Making renewable hydrogen cost-competitive

Policy instruments for supporting green H_2

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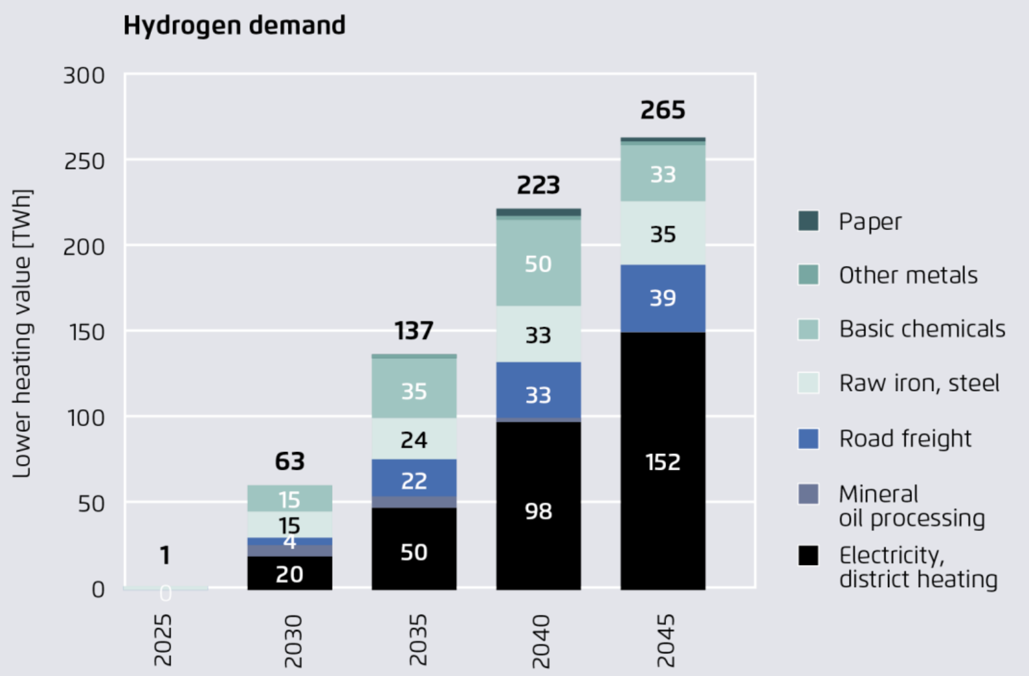
Agora Energy – Who we are

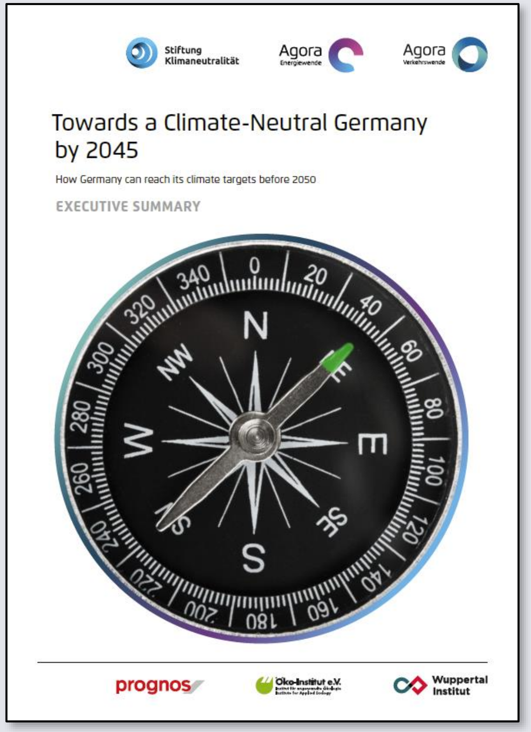
- **Think Tank** and **Policy Lab**
- Roughly **100 energy transition experts**
- **Independent** and non-partisan with diverse financing structure
- **Our vision:** a prosperous and **carbon-neutral global economy** by 2050
- **Science-based solutions and policy advise** to deliver **clean power, heat and industries** – in Germany, Europe and around the globe
- **Programmes in ~20 countries**, with offices in Berlin, Brussels, Beijing and Bangkok

Background:
Germany's demand for H_2 amounts to 63 TWh (2030) in the „Climate-Neutral DE 2045" scenario – for safeguarding security of supply in the energy system and to create a climate neutral industry.

