HYDROGEN BAROMETER 02/21_

Independent assessment of the hydrogen market development in Germany

E-Bridge
competence in energy

July 2021

The hydrogen barometer

Welcome to the 2nd edition of the E-Bridge H_2 Barometer. It serves investors, legislators and other stakeholders to assess and evaluate the existing framework.

The assessment is based on E-Bridge's internal analyses as well as external market assessments. To this end, companies from all three stages of the value chain have been asked for their assessment at irregular intervals. Since the last edition of the Barometer, subsidies amounting to EUR 8 billion have been awarded and the legal framework for regulating the H_2 economy has been created with the EnWG amendment. In this issue, we assessed the impact of these steps on the investment climate.

We will cover the impact of the European Commission's "Fit for 55" legislative package, published just recently, in the 3rd issue of the Barometer. Please look forward to it already.

Sincerely, yours

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Brief overview: EUR 8 billion in subsidies provide important impetus, but EnWG amendment is not meeting expectations

Upstream/ Production — Mainly positive

- **IPCEI support for 2 GW of electrolysis capacity** is important step towards achieving 5 GW capacity target.
- **Additional electricity demand** from electrolysers is also recognized by politicians.
- The majority of the Hydrogen Council is supporting the **use of blue hydrogen** as a transition technology.
- *Still necessary:*
  - **Structured support of operating costs (OPEX)**
  - Substantial **increase** and implementation of **RE expansion targets**.

Midstream/ Transport — Mainly negative

- **Vision of a European grid infrastructure** creates link between generation and consumption centers.
- Funding under IPCEI cannot replace **lack of financing concept for systematic grid expansion**.
- **The new "transitional regulation" in the EnWG points in the wrong direction** due to the lack of alignment with gas regulation and "idiosyncratic" new regulatory elements.
- **Little progress** in creating planning, investment and transformation certainty.

Downstream/ Demand — Balanced

- Large-scale projects are given the **opportunity** with IPCEI **to implement hydrogen technologies** and further establish **demand for decarbonized hydrogen**.
- Selection of projects shows **varying attractiveness of sectors** and political priorities.
- Particularly **many projects in the steel sector** and refineries will receive funding.
- The heating sector as consumer has so far received **little attention in the promotion process**.

- The funding of **the IPCEI projects across all three stages of the value chain** with a total volume of 8 billion euros **represents an important milestone in the ramp-up of the national hydrogen economy**.
- The **necessity of using and importing blue hydrogen** as well as **increasing the national RE expansion targets** is increasingly being recognized by politicians.
- The urgently needed **long-term planning, investment and transformation certainty, particular in the midstream sector, has not been achieved** by the EnWG amendment.

