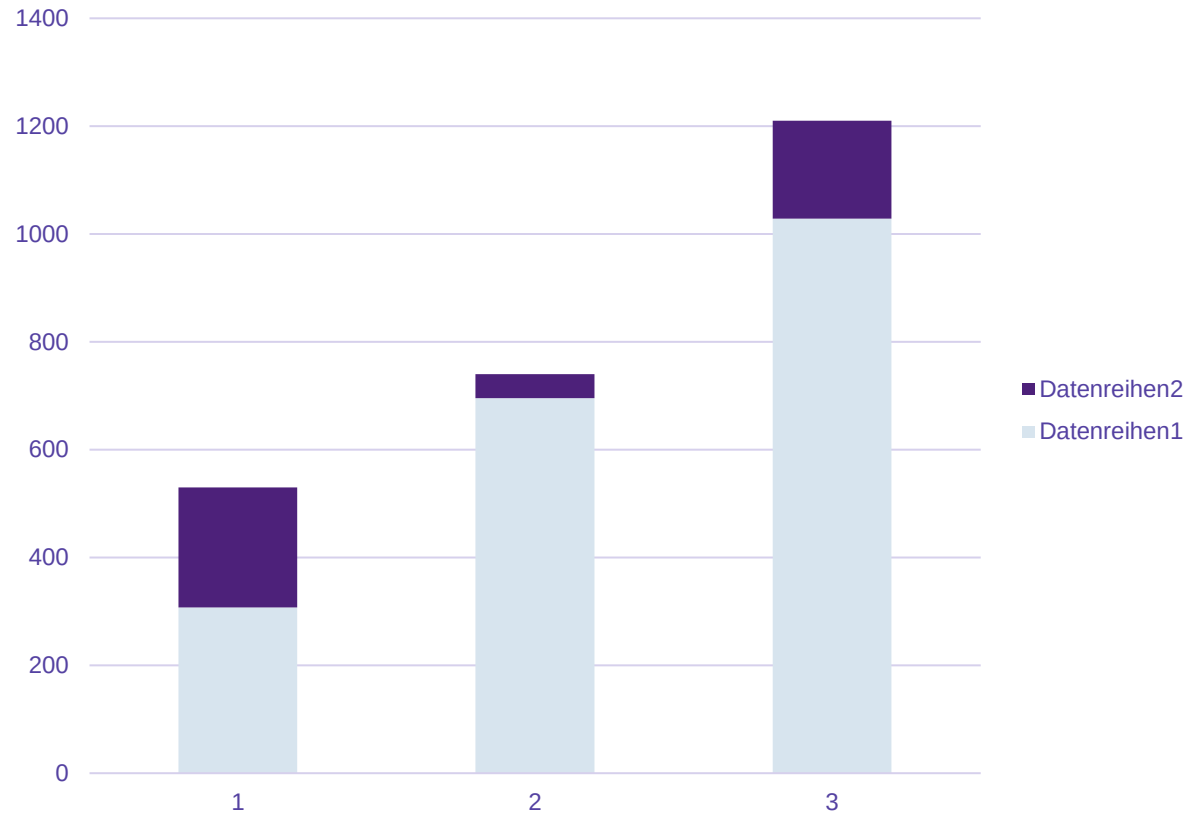
Total energy supply (TES) by source, World 1990-2018



Coal · Natural gas · Nuclear · Hydro · Wind, solar, etc. · Biofuels and waste · Oil

Even developed countries are not really GREEN
Energy Supply of Germany still about 82% Fossil



