

Industrial Applications for Green Hydrogen

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VDMA Power-to-X for Applications

The VDMA in a nutshell

- **125 years of experience – founded in 1892**
- **36 sector associations – from agricultural to woodworking machinery**
- **Foreign and domestic subsidiaries, working groups, forums, competence centers, research associations, service companies.**

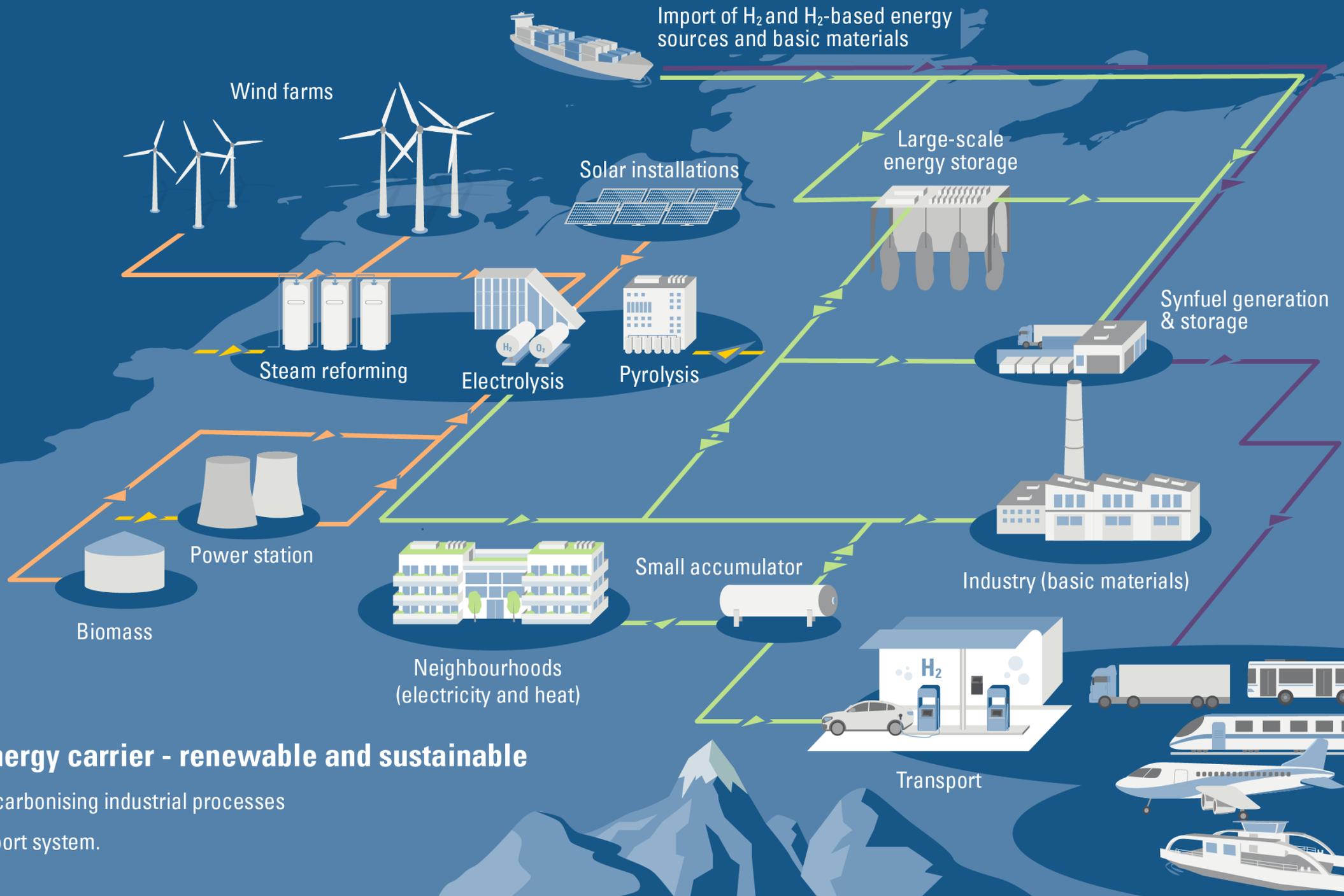
With more than 3,300 members, the Mechanical Engineering Industry Association is the largest network organization and important voice for mechanical engineering in Germany and Europe. The association represents the common economic, technical and scientific interests of this unique and diverse industry. More than 500 VDMA employees worldwide support you with practical services to make the right decisions in your company - along the entire value chain.