Hydrogen as prominent topic in the federal election*

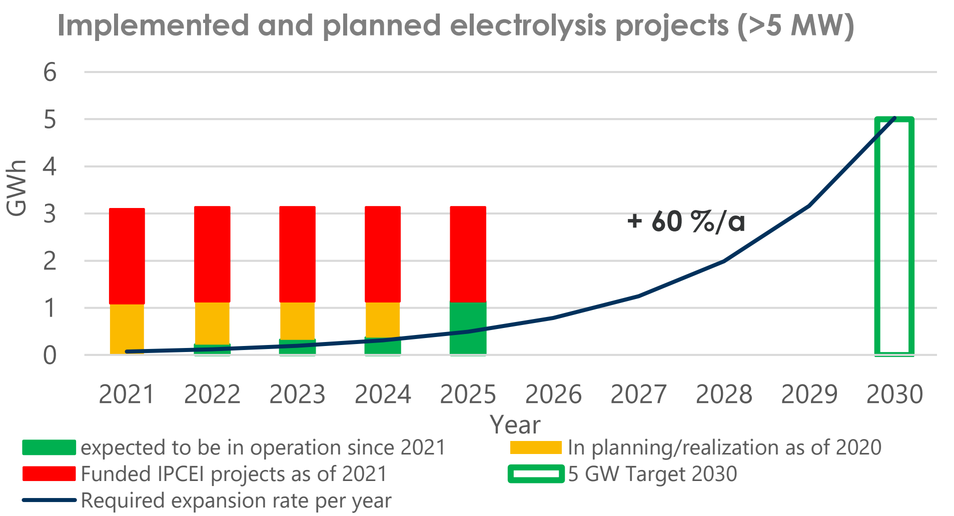
	Upstream / Production	Midstream / Transport	Downstream / Demand
CDU CSU	▪ In addition to green hydrogen, **blue hydrogen will also be accepted** for a transitional period ▪ Further development of **H_2 import promotion** through "H_2 Global“	▪ Development of the required H2 infrastructure based on existing infrastructure ▪ Expansion of gas grids and upgrading of **H2 feed-in**	▪ Use as basic material in the chemical industry or in the steel/cement industry ▪ Truck and ship transport as short- and medium-term applications in mobility
SPD	▪ Generation based on renewable energy ▪ Selective use for **non-electrifiable sectors**	▪ **More speed required for the expansion of hydrogen pipelines** ▪ Infrastructure planning should extend beyond 2025	▪ Steel and transport called (cars, trucks and shipping and aviation). ▪ Use in hydrogen trains
BÜNDNIS 90 DIE GRÜNEN	▪ Hydrogen must be **produced from renewable energy** ▪ Massive RE expansion offensive and reform of levy system needed	▪ Infrastructure for import must be established ▪ Fair cooperation with **wind- and sun-rich countries**	▪ Use of hydrogen very selective; **use of fossil technologies as illusion** ▪ Industry and aviation as possible applications
Freie Demokraten FDP	▪ **Use of blue and turquoise hydrogen** also planned for ramp-up ▪ Goal: large quantities at affordable prices	▪ No direct statement on infrastructure ▪ However, import of hydrogen in the course of a **European alliance** favored	▪ Substitution of fossil fuels in steel, transport (cars, ships, aircraft) and **heating sectors**
DIE LINKE.	▪ **Exclusively green hydrogen favored** ▪ Generation targeted for non-electrifiable sectors	▪ No statement	▪ Steel, chemicals, aviation and maritime transport, and reverse power generation. ▪ **Heat and remaining transport sector not favored**

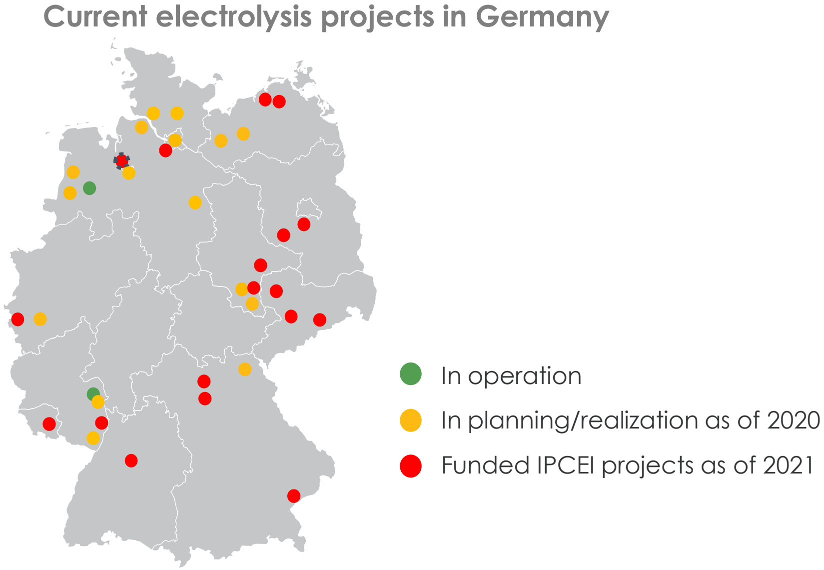
*No concept available in the AfD party program.

+ Only CDU/CSU and FDP include **technology to bridge the expansion targets for green hydrogen and the overall H_2 expansion targets** in their party programs.
+ SPD calls for the **creation of long-term planning certainty**, which is also frequently demanded in the industry, but without naming any concepts for financing.
+ Green Party is focusing - also in the transition phase - on the **exclusive production of hydrogen from renewable energy** and linking this to a comprehensive reform of taxes and levies.

EUR 8 billion to promote hydrogen projects

- With the announcement of the awarded projects under the "IPCEI" funding program, 62 projects will receive funding totaling € 8 billion. In addition to projects for the production of green hydrogen, the German government is also funding the transformation of hydrogen pipelines and explicit projects in the downstream sector.
- 19 project proposals with a projected electrolysis capacity of 2 GW will be supported. This corresponds to 40 % of the 5 GW aspired in 2030.
- Taking into account existing projects, electrolysis capacities of at least 2 GW will nevertheless have to enter the planning phase in the near future in order to achieve the expansion targets for 2030.
- 25 % (€ 2 billion) of the subsidy will go to the steel sector. Here, very high CO_2 savings can be expected through the replacement of coking coal.
- On the midstream side, support is also being provided for the development of hydrogen infrastructure. The IPCEI could create 1,700 kilometers of hydrogen transport pipelines. The largest projects are GET H2, AquaVentus, and HyPerLink.