Demand for CO_2-free H_2 in Germany between 2025 and 2045



Towards a climate-neutral Germany by 2045



Prognos et al. (2021); Note: Hydrogen only. In addition, Germany will need 158 TWh of Power-to-Liquid by 2045.

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Project overview: Making renewable hydrogen cost-competitive

Commissioned by: Agora Energiewende

Partners: Guidehouse, with research support from Becker Büttner Held

Question: Which policy instruments are best-suited to bring green H_2 to the applications that really need it to become climate-neutral?

Methodology:

→ Analysis of regulatory context and economics of renewable H_2

→ Analysis of policy instruments needed in 2020s and outlook beyond 2030

Results:

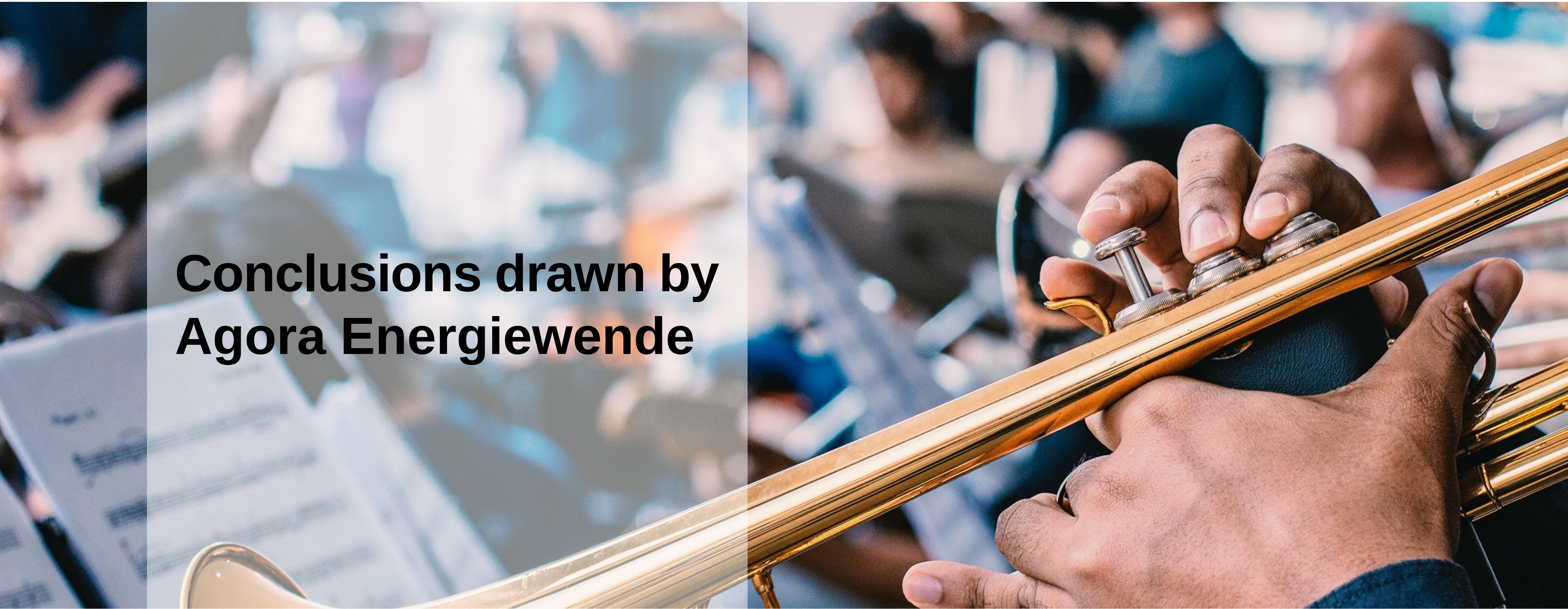
→ Policy instrument factsheets

→ Legal analyses of each instrument by BBH (forthcoming)

Download:

- Publication

Conclusions drawn by Agora Energiewende



There is a limited set of applications in all sectors that urgently need renewable hydrogen to become climate-neutral.