Power-to-X for Applications

170+ members from the complete value chain



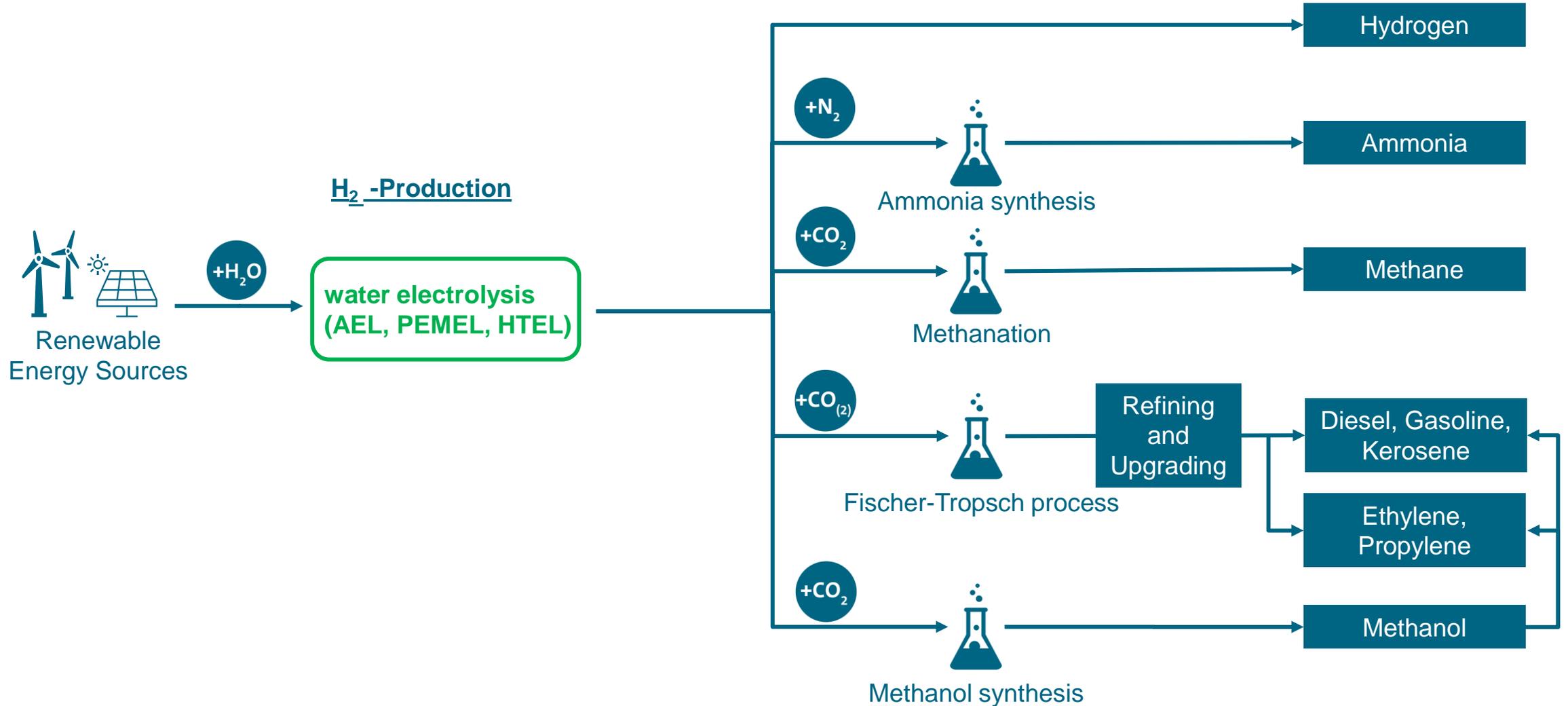
- Power grid
- H₂
- Fossil energies
- Synfuel



Hydrogen as an energy carrier - renewable and sustainable

Hydrogen is the key to decarbonising industrial processes and the energy and transport system.

