H_2-BAROMETER

Independent evaluation of the hydrogen economy in Germany

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The H_2-Barometer

E-Bridge's H_2 Barometer assesses the investment climate in the hydrogen economy in Germany. It serves investors, legislators and other stakeholders to evaluate the existing framework conditions.

The H_2 Barometer analyzes the three elements of the value chain separately in order to get an overall estimation of the German hydrogen market.

The assessment is based on an E-Bridge internal analysis as well as a market evaluation. For this purpose, companies from all three stages of the value chain were asked for their feedback. The Barometer is published quarterly in order to monitor developments in Germany on a regular basis.

This is the first edition of the Barometer. I look forward to receiving your comments and feedback.

Yours,

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Overview: Mixed mood in the German hydrogen industry

Upstream / Production — Moderately high

+ **Cost difference** between **green and CO_2-compensated gray hydrogen decreases** faster than expected
+ **Good mood and high willingness to invest in electrolysers: Planned projects >1 GW. Reason for this includes high subsidies in the billion-euro range**
+ *What is required now:*
  - **Structured promotion of operating costs (OPEX)**
  - Massive **increase** and **implementation** of **RE expansion targets**
  - Expansion of **alternative transition technologies** and an **import infrastructure**

Midstream / Transport — Moderately low

+ **Critical mood:** 43% of the network operators surveyed rate the investment climate as poor. The lack of vision for integrated network development is criticized.
+ **Gas network operators ready to start:** 70% of the network operators surveyed are nevertheless trying to invest as "H_2-ready" as possible already today.
+ *What is required now:*
  - **Planning security,** i.e., integrated network development planning for gray & green gases
  - **Investment security** through integrated natural gas/H_2 regulation or tax-financed transitional regulation
  - **Transformation security** through a balance sheet blending quota for hydrogen in the gas grid

Downstream / Demand — Normal

+ **Large existing hydrogen demand** and **decarbonization targets** offer **high demand potential for CO_2-free hydrogen**
+ Initial **economic incentives show effect, but are not sufficient** for cross-sector sustainable demand
+ *What is required now:*
  - Utilization of the heat market by **increasing blending rates**
  - **Economic incentives** for new investments in H_2 technologies
  - **Decoupling of demand and production** through grid expansion

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+ The **development of green H_2 production in Germany is promising**. However, viable concepts for bridging the gap between the overall expansion targets and the share of green hydrogen are lacking.
+ Lack of planning, investment and transformation certainty for H_2 grids **determine the investment climate in the midstream sector.**
+ Demand for CO_2-free hydrogen is increasing, but the spatial coupling currently required for hydrogen production is inhibiting development. **The potential of the heat market is not being exploited.**

UPSTREAM PRODUCTION

MIDSTREAM TRANSPORT

DOWNSTREAM DEMAND

CO_2-free hydrogen is not only "green"

