HYDROGEN BAROMETER 03/21

Independent assessment of the hydrogen industry in Germany

E-Bridge
competence in energy

November 2021

The Hydrogen Barometer

Welcome to the 3rd edition of the E-Bridge H_2 Barometer. It serves investors, legislators and other stakeholders to assess and evaluate the existing institutional and regulatory framework.

The assessment is based on E-Bridge internal analyses as well as external market assessments. Once again, companies from all three stages of the value chain were asked for their assessment. It can be observed that since the last edition of the Barometer, the high natural gas and CO_2 prices have taken their toll. The competitiveness of green hydrogen is becoming increasingly difficult. At the same time, the outlook on the demand side is slowly brightening. This is particularly true in the chemical sector.

I hope you enjoy reading this issue and that we can once again provide some input for new impulses.

Yours

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Brief overview: Investment climate in Germany on the demand side brightens, but uncertainties regarding future infrastructure remain a major obstacle

Upstream/ Production

Moderate negative

- **Competitiveness of green H_2** compared to blue and gray has declined in recent months - with a downward trend.
- According to the market survey, **the investment climate for electrolysers is viewed rather critically.** An improvement is expected in the next three to five years.
- **Potential for green H_2 from European sources** is often underestimated.
- **"Fit for 55" requires additional efforts :**
  - Technology openness in the production of CO_2-free hydrogen
  - Increased expansion of RE plants in Germany and Europe
  - Strengthening of the ETS and development of a Europe-wide system of guarantees of origin

Midstream/ Transport

Mainly negative

- **Despite much diligent work on the legal and regulatory framework,** there is still **uncertainty about** the principles of future **hydrogen regulation.**
- **Dynamic regulation along the lines of telecommunications** is being propagated by the Monopolies Commission and ACER. Is a happy medium emerging here in the dispute over the pros and cons of integrated gas/hydrogen regulation?
- Wait and see also seems to be the motto in the industry. According to the market survey, voluntary regulation has not been a big issue so far. However, if a **bait-and-switch offer of 9%** interest on equity is actually made, this might change quickly.

Downstream/ Demand

Moderate positive

- The investment climate is assessed as **positive**, particularly **in the chemicals sector.**
- **Demand projects are growing at a high rate**. In the short term, the transport sector appears to be promising. The steel, chemicals and refineries sectors are attractive in the medium term.
- Key drivers are meeting the **quota requirements from RED II**, adaptation to customer processes and **expected economic benefits.**
- The **heat sector** is also considered as **a long-term option** by the participants in the E-Bridge survey.

- The competitiveness of green hydrogen is declining. On the upstream side, the **demand for technology openness**, i.e. an equal coexistence of all options for CO_2-free hydrogen, remains.
- The basic direction of **future hydrogen grid regulation remains open**.
- The **development of demand is becoming a driver of an H_2 market**. The heat sector is also being considered as a demand driver in the long term.

UPSTREAM
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DOWNSTREAM
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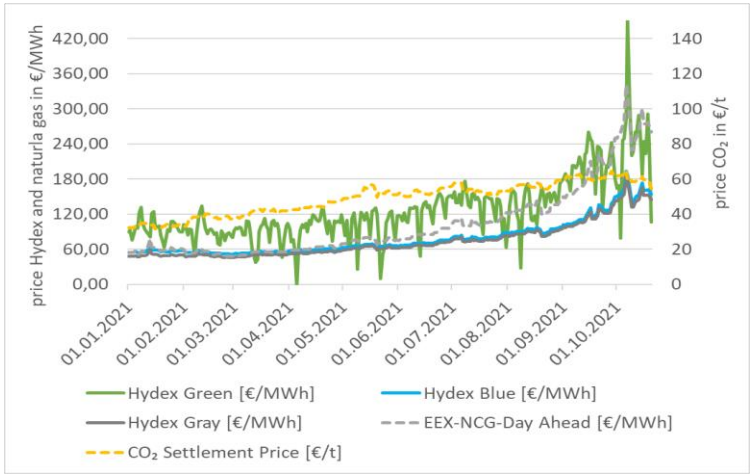
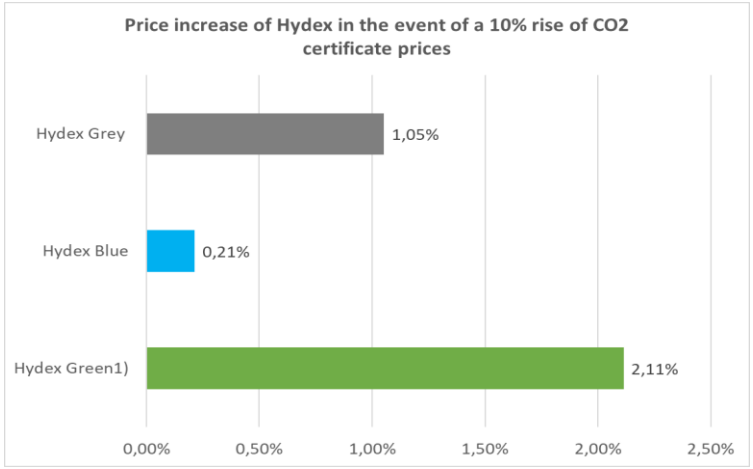
Unintended side effect: Rising CO_2 prices reduce competitiveness of green hydrogen