Applications that really need green molecules to become climate-neutral, in addition to green electrons

Green molecules needed?	Industry	Transport	Power sector	Buildings
Uncontroversial	· Reaction agents (DRI steel) · Feedstock (ammonia, chemicals)	· Long-haul aviation · Maritime shipping	· Long-term storage for variable renewable energy back-up	· District heating (residual heat load *)
Controversial	· High-temperature heat	· Trucks and buses ** · Short-haul aviation and shipping	· Absolute size of need given other flexibility and storage options	
Bad idea	· Low-temperature heat	· Cars · Light-duty vehicles		Individual buildings

* After using renewable energy, ambient and waste heat as much as possible. Especially relevant for large existing district heating systems with high flow temperatures. Note that according to the UNFCCC Common Reporting Format, district heating is classified as being part of the power sector.

** Series production currently more advanced on electric than on hydrogen for heavy duty vehicles and busses. Hydrogen heavy duty to be deployed at this point in time only in locations with synergies (ports, industry clusters).

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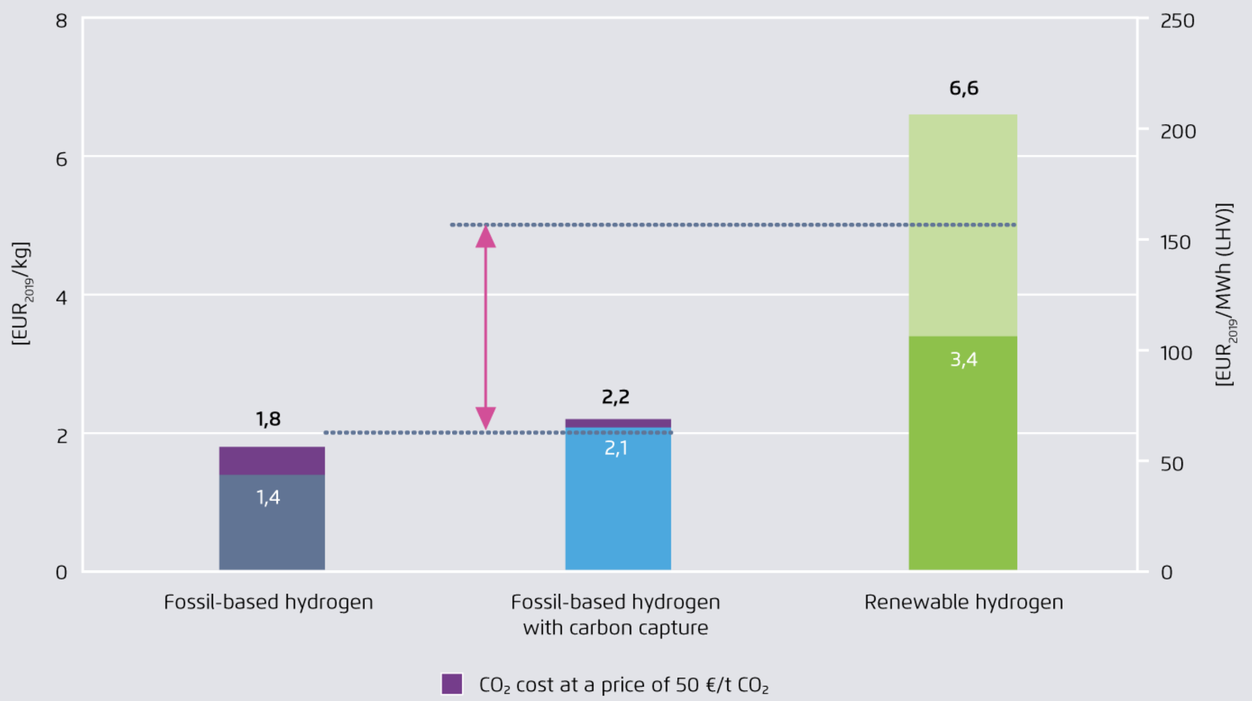
Ramping up renewable hydrogen will require extra policy support that is focused on rapid cost reductions.