CO_2-Treatment

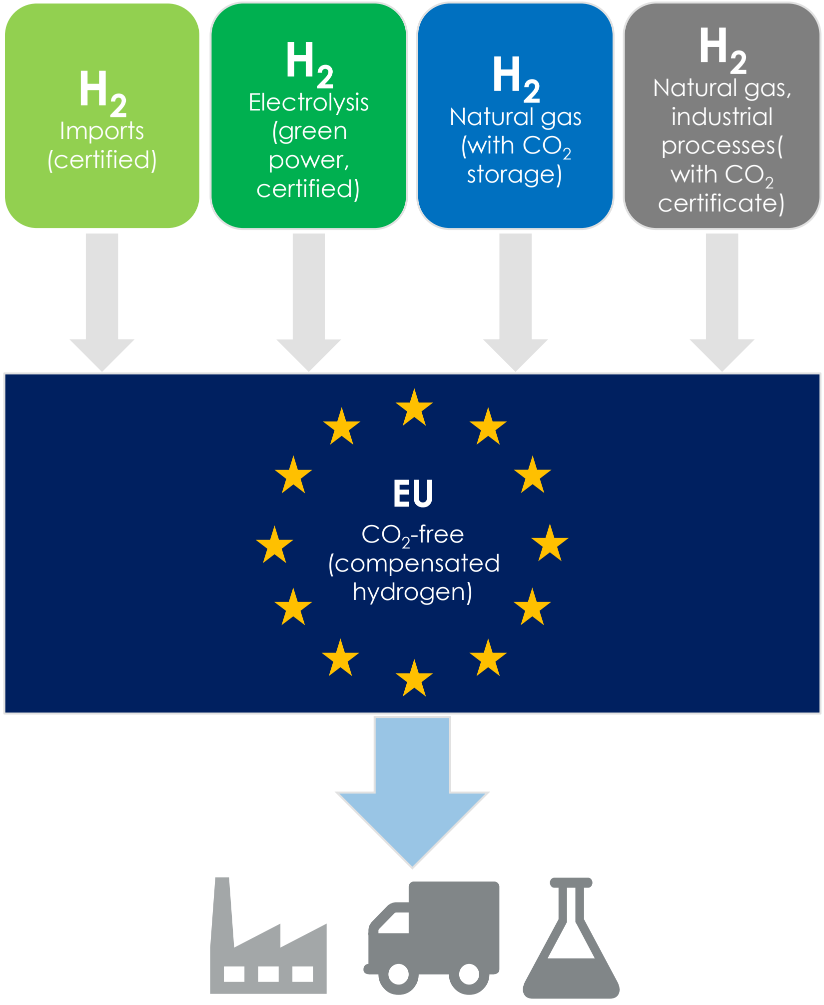
+ Any **CO_2 release** during the production of CO_2-free hydrogen **requires emission allowances**. If the emission limits do not increase as a result of hydrogen production, gray hydrogen associated with emission certificates can also be designated as CO_2-free or -compensated.
+ **Green hydrogen** must come from **RES-E Green** electricity certificates (guarantees of origin) required.
+ **Blue** and **turquoise hydrogen** are **produced from fossil hydrocarbons** with capture and storage of the CO_2 (blue) and carbon (turquoise), respectively.

Imports

+ **Equal treatment of imported** and locally produced **hydrogen requires** either recognized green power certificates or **EU emission allowances**.
+ **Without recognized** certificates, gray production could be assumed for imports and the procurement of ETS certificates could be required.

Existing production from industrial processes

+ **Hydrogen from industrial processes** must be assessed **individually**.
+ If the hydrogen is not traded, a **CO_2 offset** must be attributed to the respective industrial processes.



If no additional emissions are generated during the production of CO_2-compensated hydrogen from fossil sources, it is **equivalent to green and blue hydrogen in terms of emissions** and is therefore a **suitable transitional substitute product**.

Generation costs for green hydrogen could fall faster than expected

Exemption from the EEG levy

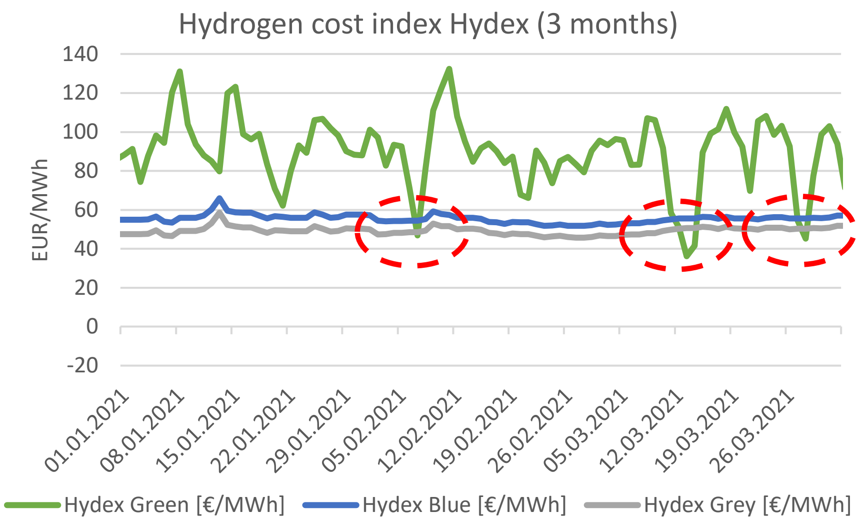
+ With the amendment of the EEG in December 2020, the **production of green hydrogen will be exempt from the EEG levy**. In addition, electrolysis electricity is exempt from electricity tax under $9a StromStG and from network charges under EnWG $118. **Significant relief on variable generation costs.**