- The **renewable electricity required to produce green hydrogen** is **subject to opportunity costs** on the electricity market.
- Pricing on the electricity market is at "marginal cost," i.e., based on the bids of the most expensive power plant unit called upon.
- Over the **next few years**, it is expected that despite the addition of RES, **conventional fossil power plants** will set the marginal prices in numerous hours and thus also determine the price of green power.
- Fossil power plants must purchase sufficient CO2 emission certificates for their electricity production. **Rising CO_2 prices thus increase the electricity production costs** of fossil power plants and thus the **prices on the European electricity market.**
  - CO_2 certificates are also required for the production of grey hydrogen. Due to the different efficiencies of the entire production chain, **CO_2 prices have a more significant impact on green hydrogen than on grey hydrogen.**
  - The **increase in natural gas prices has a similar effect**, which also weakens the competitiveness of green hydrogen.

Price development of H2 (Hydex) compared to price development of natural gas and CO_2





1) Assumption: spot price corresponds to short-term marginal costs of a gas-fired power plant, average efficiency: 50%.

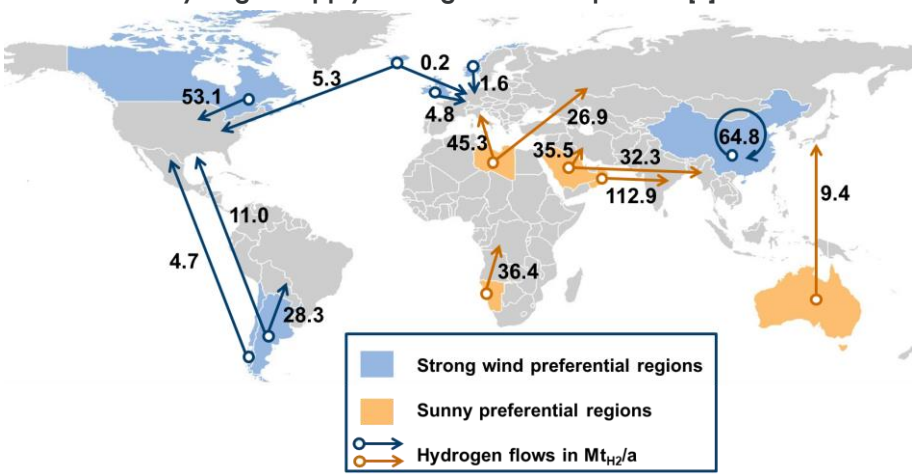
As long as fossil power plants determine the electricity spot price, **the competitiveness of blue versus green hydrogen will continue to increase as primary energy and CO_2 prices rise**

The potential of regional imports of green H_2 from the European environment is often underestimated