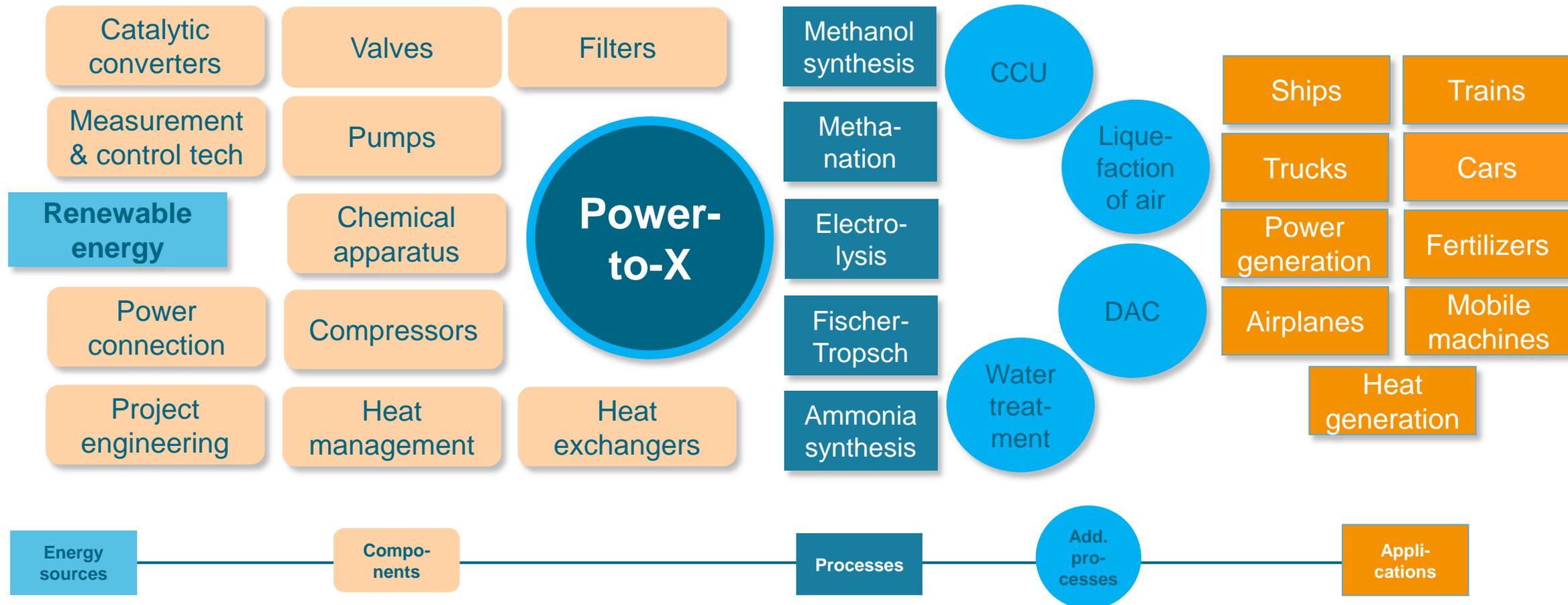
Power-to-X Production and Products



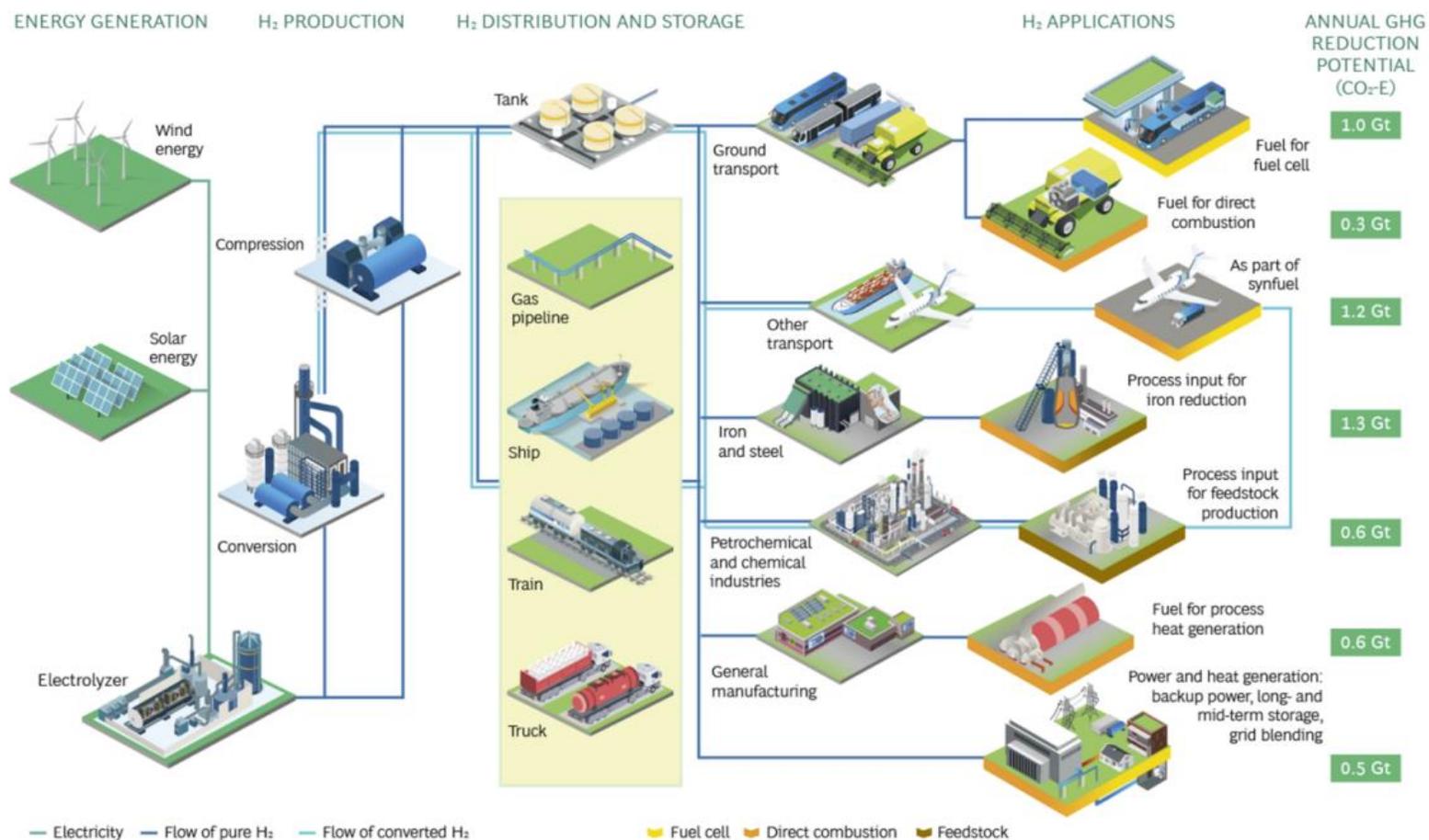
Power-to-X has a long value chain – European SMEs are leading