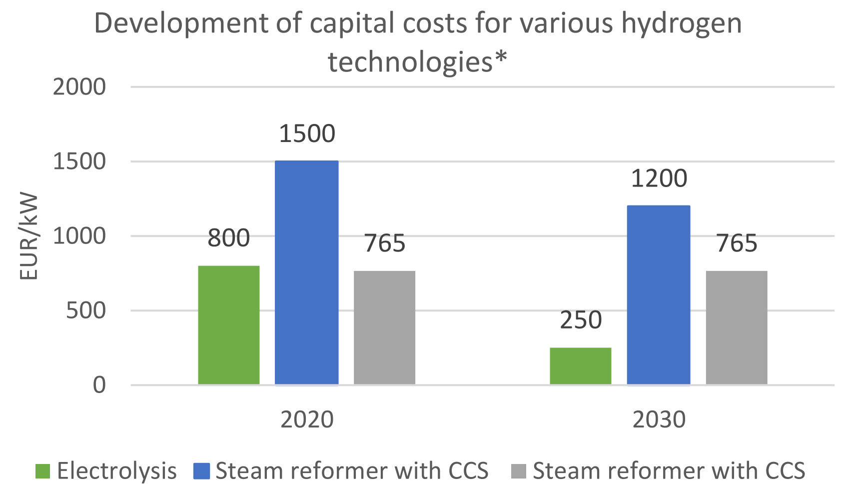
Competitiveness of green hydrogen

+ The cost index **Hydex** developed by E-Bridge shows that **green hydrogen can already be competitive** with blue and grey hydrogen, **if the RE supply is high**.
+ During a transition period, **electricity based on green electricity certificates (HKN) should be accepted for green hydrogen.** This demand is also supported by our market survey.

Cost of capital expected to fall rapidly

+ **Rapid increase of production capacities** of different manufacturers to combined 3 GW/a (Hydrogen Council 2021) could **reduce capital costs faster than originally assumed** (reduction from 2020-2030 by 2/3 at learning rate of 15%).





* Electrolyzer (stack) costs excluding installation and grid connection; source: Hydrogen Council/McKinsey

Due to expected economies of scale in the ramp-up of electrolysers and with the help of **relief from levies and fees**, **green hydrogen can become competitive more quickly** than originally assumed.

Electrolysis capacity must grow by approx. 60 % annually

Increasing demand for hydrogen

- Currently, the largest H_2 production in Europe is in Germany. About 55 % is currently produced by steam reforming, 37 % in industrial processes and 8% by electrolysis.
- Doubling of hydrogen demand to 90 to 110 TWh is expected by 2030. An expansion of electrolysis capacity to 5 GW in Germany and to 40 GW in the EU is planned.

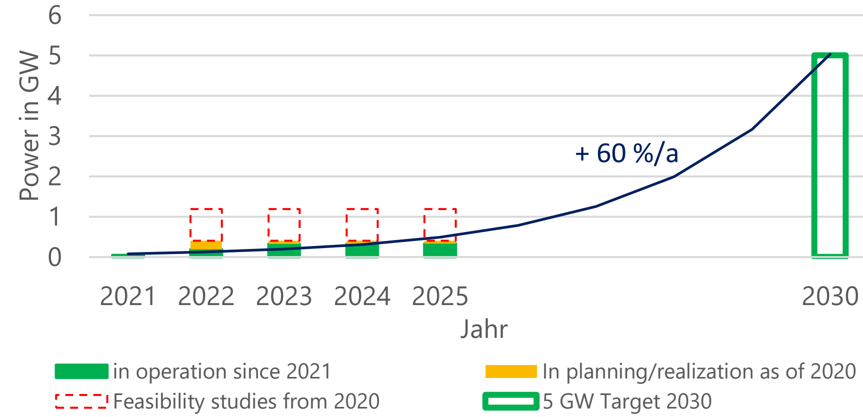
Meeting demand with green hydrogen and imports

- 50% of the future additional demand is to be covered by green hydrogen, the rest by fossil-based production or imports. Energy partnerships are planned with Chile, Australia, Morocco, Tunisia and Saudi Arabia.
- The production potential for blue hydrogen in Germany is limited due to lack of availability and acceptance of CO_2 storage facilities and will have to be imported in the future.