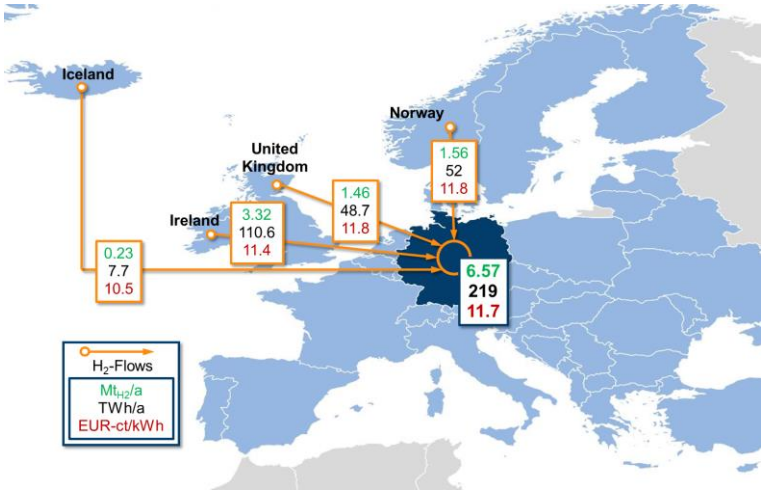
- Current **energy partnerships of interest with regard to H_2 exist with Australia, Chile, Japan and Morocco**. However, no definite export or import intentions have been expressed yet.
- According to a **study by the Jülich Research Center**, the 95% emission reduction target cannot be achieved in an economically efficient manner without hydrogen imports.
  - If **only green hydrogen** is used as a basis, **H_2 flows** as shown on the **right above** will emerge (total cost-optimal hydrogen allocation).
  - Due to the **globally distributed demand** and at the same time **relatively high transport costs**, a **regionalized distribution with short transport distances** will emerge.
  - From this, a **cost-supply function** was derived for Germany, which describes the respective import quantities and the correlating costs (border-crossing prices)
  - In the **global cost optimum**, demand is met by **wind-based H_2 imports from Iceland (5%), Ireland (50%), the United Kingdom (22%), and Norway (23%).**
  - These volumes result in a weighted import cost of 11.7 EUR-ct/kWh (3.90 EUR/kgH_2)

[1] Cerniauskas et al. (2021) Paths for the energy transition - Cost-efficient and climate-friendly transformation strategies for the German energy system up to the year 2050".

Worldwide hydrogen supply in the global cost optimum [1].



Detailed view of import flows to Germany, taking into account import volumes and costs [1].



According to a **study by FZ Jülich**, a **long-term regionalized import of hydrogen from the European environment appears attractive** and should – despite the uncertainties in the assumptions – be an important cornerstone of political action.

According to the E-Bridge market survey, there is still considerable need for action in the upstream area for "Fit for 55"

- **Expansion targets for renewable energies**
  - The targets for the expansion of renewable energy production urgently need to be adjusted in Germany and Europe.
  - According to the E-Bridge survey, this is one of the biggest obstacles to the development of an H_2 market.
- **Europe-wide guarantees of origin (HKN)**
  - A pan-European system of guarantees of origin is seen as essential by almost all participants of the market survey. It must show the origin and use of decarbonized hydrogen transparently and reliably. The tradability of the HKN must be ensured.
- **Emission Trading System (ETS)**
  - The European Emission Trading System (ETS) should be strengthened. Further development includes an abolition/reduction of fossil energy subsidies, avoidance of double taxation and promotion of decarbonized energy sources.
  - Hydrogen Europe believes that transport and shipping should also be integrated into the ETS.

- **Investment climate**
  - The investment climate is rated rather critically in the upstream sector in E-Bridge's second market survey.
  - Import capacities are rated neutral, while the investment climate for gas reformers (including blue hydrogen plants) is rated most negative.
  - At the same time, a brightening of the investment climate for electrolysers within the past six months is recognized. This trend is expected to continue over the next three to five years.
- **Suggestions to reduce barriers to the development of a sustainable H_2 economy (opinions of market survey participants).**
  - Do not weaken the green power additionality requirements, and the requirement of synchroneity between power and H_2 production.
  - Targeted (i.e., not too narrow) interpretation of European requirements and technology openness (e.g., no focus on electrolysers). Group D quality is proposed as the standard for the quality of H_2 at the long-distance gas stage (DVGW G260 H_2).
  - The introduction of a "floating market premium" is proposed to achieve the expansion targets.