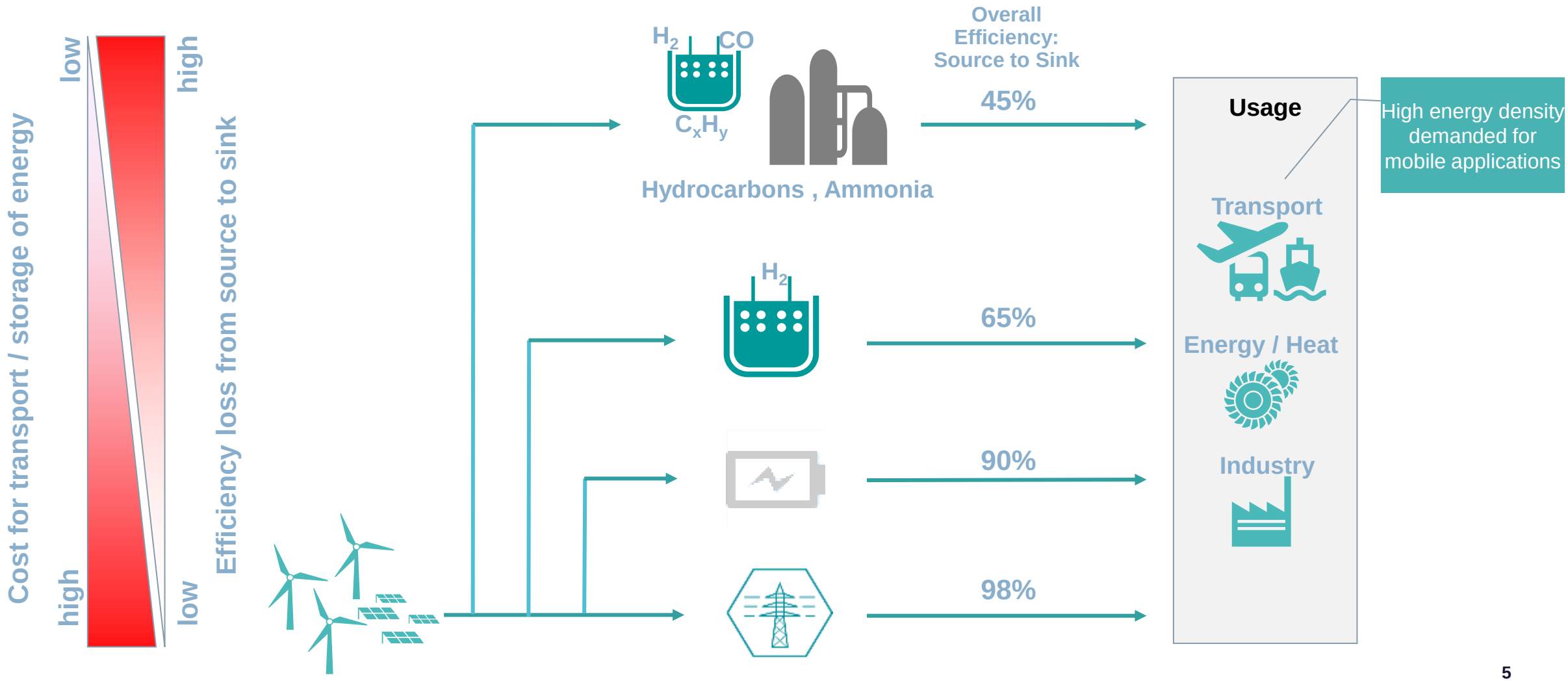


Quelle: Dr. Jörg Fabri, ÖGEW Vortrag 13.11.2020, Umweltbundesamt 2019

Various countries demonstrate strong potential for PtX production / exports …

Source: Frontier Economics

Direct electricity use is most efficient but electricity has highest cost for transport/storage and is not suited for all applications



9000HL: How much H2 onsite storage is needed?