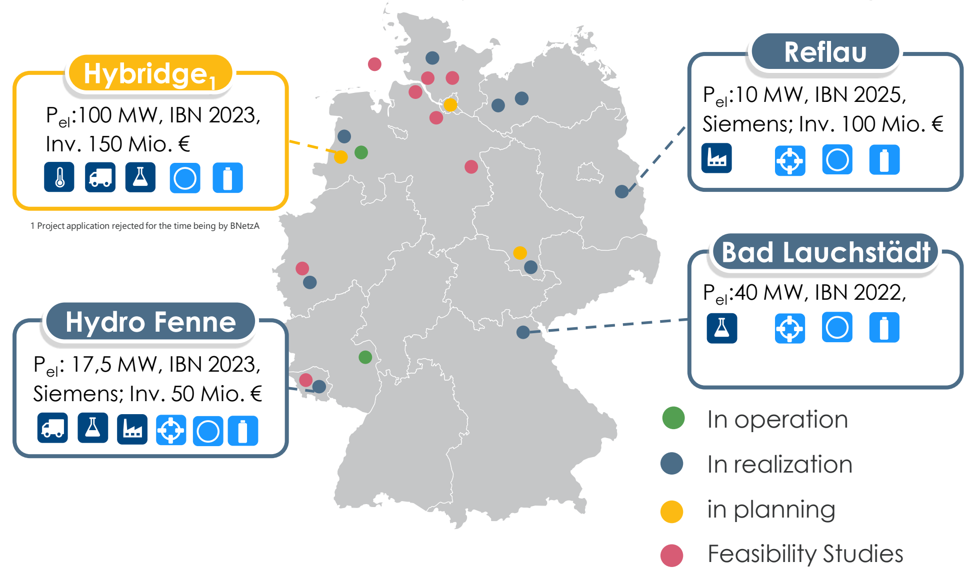
Capacity increase and import infrastructure imperative

- A significant increase in electrolysis capacity is evident - but to meet 50 % of the additional demand, exponential growth in RE and H_2 generation capacity is still required.
- To fully achieve the policy goals, both fossil production capacities need to be expanded and import infrastructures need to be created

Implemented and planned electrolysis projects(>5 MW)



Selected electrolysis project in realization and planning



To meet demand and achieve climate targets, **massive capacity increases of RE and electrolysers are required** on the one hand, and on the other hand, **capacities for fossil-based hydrogen have to be expanded** and an **import infrastructure has to be installed.**

UPSTREAM
PRODUCTION

MIDSTREAM
TRANSPORT

DOWNSTREAM
DEMAND

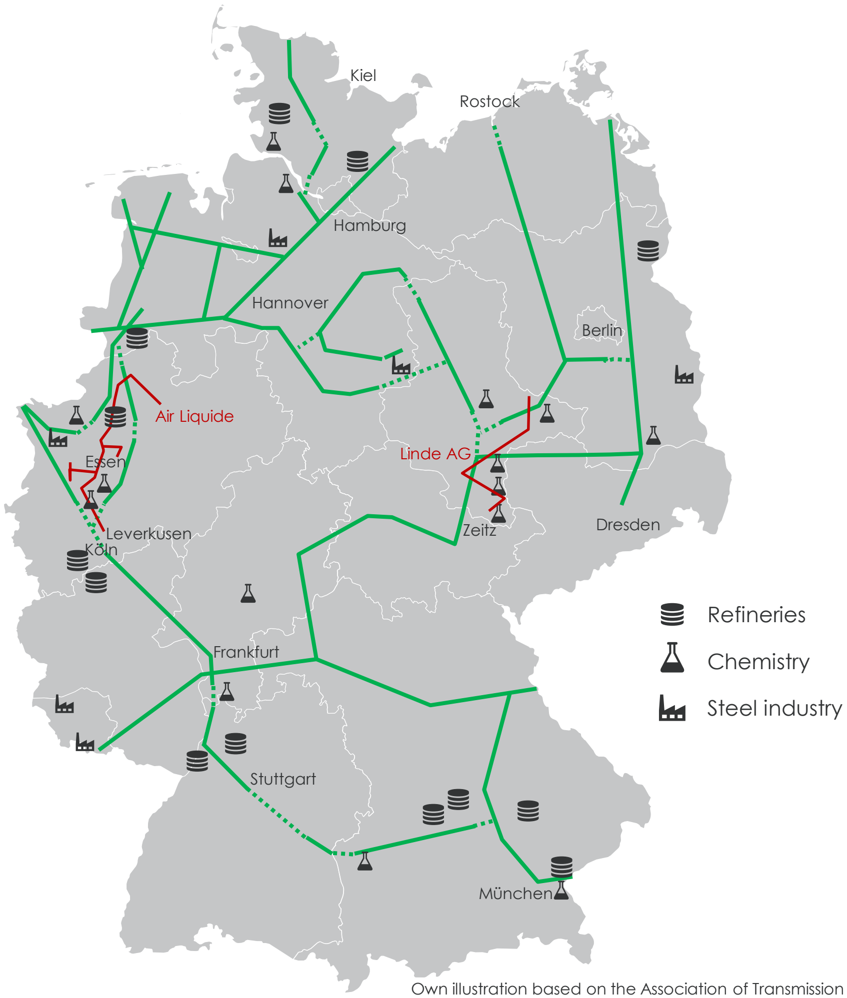
Transition from island networks to national hydrogen network