With the comprehensive IPCEI funding, the German government has sent a clear signal for the concrete implementation of the hydrogen strategy.
However without a clear regulatory concept, **this will not be enough to achieve the 2030 expansion targets.**

UPSTREAM
PRODUKTION

MIDSTREAM
TRANSPORT

DOWNSTREAM
DEMAND

Germany sets criteria for green hydrogen

The amended Renewable Energies Ordinance defines the "production of green hydrogen".

Positive in this respect are :

- Consideration of new and de-subsidized installations to maximize the **potential of unsubsidized renewable electricity**.
- The **elimination of direct measurement** of coincidence of time using guarantees of origin as a proven balancing instrument

The disadvantage for investors, on the other hand, is:

- The **limit of 5,000 or 6,000 full-use hours** as a pragmatic proxy for meeting the concurrency requirement.

The demand for simultaneous production of RE plants and electrolysers is certainly to be welcomed in the medium term. **In the short term, however, this requirement inhibits the necessary rapid market ramp-up.**

Integrated system and site planning that efficiently connects RE hubs, electrolysers, and consumers via H_2 grids **could avoid potentially high redispatch costs**.

Germany - Essential requirements for green hydrogen (Ordinance on the Implementation of the Renewable Energy Sources Act 2021):

- No location criteria
- Operation with a **maximum of 5000 h hours of use/later 6000 h**
- Demonstrably from plants for the generation of **electricity from renewable energy sources** (within the meaning of § 3 EEG)
- Share of electricity of at least **80 percent from locations in the price zone for Germany**/maximum 20 percent from plants outside Germany
- Electricity purchased from the **grid based on guarantees of origin (HKN)**

EU - Essential requirements for green hydrogen (according to draft "delegated Regulation European Commission"):

- **Principle of additionality** for the renewable electricity purchased.
- **RE plant** must be operational within 12 months and is built without subsidies
- **Principle of simultaneity:** proof that hydrogen production takes place in the same quarter hour as green electricity production
- **No grid congestions between green power production site and electrolysis plant site/sites** should be in same bidding zone
- Renewable electricity used for production **must not be subsidized**

- The pragmatic definition of the criteria for green hydrogen facilitates the rapid market ramp-up - continuing uncertainty due to open definition at the European level.
- Furthermore, the definition of the criteria lacks integrated system planning. This creates the risk of infrastructure restrictions.

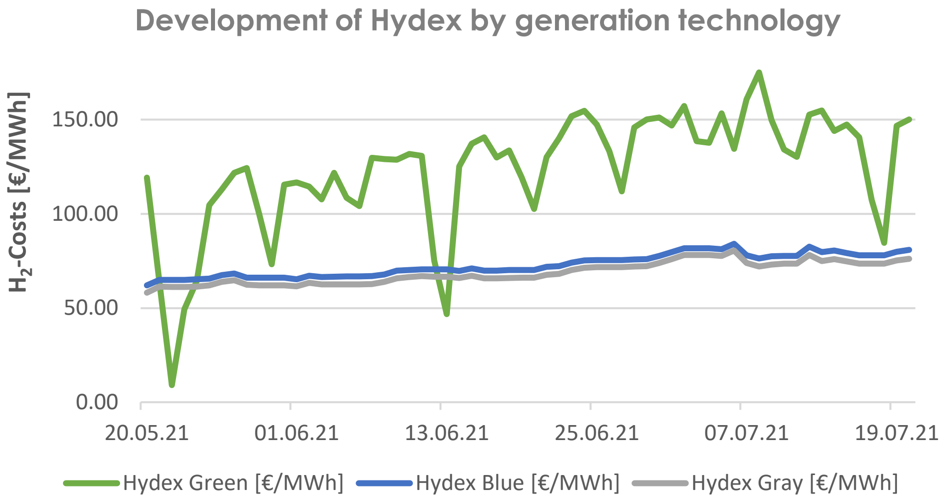
Favorable electricity costs as the key to competitiveness