1 HOUR
= 4km
1.4m pipeline

1 DAY
=
4x

1 WEEK
=
9x

1 MONTH
= 2,500km
1.4m pipeline

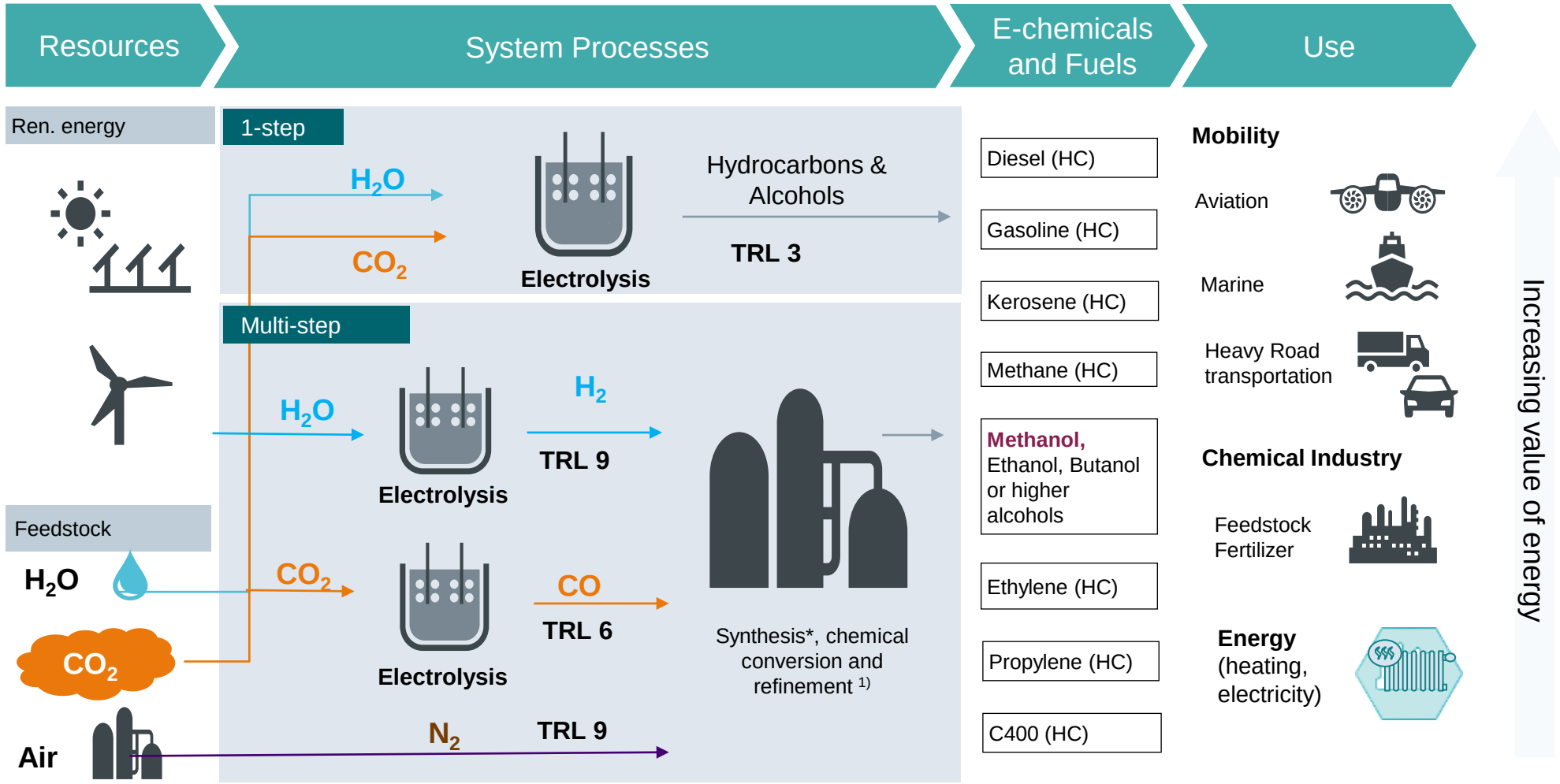
41.5
tons H_2/hr

870 MW*
63% eff
*CCGT

Assumptions: Tube trailer = 500 kg H_2, Pipeline[1]: 1.4 Diameter pipeline at 100 bar (12 ton H_2/km), NASA Spherical Liquid Cryogenic Tank[1]: 230 tons H_2, Teeside Salt Caverns[2] 810 tons (210,000 m^3 at 45 bar)

1. J. Andersson and S. Gronkvist, “Large-scale storage of hydrogen,” *International Journal of Hydrogen Energy,* vol. 44, pp. 11901-11919, 2019.
2. E. Wolf. “Large-scale hydrogen energy storage,” J. Garche (Ed.), *Electrochemical energy storage for renewable sources and grid balancing*, Elsevier, Amsterdam (2015), pp. 129-142