Transport options for hydrogen

+ **Overseas and inland shipping** will enable international H_2 imports and national distribution in the future.
+ **Road and rail transport** are economical for relatively short transport distances and small volumes.
+ **Pipeline networks** (inevitable in the long term for larger requirements, currently only as island networks (Linde, Air Liquide) and as individual projects (Get H_2 Nucleus).

Vision for hydrogen network

+ Proposal of the transmission system operators describes a **German hydrogen network for 2030**.
+ **Intermeshed network topology** with 5900 km of lines is created by 90 % conversion and 10 % new construction.
+ Grid development from north to south includes **import, storage and large industrial consumers**.
+ In addition to the conversion, **technically permissible admixture quotas of hydrogen in the natural gas network** should be used.



Own illustration based on the Association of Transmission System Operators (Vereinigung der Fernleitungsnetzbetreiber e.V.).

H2 lines after potential conversion of existing infrastructure.

Possible new construction areas for H2 lines

Existing private hydrogen network (Air Liquide & Linde AG)

A **hydrogen grid vision** already exists for economic transport and decentralized supply. Implementation of this vision is **possible through increased H2 blending and conversion of natural gas pipelines**.

Critical mood among network operators

Gas network operators support the politically driven transition to a hydrogen economy

+ **Transformation concepts**, such as the "visionary hydrogen network" of the FNB and the "H_2 vor Ort" initiative of the distribution network operators with the DVGW, have been available since 2020.

+ **70 %** of the network operators surveyed are **already preparing their existing networks for hydrogen use** - as far as technically and economically possible.

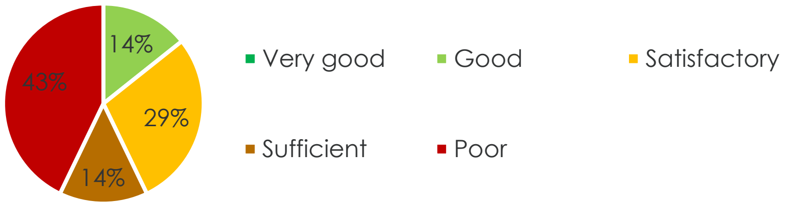
Sentiment in the midstream is significantly more critical than in the industry as a whole

+ **Progress in expanding the H_2 infrastructure** is rated as **good** by only 14% of respondents. **43 %** even rate it as **poor**.

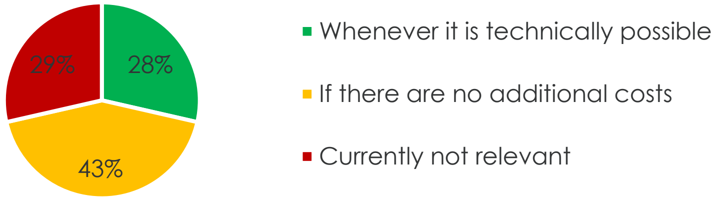
Lack of regulatory framework

+ **70%** of respondents see **lack of clarity** in feed-in and offtake and **insufficient regulation** as the main barriers to hydrogen infrastructure.

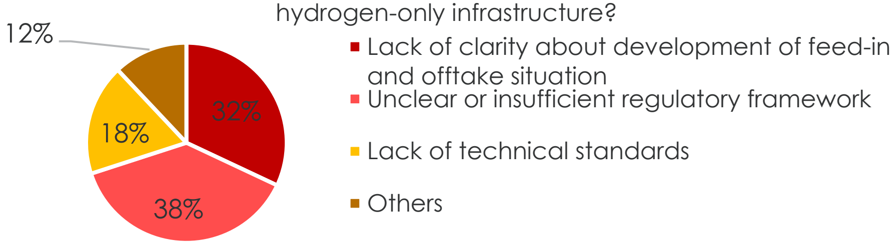
How do you assess the progress made so far in the intended development of the hydrogen infrastructure?



To what extent are investments in your network already "H2-ready" today (2021)?



What are the most significant barriers to converting or building a hydrogen-only infrastructure?