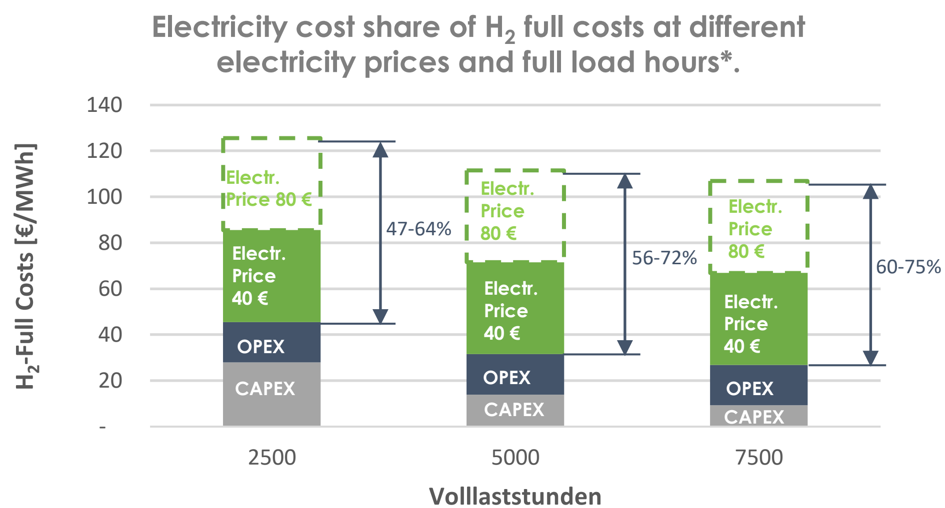
Electricity costs based on guarantees of origin rise

- If green electricity for electrolysis is purchased on the electricity market based on guarantees of origin, the electricity costs are exposed to fluctuations and price movements on the electricity market.
- The production costs for green H_2 (Hydex Green) have increased significantly since the beginning of the year compared to the costs for gray and blue H_2 (see figure above).
- Main reason for the rise in H_2 prices and the increase in the spread is the rise in CO_2 prices.

Electricity costs have significant impact on full cost of green hydrogen

- Electricity costs account on average for more than 50 % of the total costs of H_2 production.
- At high electricity prices and high utilization rates, the share can increase to 2/3 or even 3/4 of the full costs (see figure below).
- This illustrates the need for low electricity costs in order to operate electrolysis plants competitively even at high utilization hours.





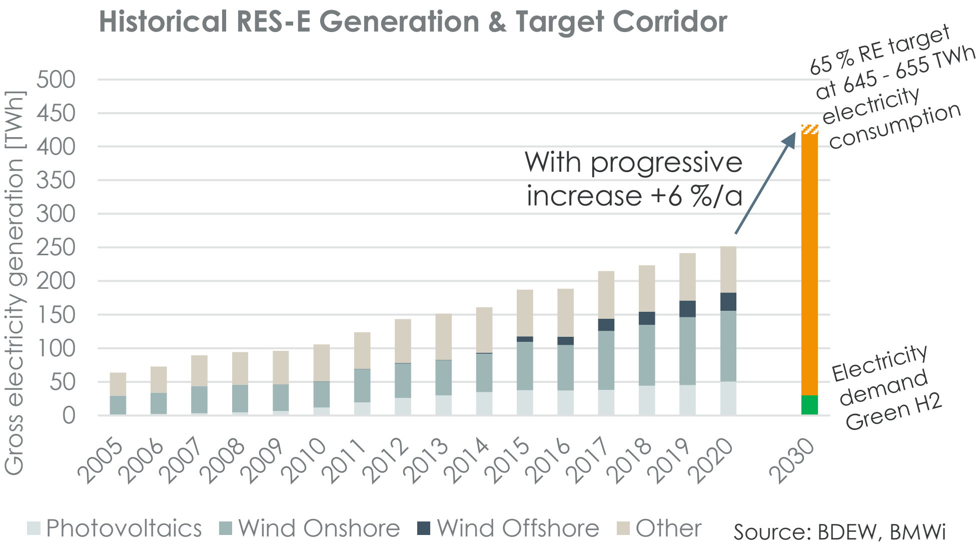
*)Forward market prices electricity/gas/CO2; Capex: electrolyzer 800 €/KW SMR o.CCS 800 €/kW; SMR w.CCS 1450 €/kW; Opex: electrolyzer 2.2 %; SMR o.CCS 4.7 %; SMR w.CCS 3 %, 4000 operating hours, no EEG levy, electricity tax, grid charges for electrolysers; (lower) calorific value

The competitiveness of green hydrogen depends on the availability of low-cost renewable electricity. High electricity market prices have a negative impact on the competitiveness of green hydrogen.