Siemens Energy active on several routes towards green synthetic fuels

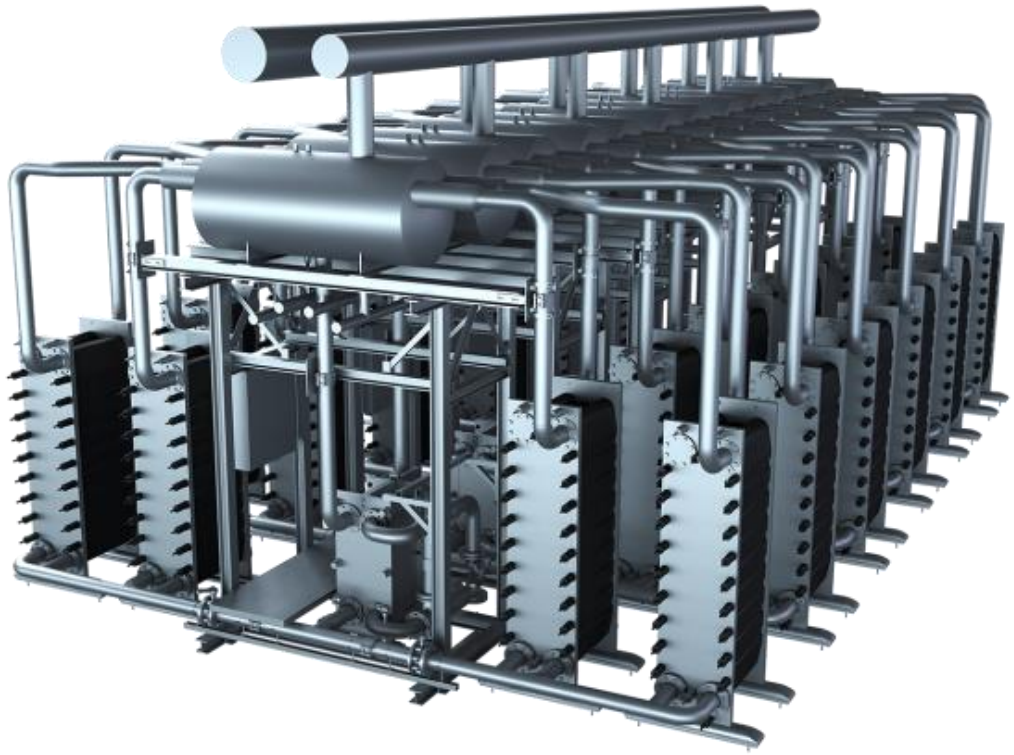


TRL: Technology readiness level * (Fischer-Tropsch, Sabatier, Methanol, Fermentation, Haber-Bosch …) 1) DME/OME-synthesis, olefin-synthesis, oligomerization, hydrotreating,…

Silyzer 300 – the next paradigm in PEM electrolysis

17.5 MW	Power demand per full Module Array (24 modules)
75 %	System efficiency[1] (higher heating value)
24 modules	to build a full Module Array
340 kg	hydrogen per hour per full Module Array (24 modules)

[1] Ambient temperature 15ºC, air cooled



Silyzer 300 – Module Array (24 modules)

Silyzer 300 – latest and most powerful product line in the double-digit megawatt class

High performance

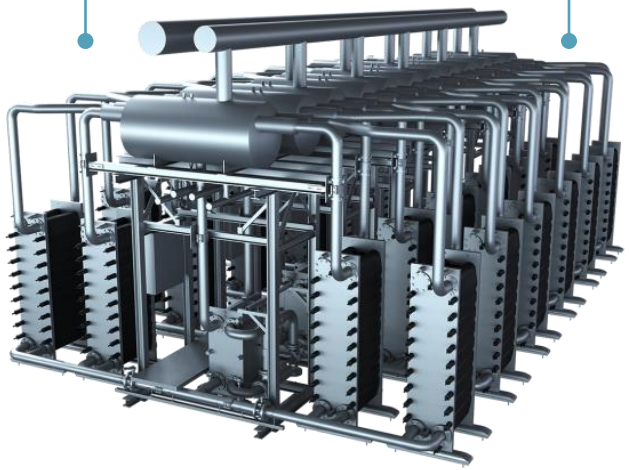
High efficiency: system >75%
Modular: H_2 production range 100-2,000 kg/h

Maintenance friendly

Maintenance free module 80,000 OH[1]
Easy exchange of modules
No cleaning effort
World wide service coverage

Digitally enabled

Data Driven Operation and Service
Secure Remote Support
Mindsphere



High availability

Advanced design for low degradation
Robust industrial design

Flexible operation

Fast start-up and shut-down
High dynamics
High Gas purity
No Ex-zone within PEM Array
No hazardous chemicals
Power factor compensation
No permanent operating personnel required

[1] Operating Hours

H2FUTURE – a European Flagship project for generation and use of green hydrogen

6 MW

Power demand based on Silyzer 300

1.200 Nm³

of green hydrogen per hour

Project

- Partner: VERBUND (coordination), voestalpine, Austrian Power Grid (APG), TNO, K1-MET
- Country: Austria
- Installed: 2019
- Product: Silyzer 300

Use cases

Hydrogen for the steel making process

Supply grid services

Challenge

- Potential for “breakthrough” steelmaking technologies which replace carbon by green hydrogen as basis for further upscaling to industrial dimensions
- Installation and integration into an existing coke oven gas pipeline at the steel plant
- High electrolysis system efficiency of 80%

Solutions

- Operation of a 12-module array Silyzer 300
- Highly dynamic power consumption – enabling grid services
- State-of-the-art process control technology based on SIMATIC PCS 7

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 735503. This Joint Undertaking receives support from the European Union‘s Horizon 2020 research and innovative programme and Hydrogen Europe and NERGHY.