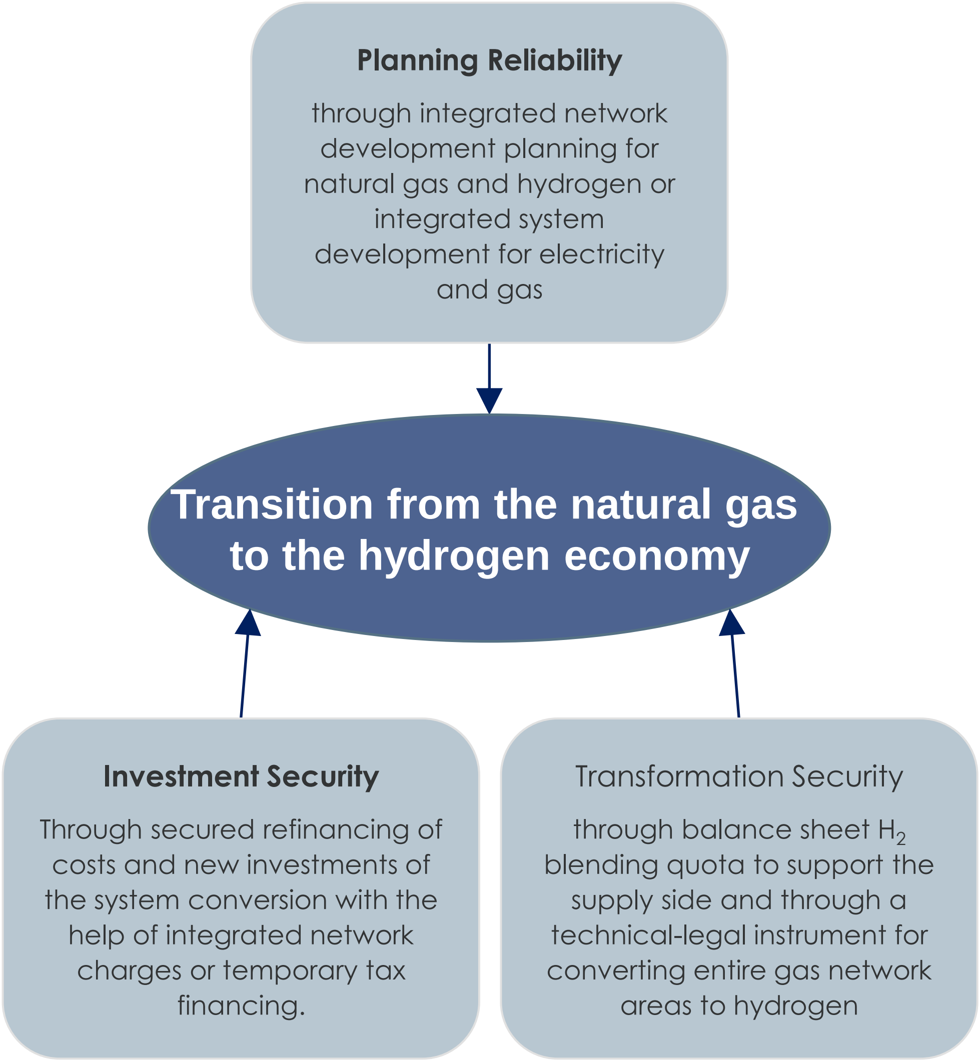
Despite a high willingness to invest in the transition to the hydrogen economy, the **mood of network operators is clouded**. A **clear regulatory vision** could remedy this situation.

"H2 triad" for hydrogen grid infrastructure

+ **Rapid political decisions** are needed to ensure that grids do not become the bottleneck of development, as is the case with the expansion of renewables.
+ The **current EnWG amendment** provides only **fragmentary** and **highly controversial regulatory elements** (negotiated grid access and opt-in model).
+ The **insufficient regulatory framework inhibits willingness to invest** and threatens to **slow down the desired H_2 ramp-up.**
+ **Waiting for European hydrogen legislation** (draft end 2021/beginning 2022) would mean a **loss of time** of approx. 4 years and a corresponding **postponement of sector regulation until 2025**.
+ Insofar as **integrated natural gas and hydrogen regulation** is not yet considered possible under European law, at least a **clear political perspective** and **concrete transitional solutions** for integrated infrastructure development are required. Instead of integrated gas network charges, **tax financing for hydrogen networks** should be considered as a transitional measure.

What is required now?