Additional renewable generation capacity

- The production of green hydrogen ensures national value creation and reduces dependence on imports. At the same time, very large amounts of renewably generated electricity will be required.
- According to current estimates by the BMWi, electricity consumption will increase to 645 - 655 TWh by 2030, of which electrolysers alone will cause an additional demand of 30 TWh.
- The consequences of the increased demand are illustrated by an approximation of additionally required renewable generation capacities triggered by electrolysers alone.
- If the demand for green H_2 were met exclusively by PV plants, 32 GW of additional PV plant capacity would be needed. Meeting the demand exclusively by onshore wind would require an additional 16 GW. With a mix of technologies, the demand is reduced accordingly.
- Based on the historical amounts of RE energy generated, it is clear that a different dimension of renewable generation capacity expansion is needed quickly.
- Considering the limits of the energy system, for example with regard to grid expansion, intelligent concepts for integrating the additional generation capacities are increasingly coming to the fore.

Assumptions: Full load hours PV 950 h; Wind Onshore: 1900 h



Required measures:

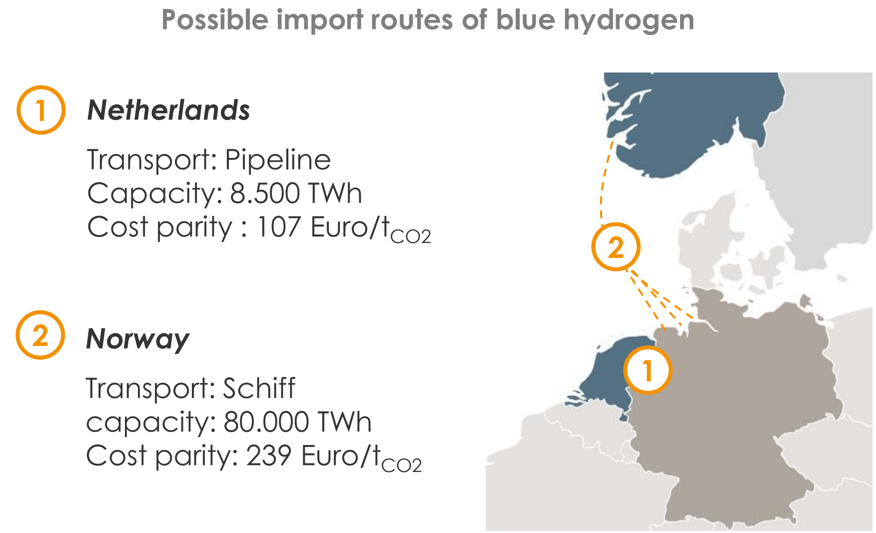
1. The capacity of onshore wind must be increased significantly faster so that synergies of wind and PV can be leveraged.
2. Additional generation capacity must be efficiently integrated into the energy system through the targeted construction of plants.
3. The tax and levy system must encourage system-serving behavior and enable harmonization of generation and consumption.

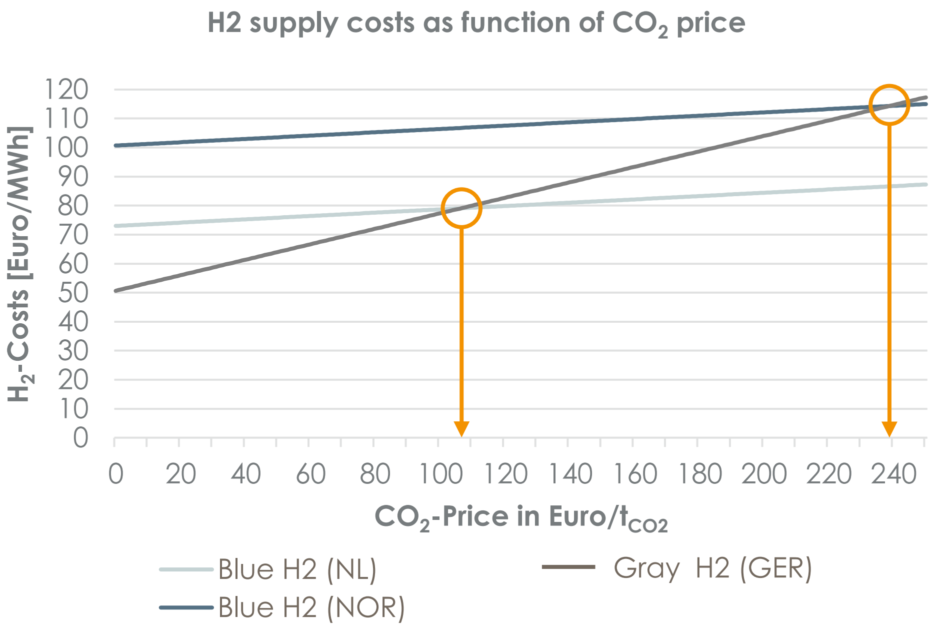
Decarbonization and ramp-up of the hydrogen economy require a new dimension in the addition of renewable generation capacity in Germany. At the same time, additional capacities must be integrated into the system as efficiently as possible and appropriate framework conditions must be created.