Our Electrolyzer portfolio scales up by factor 10 every few years
Product portfolio and technical specification

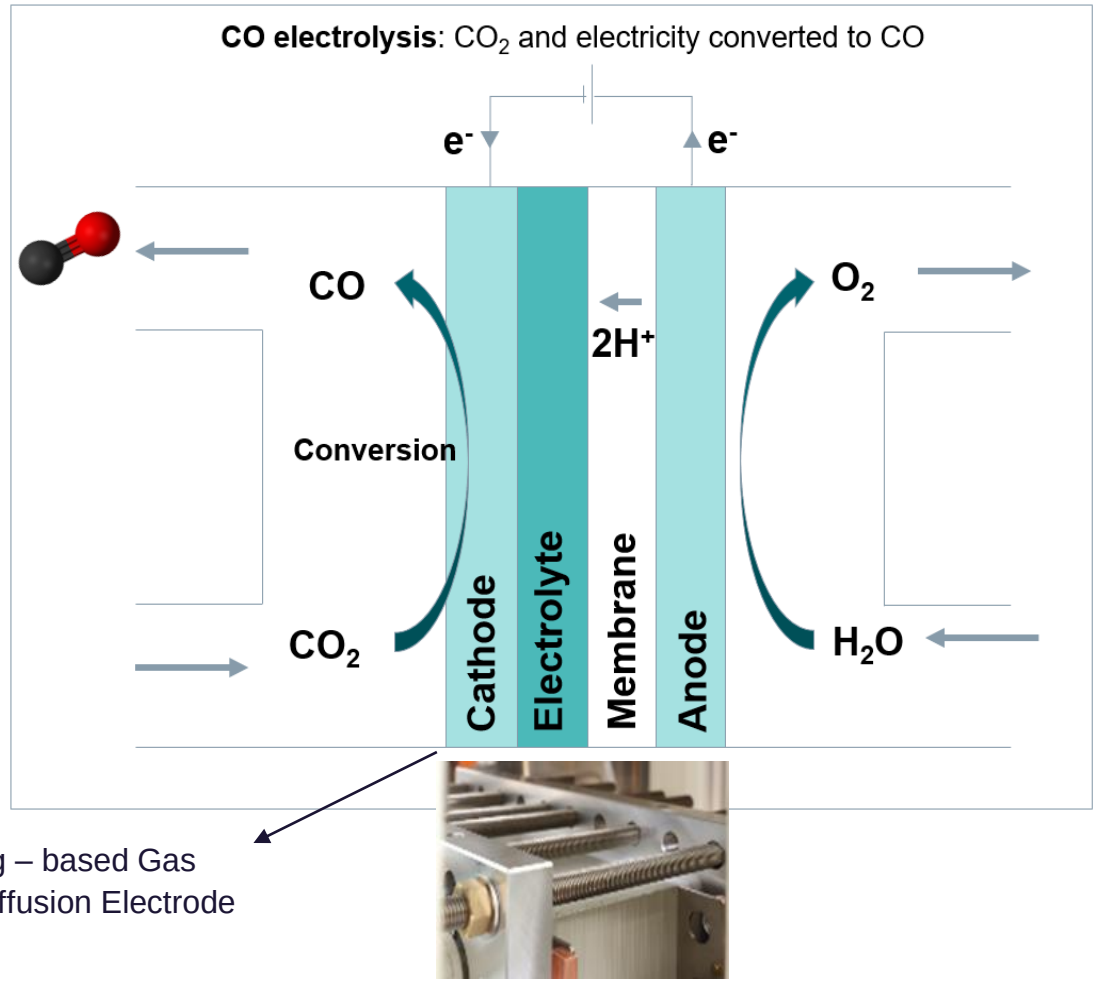
SIEMENS energy

2011	2015	2020	2022	2025+
Silyzer 100 Lab-scale demo ~4,500 OH[1)] ~150k Nm³ of H_2	**Silyzer 200** 1.25 MW, 65%[2)], 35 bar cur. density 1.6 A/cm² ~86,500 OH[1)] ~7.3 mil. Nm³ of H_2 	**Silyzer 300** 10-100 MW, 75%[2)], cur. density 1.5 A/cm², atm. pilot plant Linz in operation 	**Silyzer 300p** 8-100 MW, 70-75%[2)], cur. density 2 A/cm², 6-10 bar[3)] 	**Future Portfolio** PEM for industrial scale 

Next Generation
under development

1) Operating Hours; Data OH & Nm³ as of Dec. 2019
2) System efficiency
3) Target range for development

NexGen Electrolysis: direct electroreduction of CO2 for carbon neutral production of CO, chemicals and syn fuels



$CO_2 \rightarrow CO + ½ O_2$

CO Electrolysis

- Use of CO2 and electricity from renewables as feedstock in the production of CO for direct use and CO as an intermediate towards chemicals and synthetic fuels

Benefits

- Zero emission technology
- Excellent scalability to customer demand
- Scale-up to very high volume applications
- Resolves CO supply chain restrictions resulting from CO transport and storage regulations ➢ Decentralized on-site CO production