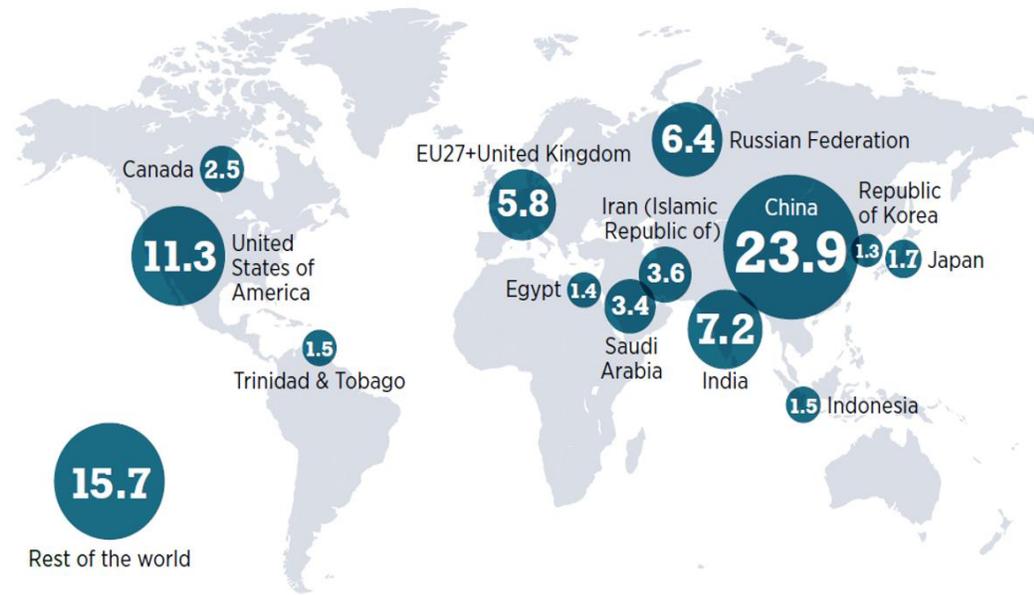
The PtX eco system



The Green Hydrogen Ecosystem offers major GHG reductions

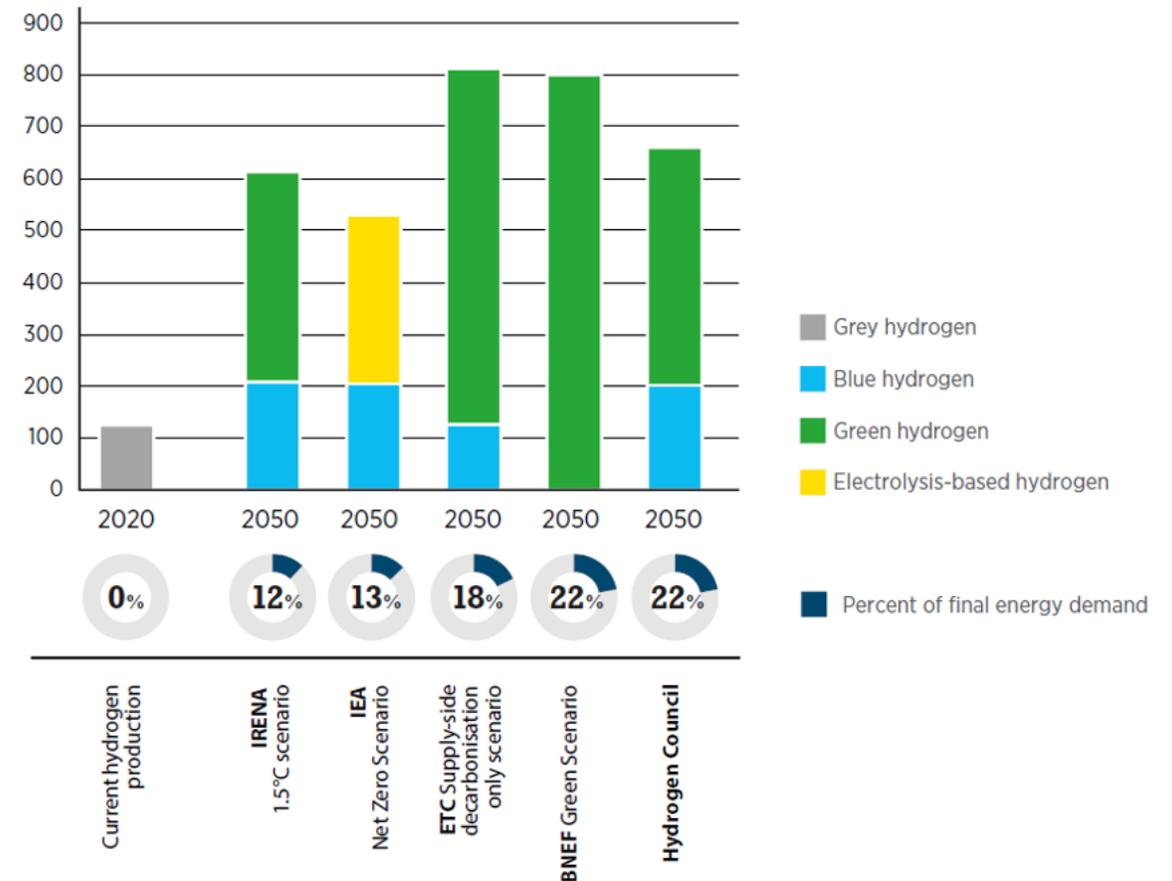


Hydrogen consumption in 2020 along with estimates for global hydrogen demand in 2050



Note: (million tonnes per year)