Technology openness, a Europe-wide system for guarantees of origin and a strengthened ETS should form the basis for the development of a competitive H_2 economy. **The investment climate in Germany is assessed critically at the present time, even for electrolysers.**

UPSTREAM
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TRANSPORT**

DOWNSTREAM
DEMAND

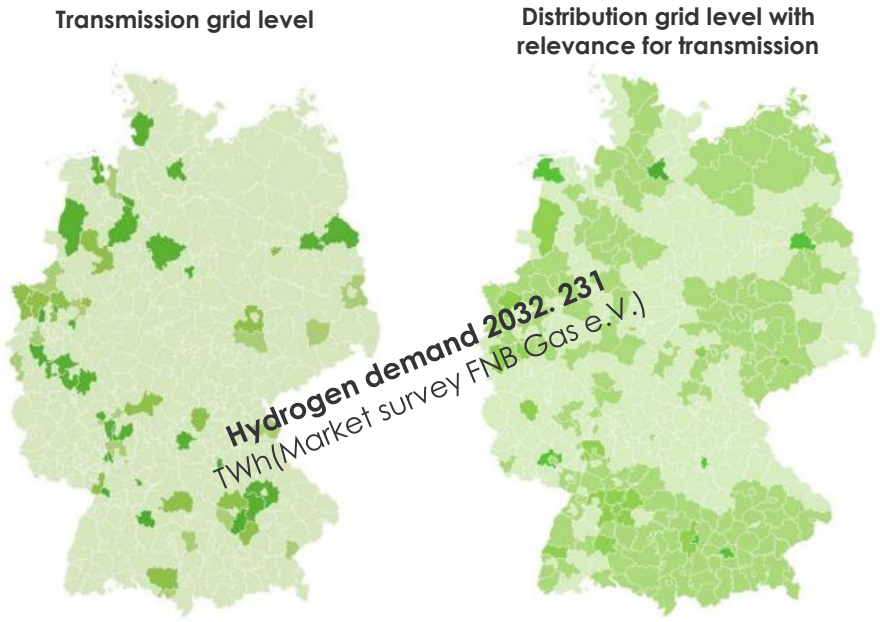
Quo Vadis, H_2 Grid Regulation ?

+ With EnWG transition regulation, EEG surcharge regulation for H_2 producers and the first IPCEI tender, Germany (in an election year!) has presented numerous building blocks for the entry into the H_2 economy (cf. Interim Report of the Federal Government on the Implementation of the National Hydrogen Strategy of 22 Sep. 2021).
+ At the same time, the current draft of the H_2 Grid Charging Ordinance lures infrastructure operators to enter voluntary regulation with a 9% return on equity (!).
+ However, before the new German government takes office and the EU Commission presents its gas/hydrogen package, there is still uncertainty about future H_2 regulation.
+ How do the 1700 km of "pure" H_2 pipelines reported by IPCEI projects fit into the desired integrated grid expansion planning for electricity and gas? Will the Commission's proposal provide sufficient clarity on an integration of natural gas and hydrogen regulation, or will there be years of uncertainty?
+ The current market survey of VNB Gas shows that the development of hydrogen supply and demand could be much more dynamic than previously expected. However, this also increases the need for an area-wide development of the infrastructure.

Comprehensive planning of H_2 grid requirements & dovetailing with NEP electricity required

The nationwide emerging hydrogen demand demonstrates the urgency of national demand planning. The central question is whether future electrolysis sites will be located at RES power generation or at H_2 consumers. In the first case, transport is via gas pipelines to be converted; in the second, there is a threat of additional strain on the electricity transmission grid.

Geographical focus of H_2 demand in 2032 according to FNB Gas e.V. market survey. (Sept. 2021) Figures: FNB Gas e.V.



"We ourselves stand disappointed and look stricken, the curtain closed and all questions open."

Bertolt Brecht, The Good Man of Sezuan

"Dynamic regulation" based on the TK model as a model alternative?