CO Electrolyzer delivered to Evonik

➢ Project Rheticus

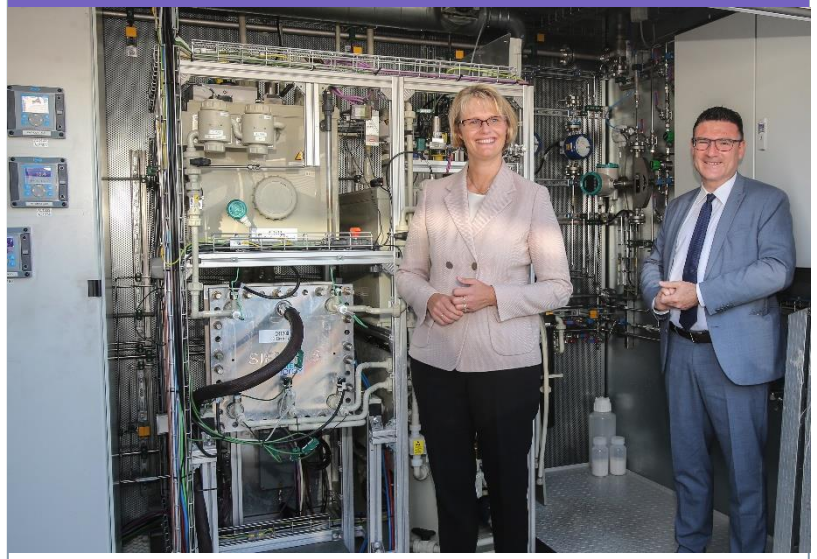
Rheticus: BMBF[1)] funded project between Siemens Energy & Evonik for the production of butanol and hexanol.

- Electrochemical conversion of carbon dioxide into carbon monoxide
  - ➢ Carbon dioxide turns from greenhouse gas into feedstock
- Microorganisms are used to produce specialty chemicals
- Target for future applications: Synthetic fuels and bulk chemicals

2.5 kW power consumption of CO_2 to CO electrolyzer for the production of ~0.3kg CO/h

1) BMBF: Bundesministerium für Bildung und Forschung

The world's first fully automated CO electrolyzer from Siemens Energy



Federal Research Minister Anja Karliczek said on the occasion of the commissioning in Marl: "I am delighted that we have given the go-ahead today in Marl for a new test facility at the very highest level" … "

CO Electrolyzer Roadmap

2 ➢ **Synthetic fuels**

1 ➢ **From specialty to bulk chemicals & industrial gases**

Active area / cell
300 cm²

➲ **Scale-up**

mid 2020 ✓

2.5 kW
Specialty Chemicals
Siemens Energy – EVONIK INDUSTRIES
BMBF funded project **Rheticus**

Active area / cell
>3000 cm²

end 2020

3 – 5 kW
Pilot operational
@ Campus Erlangen
Application: 0.5 – 10 MW

➲ **Commercialization**

2026

0.5 – 1 MW
1st industrial application
Customer Pilot
Chemicals / Industrial Gases