Blue hydrogen shows considerable potential in the ramp-up phase

- The importance of this technology for decarbonization has increased significantly in recent years, particularly in other European countries:
  - The Northern Lights project (investment volume: €2.6 billion) received funding approval (80%) from the Norwegian government last year and is scheduled to be operational from 2024.
  - The investment decision for the Porthos project in Rotterdam is expected this year. If the decision is positive, operations are scheduled to start in 2023.
- The enormous potential of this technology is manifested in the geological storage capacity. In the Netherlands alone, the storage capacity for blue H2 is 8,500 TWh, and in Norway it is as high as 80,000 TWh (In comparison, the projected H2 demand in 2030 in Germany is 100 TWh).
- Due to the existing natural gas deposits, both countries offer themselves as exporters. While transport from NL is possible by pipeline, Norwegian capacities have to be developed by ship transport.
- This creates differences in cost parity. Imported blue H_2 from the Netherlands is already competitive at a CO_2 price of 107 Euro/tCO_2. For an import from Norway, a price of 239 Euro/tCO_2 has to be reached.
- Consequently, if CO_2 prices continue to rise, market-driven demand for blue H_2, especially from the Netherlands, can be expected.

Source: own calculation based on Cerniauskas et al. (2021)





The import of blue hydrogen shows considerable potential as a bridging technology to close the gap between the demand for decarbonized hydrogen and green generation potential. To this end, import routes and trading partnerships with potential exporters of blue H_2 should be developed.

UPSTREAM
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DOWNSTREAM
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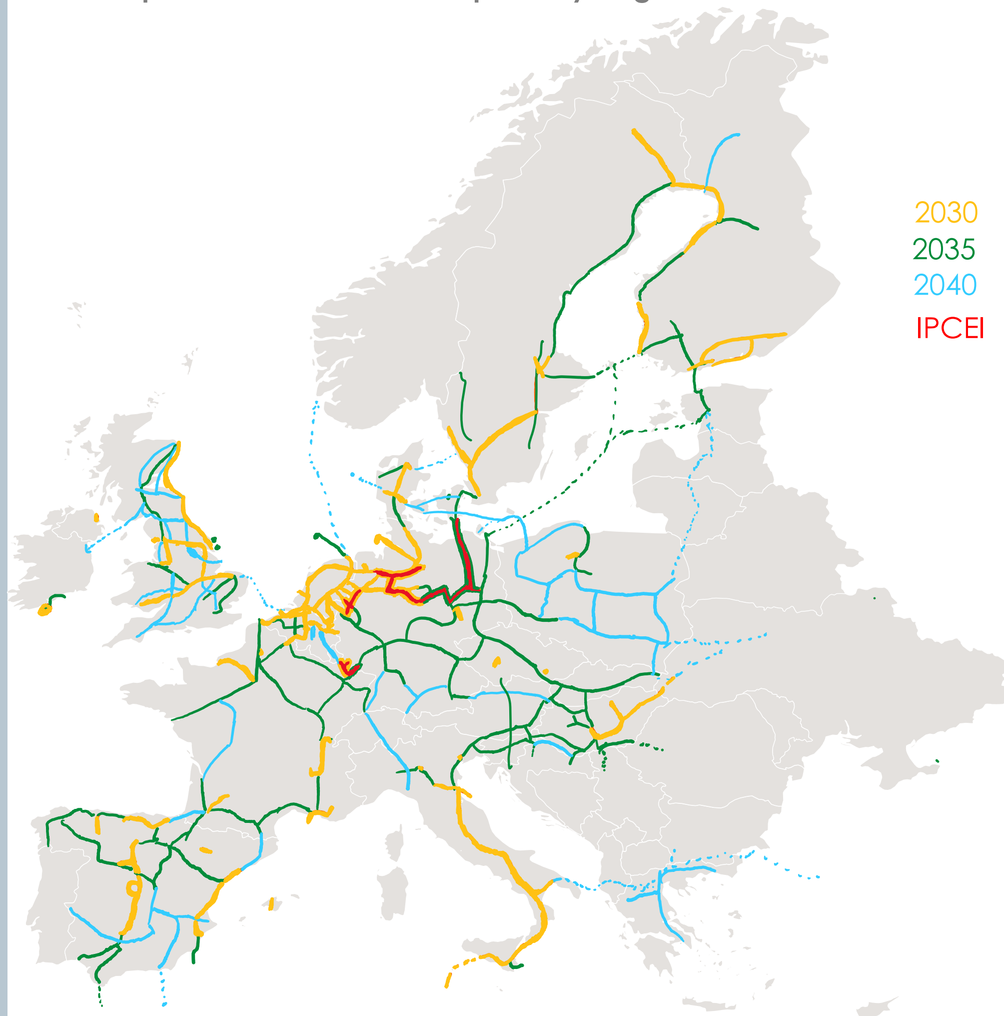
Establishment of an international transport infrastructure