The first H_2 network regulation already contains the mandate for the amendment for the BMWi to submit a concept for joint regulation to the EU Commission by the end of 2022 in light of the announced proposals for the regulation and financing of hydrogen and gas networks (Section 112b (1) EnWG). Three approaches are under discussion:

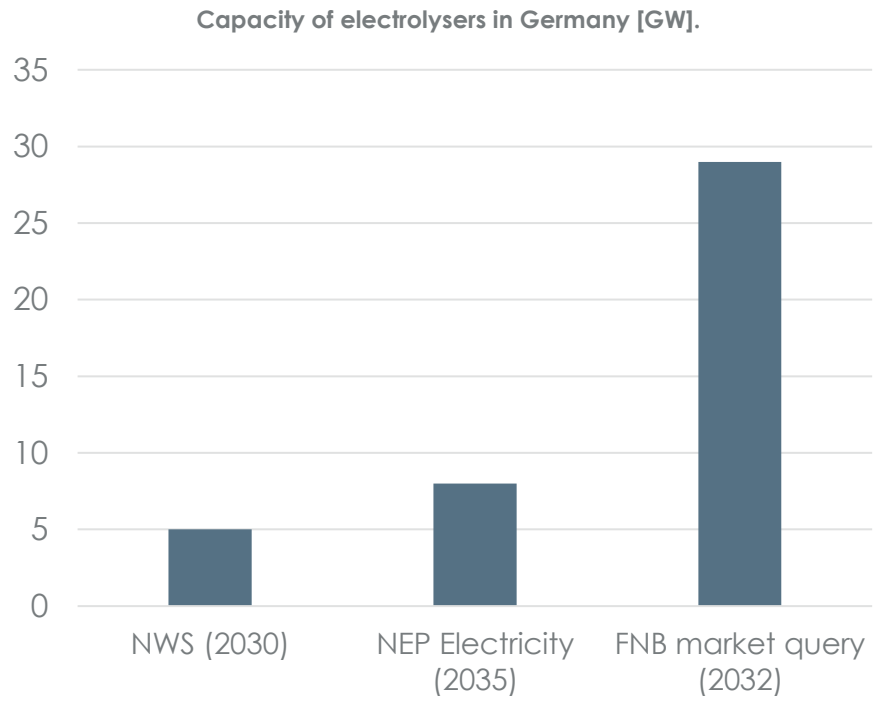
1. EnWG Transition Model
(see also Hydrogen Barometer 2/2021)

2. Integrated gas regulation
(Direct joint regulation and financing of natural gas and hydrogen networks).

3. Dynamic regulation based on the telecommunications model
The idea here is to regularly analyze the need for regulation in submarkets and, in the event of barriers to market entry or (too) low competition intensity, to apply regulatory instruments previously defined by law. These could correspond 1:1 to gas market regulation and thus enable the gradual integration of new hydrogen networks into gas network regulation. However, the question arises whether the rather reactive model approach fits the expected high dynamics of H_2 market development.

Dynamically or directly integrated?

To prevent the grid from becoming a brake on development, future H_2 grid development must be synchronized with hydrogen production and offtake. The latest market survey by the FNB indicates that development may be much faster than previously expected.



NWS: National Hydrogen Strategy, NEP: Network Development Plan

The EU Commission and the new German government have it in their hands to provide clarity on the future regulatory framework in the coming months.

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To achieve the goals of the "Fit for 55" package, the potential of all sectors must be harnessed.

- **Investment climate**
  - For the chemical industry, the investment climate is assessed as **very positive** at this point in time.
  - The **assessment is ambivalent** for the steel, refinery and power generation sectors.
  - The investment climate is **assessed as poor** in the transport and heating sectors.
- **Connection to a pure H_2 network**
  - Almost all participants in the survey stated that a **connection to a pure H_2 network is required**. About half of the participants are additionally constructing near-consumption electrolysers.
  - Insufficient grid capacity in the H_2 grid is seen as **a limiting factor for timely expansion of demand.**
- **Motivation for additional H_2 demand**
  - Most participants indicate **that economic benefits are to be achieved.**
  - Additional drivers are **to meet quota regulations (RED II)** and to **show customers' entire process chain**.