1. Planning Reliability
2. Investment Security
3. Transformation Security



The transition from the natural gas to the hydrogen economy requires **integrated regulation with planning security, investment security and transformation security.**

UPSTREAM PRODUCTION

MIDSTREAM TRANSPORT

DOWNSTREAM DEMAND

High demand potential for CO_2-free hydrogen

Steel and chemical industry

+ Small quantities of hydrogen can already be used in steel production. **In the future, the demand for CO_2-free hydrogen will increase**.
+ There is **already a large demand for H_2 in ammonia production** with **high decarbonization potential**.

Refineries and transport sector

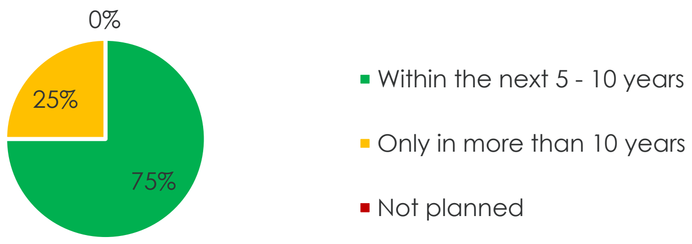
+ Conversion of **high demand to CO_2-free hydrogen** contributes to decarbonization of the **petroleum sector.** In the long term, however, H_2 demand will **decrease** again due to the increasing electrification of the transport sector.
+ **H_2 demand in the transport sector will grow slightly** until 2030 and depends on the development of alternative technologies and transport infrastructure until 2050.

Heat and power sector

+ In the **heating sector**, **large sales volumes** can be tapped by **blending CO_2-free hydrogen** into the natural gas network. The development of the heating market can make a decisive contribution to achieving the political demand targets.
+ Blending also **leads to lower emissions** in the power sector

How do you see your hydrogen demand developing by 2030?

Do you plan to use decarbonized hydrogen in the future?



The decarbonization targets in all demand sectors require the **switch to CO_2-free hydrogen** and provide potential for increasing the already relatively large demand. With the help of a **higher blending rate** in **the gas grid**, the enormous demand potential in the heating market can be tapped.

Use of CO_2-free hydrogen becomes more economically attractive

Steel and chemical industry

+ Conversion to **CO_2-free hydrogen increases operating costs**. However, sustainable **new investments become more attractive** due to the long technical service life **Targeted incentives** for investment in H_2 technology secure key industries.