- With the "European Hydrogen Backbones", the transmission system operators present an impressive vision of the transformation of the necessary infrastructure.
- With the implementation of the backbone, regions with optimal generation conditions can be successively connected with consumption regions. This addresses two problems.
  - On the one hand, the backbone can provide large quantities of hydrogen, which are needed for the transformation of large consumers.
  - On the other hand, hydrogen can be imported from regions where low-cost production is feasible. In Spain, for example, the coupling of PV and electrolysers allows optimal production conditions. At the same time, the backbone can also be used to import blue hydrogen from Norway or the Netherlands.
- The funding of the first sections under the IPCEI program represents a milestone in implementation. However, this can only be a first step in the fundamental transformation.
- The transmission system operators are making advance payments with the extensive studies on which the vision is based. Policymakers should ensure the successful implementation of the vision by providing planning and investment security.

Implementation of the European Hydrogen Backbone on schedule



Source: Gas for Climate

With their vision of an international infrastructure, network operators are providing important impetus and assuming their responsibility as enablers of the transformation. Policymakers must now create the appropriate framework conditions so that the transformation can be implemented successfully.

Provisional "H_2 grid regulation light" with short life expectancy

- With the amendment to the German Energy Act (EnWG), a legal regulatory framework for hydrogen networks came into force for the first time on July 1, 2021. However, its life expectancy is rather short, because according to a resolution of the Bundestag:
    - the BMWi is to present a concept for joint regulation and financing of gas and hydrogen networks as early as the end of 2022,
    - and as soon as joint regulation becomes possible under European law, the German government is to submit a corresponding bill.

A need for legislative improvement is already foreseeable today because of

- the fragmentary nature of many regulations, for example on network access and network charges, the unnecessary deviation from proven regulatory structures for electricity and gas networks and the intended joint regulation with gas networks,
- the lack of systematic co-financing of the hydrogen networks, which avoids prohibitive network fees in the start-up phase, the lack of a holistic network demand planning for hydrogen networks as well as integrated planning for gas and hydrogen networks or a system development with electricity networks and electrolysis sites.

Key points of criticism

Opt-in regulation:
The right to opt in exists not only for existing industrial networks, but also for new infrastructures. It is unclear how a foreseeable future re-regulation is to take place. In view of the unclear remuneration of regulated hydrogen networks, investment incentives are unlikely to be provided by the right of option.

Negotiated grid connection and access
Negotiated network connection and access without the specification of clear network access conditions jeopardizes investment security for upstream and downstream projects.

No regulation for blending hydrogen into the natural gas network
The big unknown in hydrogen development thus remains the heating market. Here, too, there is a foreseeable lack of planning certainty.

Elementary regulatory gaps for grid demand planning and grid financing (see also left page)
Uncoordinated and non-regulated H_2 infrastructures threaten to lead to undesirable developments and higher system costs.