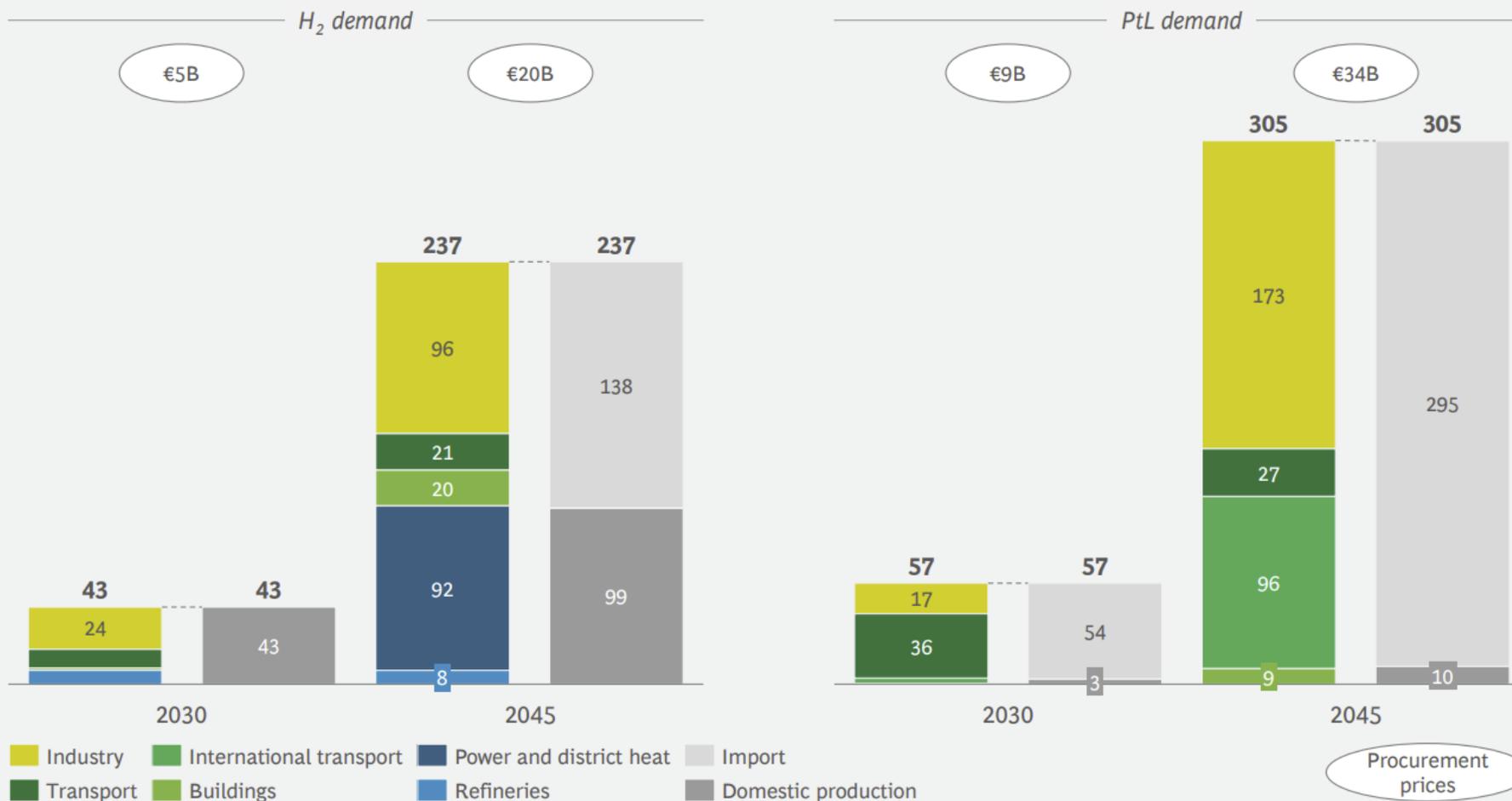
Hydrogen production (Million tonnes)



Industry, transport, and energy sectors drive H₂/PtL demand

EXHIBIT 3 | H₂ and PtL demand by sector and application 2030–2045

TWh



Note: H₂ = hydrogen from electrolysis of renewable energies (during the transition—before 2040—purchase of blue hydrogen is also conceivable); PtL = renewable synthetic fuels made of green hydrogen (especially synthetic crude, methanol); international transport = sea and air transport departing from Germany; import of fossil energy carriers amounted to €91B in 2019
Source: BCG analysis

Global opportunities to produce power-to-X

» Political stability

Trading renewable energy may become crucial for countries that have built their business models on fossil energy in the past.

» Energy diversification

It also becomes a new opportunity for „newcomers“: countries that do not have fossil resources but favorable wind and sun conditions