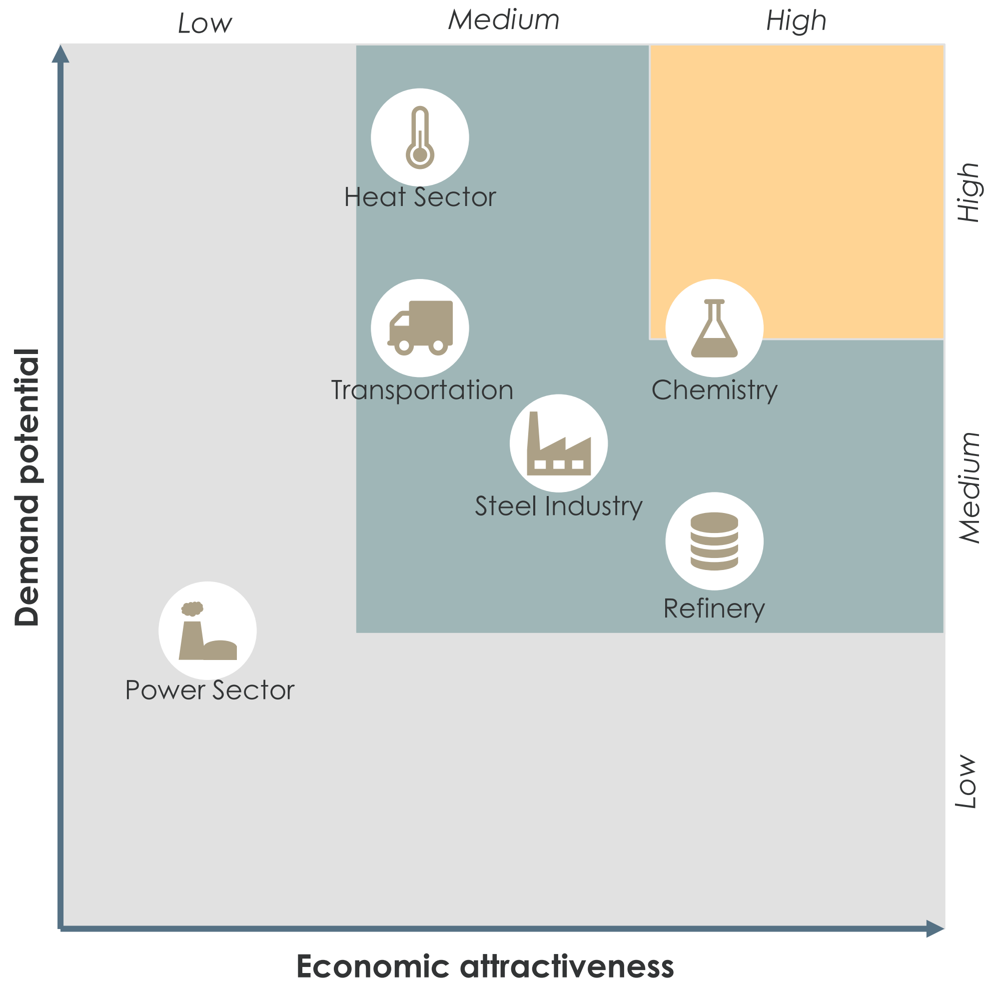
Refineries and transport sector

+ **RED II** - Directive creates **incentives for CO_2-free** hydrogen in refineries. In the transport sector, rising fuel or emission costs in the short term favor the switch to hydrogen and synthesis products, which are in direct competition with battery use. **The greatest potential is seen in the hard-to-electrify modes of transport.**

Heat and power sector

+ H_2 deployment in the heating sector **offers relatively favorable demand-side decarbonization potential**, as no additional investments are required. Here, the CO_2 price development can be a **significant driver** of economic viability. H_2 use in power plants is hardly economically feasible in the medium term.

Demand potential and economic attractiveness in demand sectors



Decarbonization of industrial processes with CO2-free hydrogen is becoming more attractive. Use in the heat and transport sectors shows great demand potential, but so far only moderate economic attractiveness and requires **incentives for sustainable new investments**.

Lack of network access is major obstacle for consumers

Steel and chemical industry

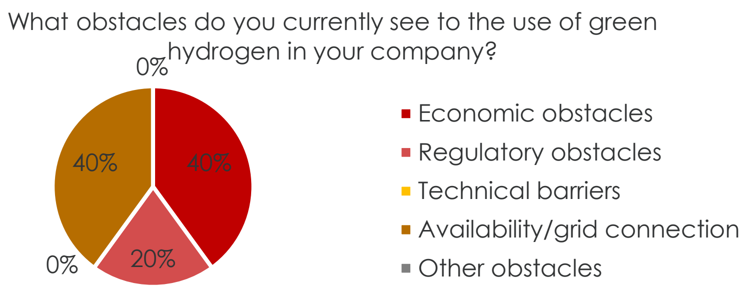
+ According to the survey, the primary obstacles to the application of **green hydrogen** in industrial processes are economic and a **lack of network access**.

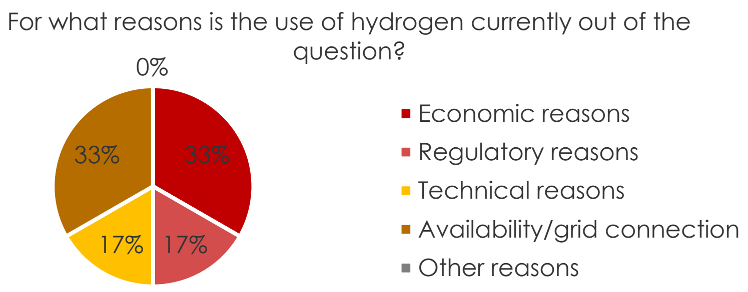
Refineries and transport sector

+ The **transport sector shows high demand potential** and medium economic attractiveness. Applications in heavy goods, shipping and air traffic appear to make sense in the long term, but there is a **lack of network infrastructure** to ensure decentralized provision.

Heat and power sector

+ The **large demand potential of hydrogen in the heating sector** is currently considered rather secondary by policymakers but shows advantages due to the low conversion costs. Here, **a higher blending rate in the natural gas grid is required to achieve the political demand targets for 2030** with the help of the heating market.





In addition to economic incentives, the **development of a network infrastructure for the spatial decoupling of production and demand** is absolutely necessary for the **cross-sectoral use of the decarbonization potential of CO_2-free hydrogen**.

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