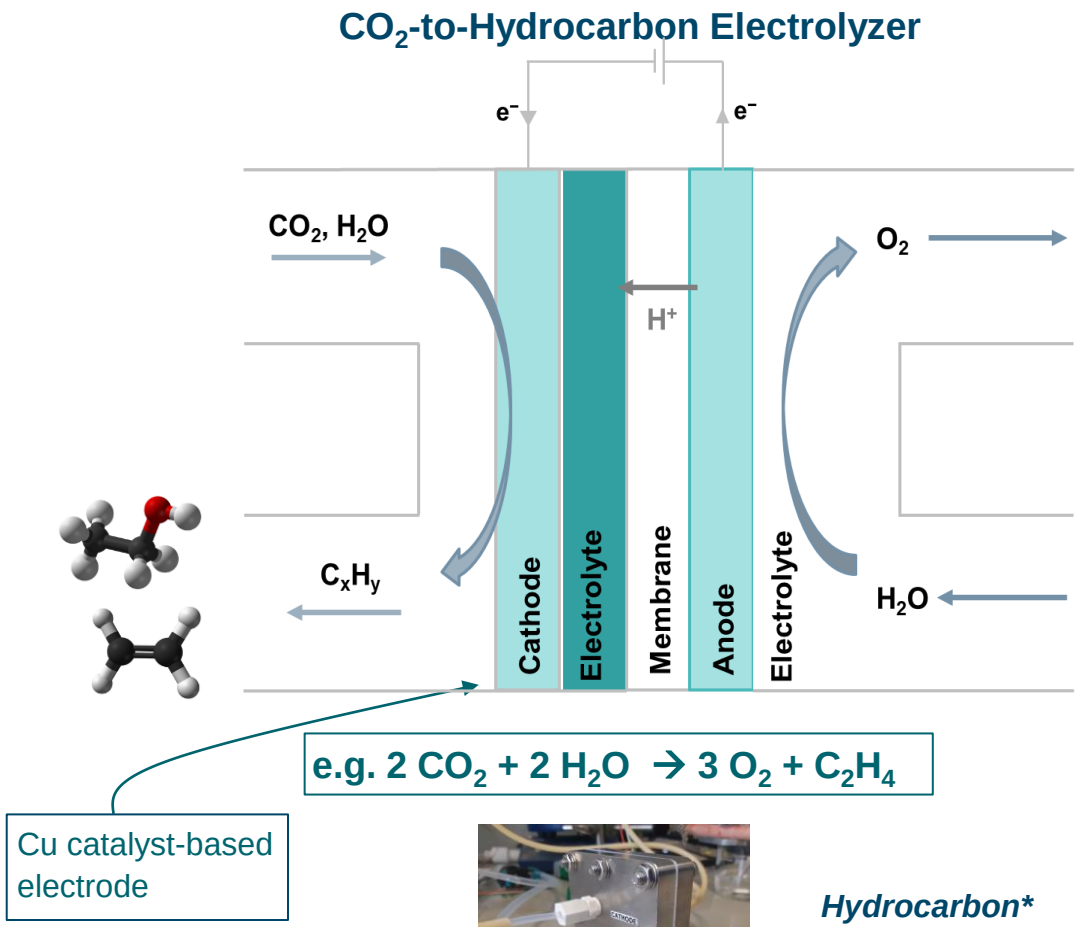
Active area / cell
>>3000 cm²

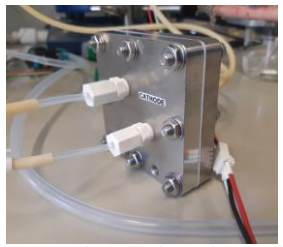
2030

X0 – x00 MW
Start concept phase
for CO electrolysis in
GTL plants

Transforming the CO electrolyzer into a CO_2 to HC (fuel precursor) electrolyzer by exchange of catalyst

SIEMENS energy





Hydrocarbon* Electrolyzer Lab Cell

Business Opportunity

- Use of CO_2, H_2O and renewable energy as feedstock for electrocatalytic synthesis of hydrocarbons to be used as CO_2-neutral base chemicals or fuels.

Benefits

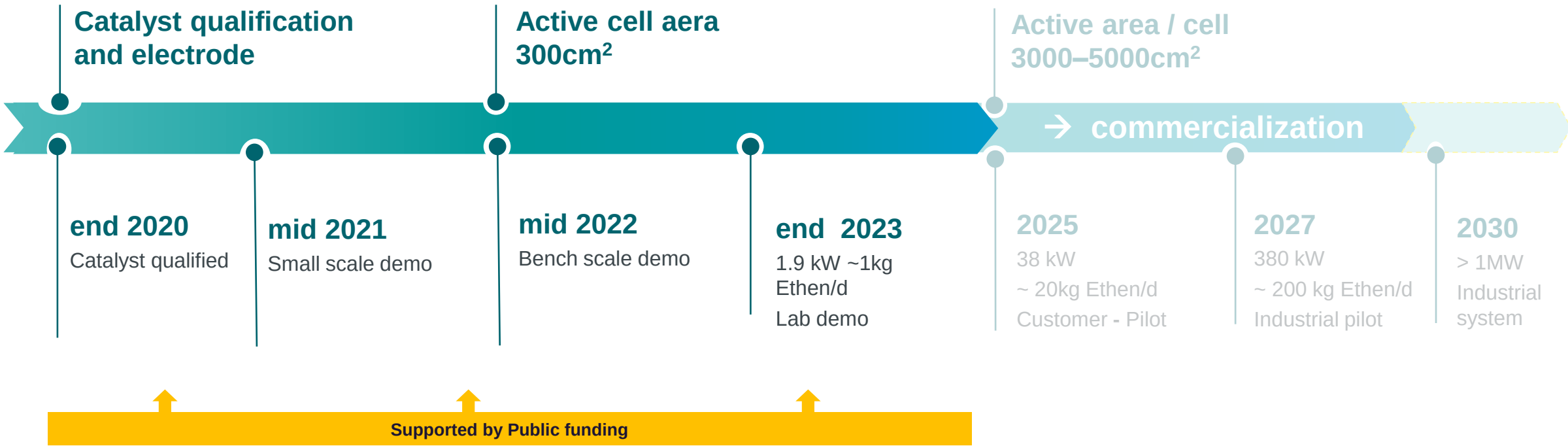
- Low temperature process with potential attractive energy efficiency
- Environmentally friendly, zero-emission technology
- Potential to disrupt thermo-catalytic chemical processes
- Strong synergies to CO electrolysis