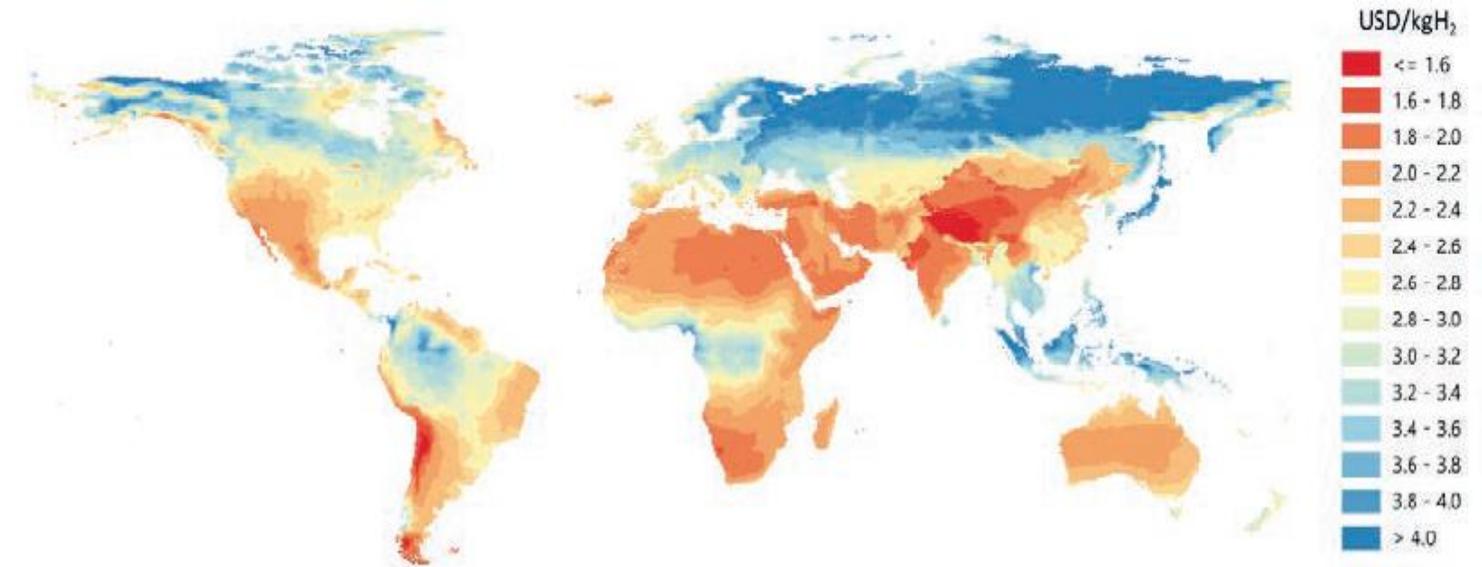
» Maintaining the balance of trade

It is important to have economically strong partners for an export-oriented EU.

» PtX- contribution

Hydrogen cannot be transported easily without a pipeline. Liquid fuels can be traded with existing infrastructure and enable an global renewable energy market.

Hydrogen costs from hybrid solar PV and onshore wind systems in the long term



To unleash the global potential, establish a European lead market

German hydrogen strategy



working group within
Power-to-X for Appli



- » The German national hydrogen strategy was launched in 2020 and will be updated this year. It
 - focuses on **scaling-up & application of H₂** as essential,
 - increases of the electrolysis target to **10 GW by 2030**,
 - facilitates **international trade** by establishing H₂ energy partnerships with future producer countries
- » Hydrogen will be mostly used in industry applications (steel & chemical sector) and transport (heavy duty, shipping & aviation). Germany launched a blending mandate for 2% of synthetic kerosene by 2030.

The European Green Deal

The Green Deal is the central strategy to transition towards climate neutrality. It aims at reconciling ambitious climate targets and a strategy for industrial growth. For P2X, it provides many opportunities:

- » **EU Hydrogen Strategy** and its 2 x 40GW objective
- » **The Fit-for 55 Package**
REDII-Revision with RFNBO quotas for 2030 in transport and industry | Renewable fuels for aviation & maritime shipping | Revision of the Energy Tax Directive | A new “fuels” emission trading system | A gas package setting up a regulatory framework for hydrogen
- » **RePowerEU**
To decrease dependency from Russian energy imports the EU aims to increase the availability of hydrogen up to 20 mt by 2030 (equals 278 GW)
An EU External Energy Strategy will complement RePower EU



Snapshot: Making Aviation more sustainable

ReFuelEU Aviation

- » EU initiative with an obligation for airlines and fuel suppliers to gradually increase the share of SAFs.
- » The blending mandate concerns both flights within the EU and flights connecting EU airports and airports from third countries.

Shares in the fuel mix (in %)	2025	2030	2035	2040	2045	2050
SAF ramp-up out of which:	2	5	20	32	38	63
Sub-mandate - advanced biofuel (incl. waste lipids)	2	4.3	15	24	27	35
Sub-mandate – green synthetic fuels	-	0.7	5	8	11	28