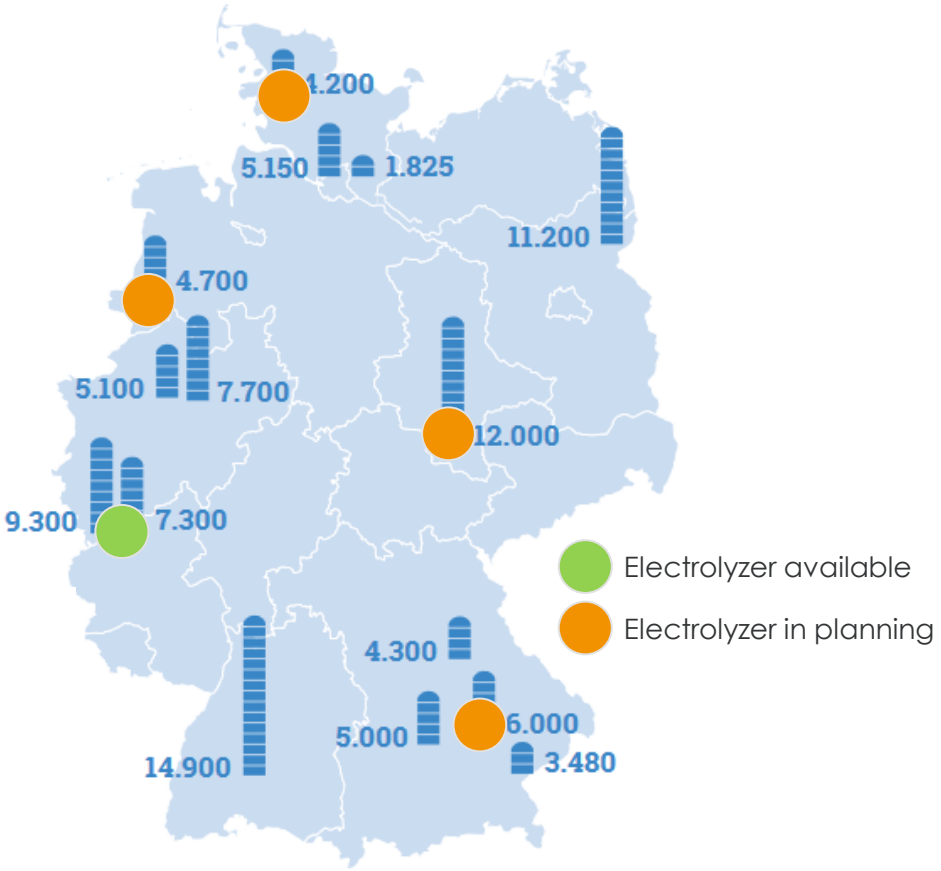
- **Biggest barriers to developing sustainable H_2 demand (quotes from market survey participants).**
  - **Sustainability** of H_2 produced in Central Europe **is not given**.
  - **Regulatory obstacles**, e.g. too narrow interpretation of European requirements, one-sided technology predefinition, one-sided sector predefinition, lack of application of regulation
  - Separate funding (no cluster procedure) **makes small plants uneconomical** (20 - 60 kg/day)
  - **Complex approval procedures**, incl. requirement of direct grid access with own transformer for granting EEG exemption
  - All participants judge today's **downstream support as insufficient.**
  - **Conversion costs at companies and end users** (e.g. household customers) should be subsidized.

The investment climate in Germany is viewed with positive optimism. It is viewed critically above all in the areas of transport and heating.

RED II as a driver of future demand for decarbonized hydrogen

- The implementation of the European RED II Directive into national law aims to reduce emissions from the use of fossil fuels. With the amendment to the BImschG, the German government integrated **a reduction quota of GHG emissions of 22% by 2030.**
- To achieve the target, companies have freedom of choice within the legal requirements. One option is to **use green hydrogen in refinery processes.**
- Hydrogen is an important component of existing petroleum refinery production processes. **Refineries recover most of the hydrogen through internal processes**. Currently, the remaining amount is usually covered by steam reforming.
- For the direct use of green hydrogen in co-processing in the refinery process, hardly any technical changes in the production process are required. Complete **substitution of the hydrogen used in the refinery process would create a demand of up to 150,000 tons (about 5 TWh) per year [2].**
- First refineries have already recognized the potential of green hydrogen. Since July 2021, an electrolyzer has covered part of the hydrogen demand of the **Shell refinery** in Wesseling. In addition, projects by **BP**, **Bayernoil, Total** as well as the **Heide refinery** were awarded a contract under the IPCEI funding.

Map of crude oil processing refineries, capacity in thousand t/a, box corresponds to 1 million t [1].



[1] dena (2018): Areas of application for power fuels
[2] IG BCE / MVV (2018): Potential Atlas for Hydrogen

Refineries have recognized the need to convert their processes. Significant growth in demand for decarbonized H_2 is expected, at least at these sites.

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