Achievements:

- First lab test cell running (> 168h)
- Current achieved FE > 70% (HC & Alcohols)

Hydrocarbon Electrolyzer (Ethylene / Ethanol)

➢ Roadmap and Potential



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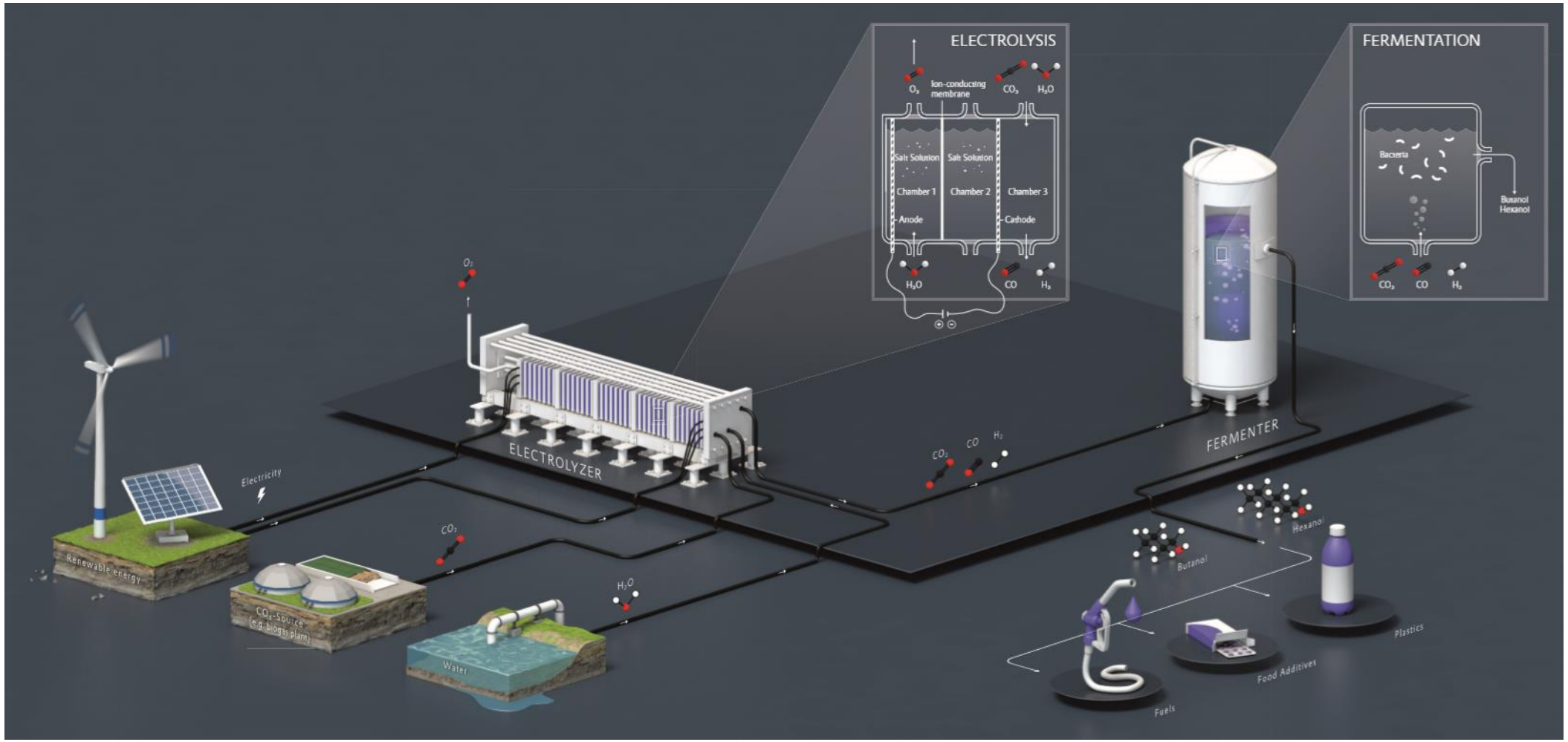

Additional links

Siemens Energy Magazine (Video included):
https://www.siemens-energy.com/global/en/news/magazine/2020/rheticus-worlds-first-automated-co2-electrolyzer.html

German Federal Ministry for Research
https://www.bmbf.de/de/fuer-eine-klimafreundliche-industrie-kohlendioxid-und-wasserstoff-als-rohstoffe-fuer-12543.html

Nature Video on Youtube:
https://www.youtube.com/watch?v=VK-dULEK-rc&list=ULaV07hCF7-AQ&index=81