Political negotiations are ongoing

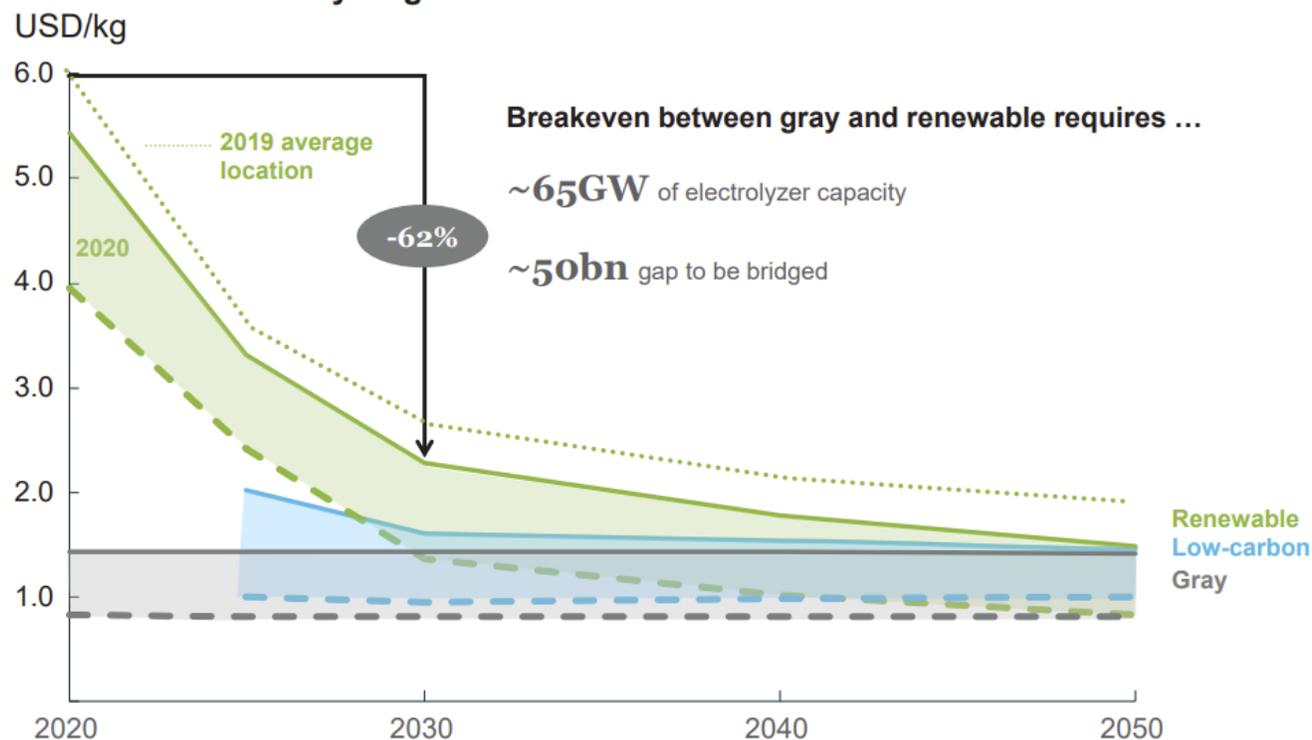
Germany already takes the lead

- » Germany already decided to implement a national PtL-blending mandate of 2% by 2030 in its national legislation

Renewable hydrogen could break even with grey H2 before 2030 in optimal regions

Production cost of hydrogen USD/kg

— Average location — Optimal location



Three factors contribute to decreasing prices:

- » Drop in CAPEX due to faster scale-up of electrolyzer supply chains
- » Decrease of levelized cost of energy (LCOE) in optimal locations (best locations include Spain, Chile, and Middle East)
- » More large-scale, integrated renewable hydrogen projects achieving higher electrolyzer utilization levels

Renewable hydrogen

- Dedicated renewable/electrolyzer system
- Fully flexible production
- Scale up of renewable hydrogen production
- Additional costs to reach end supply price

Low-carbon hydrogen

- Development of CO₂ pipelines and at-scale sites
- Scale-up of low-carbon hydrogen production
- Scale-up of CCS outside of hydrogen production

Key assumptions

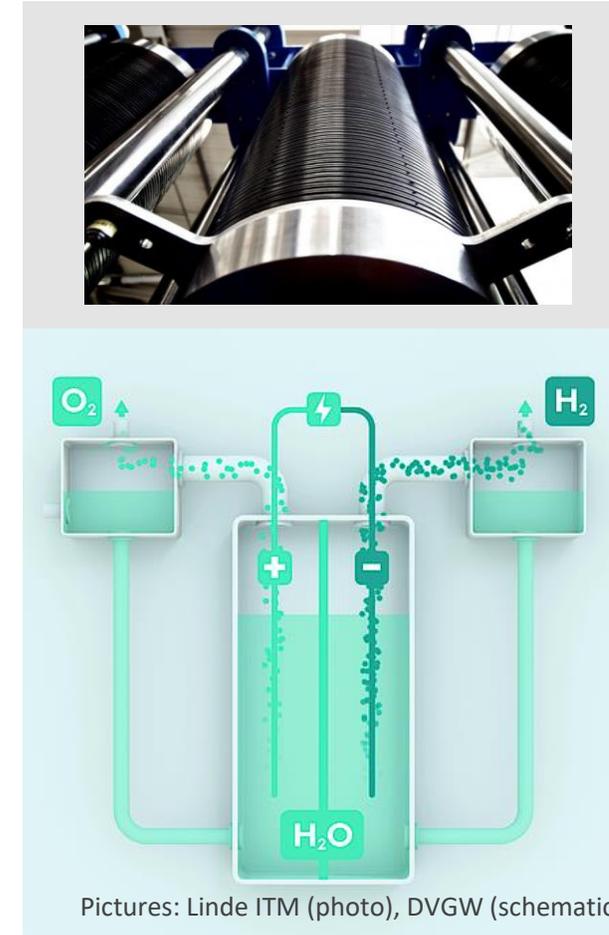
- Gas price 2.6–6.8 USD/Mmbtu
- LCOE USD/MWh 25–73 (2020), 13–37 (2030) and 7–25 (2050)

Lead project H₂ Giga: Series production of electrolyzers



Principle of electrolysis

- ▮ Conversion of electrical energy into storable chemical energy
- ▮ High technological maturity, but...
- ▮ Production of electrolyzers today still partly with manual labor, high costs, low production capacity
- ▮ H₂Giga develops manufacturing technologies that make electrolyzers reliable, cost-effective to produce in sufficient quantities



PtL plant Werlte, North Germany

- The world's first industrial-sized plant for production of eFuels in aviation was inaugurated on 4 October 2021 in Werlte, Germany.
- RES sourced regionally, CO₂ taken from the air.
- To be financed by the CO₂-compensation scheme of Atmosfair gGmbH





Producing E-fuels at industrial scale: Norsk E-fuel

UNTIL 2023: 10 MILLION LITERS RENEWABLE FUEL

By 2023 we will start operating our first industrial plant in Herøya providing 10 Mio. liters of renewable fuel annually for the Norwegian and European fuels market. The site in Herøya offers access to crucial infrastructures needed for the pilot plant to be a success.



UNTIL 2026: UPSCALING TO 100 MILLION LITER

The location of the first plant in Herøya perfectly fits the needs for the envisioned upscaling until 2026. With a production capacity of 100 Million liters annually, the plant layout will serve as blueprint for following nationwide roll-out. One full-sized plant would effectively cut the current flight emissions of the top 5 most frequently serviced flight routes within Norway by about 50 %.



THE FUTURE: CLIMATE NEUTRAL TRANSPORTATION

We make the conversion of Norway extensive renewable electricity resources to renewable fuels possible. The technologies of Sunfire and Climeworks allow us to be independent and flexible so we can go wherever renewable electricity is abundantly available.