Conclusion: Despite separate network financing due to EU law, it would have been possible to follow the existing gas network regulation as closely as possible today and would have been better in the interests of legal, planning and investment security. This opportunity was missed.

For the time being, there is little planning and investment certainty for hydrogen networks. The "actual" regulatory framework is probably not foreseeable until the end of 2022 at the earliest.

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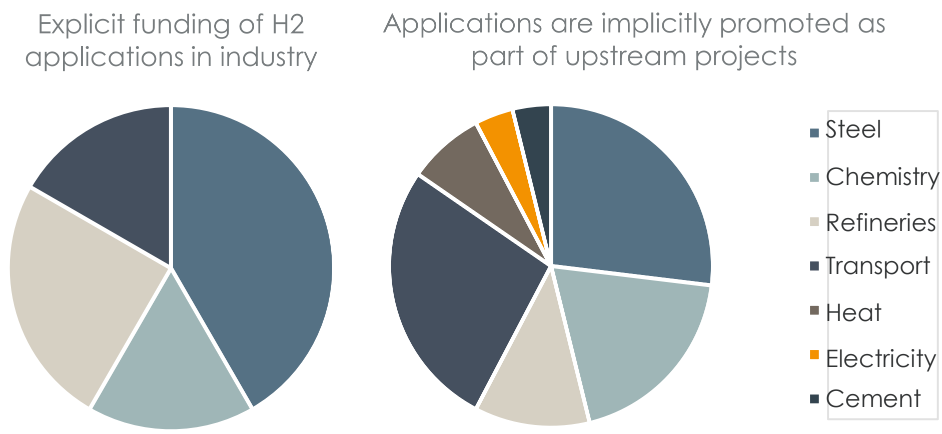
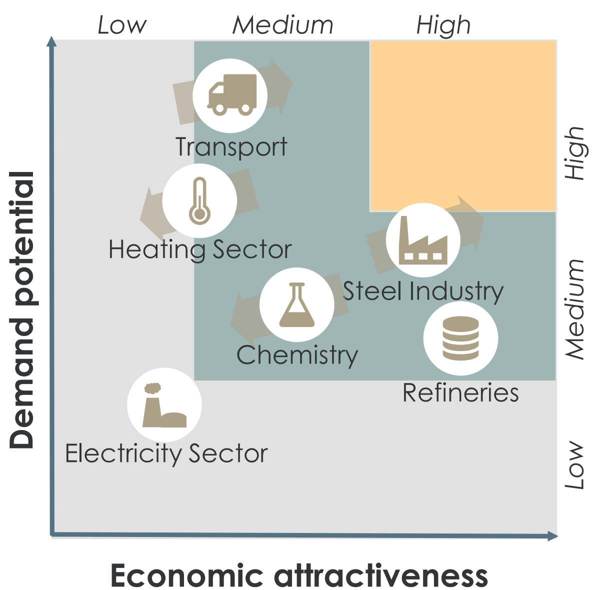
Supported application sectors within IPCEI call for proposals

- **In the downstream sector, the majority of projects are in the steel sector**. For example, ThyssenKrupp, Salzgitter, SHS Saarstahl and two projects by Arcelor Mittal received funding commitments. The total funding of around 2 billion euros demonstrates the high attractiveness of the sector.
- The steel sector is followed by funding for applications in **refineries**, e.g. the Heide refinery or Bayernoil. Projects from the chemical sector also receive funding, albeit in smaller numbers. **The entire industrial sector has a huge hydrogen demand** of up to 500 TWh in 2050, which could be as high as 50 TWh in 2030 driven by investment cycles.
- Compared to the other sectors, **support for the transport sector also includes projects where the direct application of hydrogen is not the immediate focus**. This shows that further steps are still needed to make the application in the transport sector ready for the market. In the long term, however, the sector is expected to have a very high demand of up to 300 TWh by 2050.
- **Hydrogen as an energy carrier** has a demand potential of up to 200 TWh by 2050 in the heating sector. While blending can already be implemented in the short term, pure hydrogen networks are only expected in the long term.
- In the IPCEI program, **only one heat sector project receives implicit funding**, which illustrates the lack of political commitment.

Sources: Fraunhofer ISI, ISE, IEG "Metastudie Wasserstoff"; PM of BMWi



Demand potential and economic attractiveness in demand sectors



The selection of IPCEI projects shows the high attractiveness of hydrogen applications in the steel sector and in refineries. Further funding is needed to stimulate the transformation of all sectors.

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