Fuel from wind and water: E-fuel pilot plant in Chile

**SIEMENS
ENERGY**

Pilot phase until

2022

~130.000
liters e-fuel per year

1st phase until

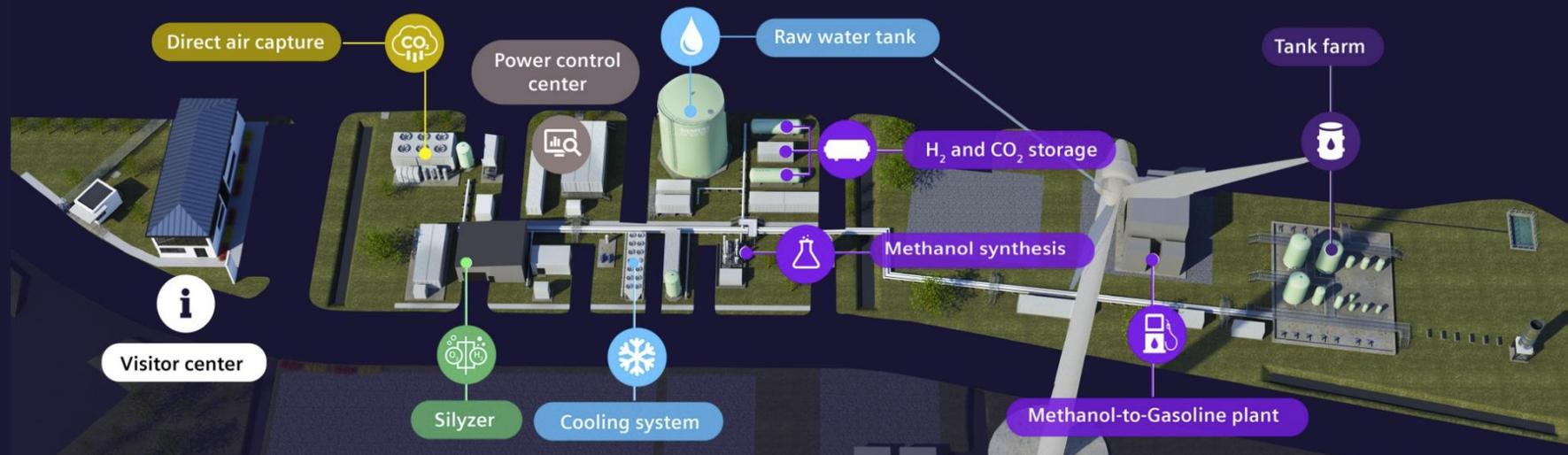
2024

~55 million
liters e-fuel per year

2nd phase until

2026

~550 million
liters e-fuel per year



That's enough fuel for over one million people to drive their car for nearly a year!



P2X in maritime shipping



- » The shipping sector is globally in the focus of GHG reduction plans
- » We are engaged in discussions with the shipping industry and political decision makers – by lobbying the **“Power-to-X Roadmap for the Maritime Energy Transition”**
- » We closely cooperate with CIMAC, the international association for the large engine industry

Conversion to SNG as marine fuel

- » Container vessel Wes Amelie was converted to dual-fuel operation in 2017
- » Now, it was renamed into ElbBLUE and converted to synthetic LNG (SNG).
- » SNG was thus used in commercial shipping for the first time ever
- » Conversion: MAN Energy Solutions, SNG was supplied by a power-to-gas plant near Cloppenburg, Germany



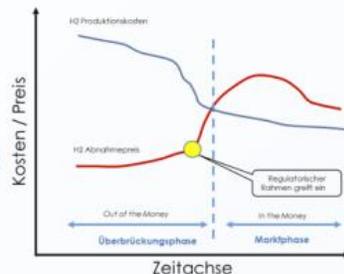
OVERVIEW: TARGETS

Key points and core elements



Bridging

- Direct creation of measures regarding the market launch until regulatory framework takes effect



Defined system

- Creation of a limited system (e.g. 1 GW)
- Clear time limit (e.g. 10 years)



Contracts for Difference

- Financial compensation in the form of CfDs
- Set up of an H₂ intermediary: the HYDROGEN INTERMEDIARY NETWORK COMPANY, HINT.CO



Auction-based

- Auctions on H₂ supply and purchase side (auctions or other competition-based allocations)
- Enabling competition-based prices on both sides



From Production to Application: The #P2X Conference



From Production to Application:

THE #P2X CONFERENCE

Düsseldorf, 19th to 20th September 2022



- » Düsseldorf / Germany, 19. / 20.9.2022
- » A cutting-edge, technical conference that puts practical issues and challenges around P2X in the focus.
- » Gather latest first-hand information, meet renowned experts from the entire value chain, find fresh ideas, and make new contacts.
- » <https://www.p2xconference.com/>



Emerging opportunities for the industry along the P2X value chain

- » The next decade will be characterized by a significant market ramp-up of green hydrogen production.
- » We will see a move from the currently installed base of electrolyzers in the lower megawatt range to gigawatt-size capacities. This will contribute to economies of scale for electrolyzers and drive down CAPEX.
- » The EU target alone indicates a cumulative market size for electrolyzers and balance of plant of more than 40 B€ within the EU until 2030.
- » Target sectors will be transport (aviation and maritime) and industry (chemicals, steel)
- » E-fuels should also play a role in road transport (e.g. long distance and heavy duty)

P2X energy carriers can become an important commodity for the international energy market and generation capacities can be built in regions with low electricity generation costs.



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