Renewable hydrogen cost gap



The figures assume a natural gas price of €20/MWh and a CO_2 capture rate of around 75%. All figures are in 2019 euros.

Agora Energiewende (2021) based on BNEF (2021), Prognos et al. (2020), Hydrogen Europe (2020), Gas for Climate (2020), Agora Energiewene & AFRY (2021)

Renewable hydrogen cost gap:

→ Future electrolysis capacity for renewable H_2 estimated at 33 GW to 90 GW.

→ How to do project developers want to bridge the cost gap?

→ Anticipating higher willingness to pay among customers and/or some form of policy support?

The cost of renewable hydrogen depends on:

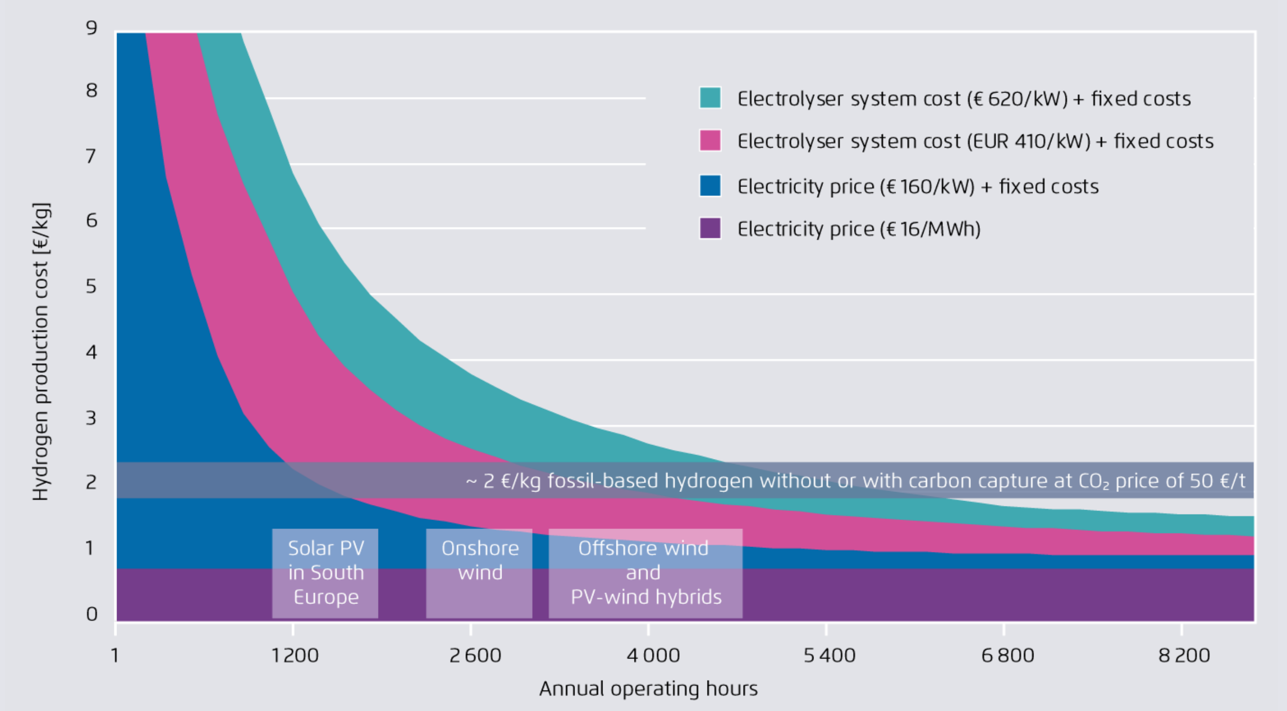
→ Cost of renewable **electricity** (which is on track to become cheaper anyway)

→ Annual **operating hours** of the electrolyser

→ **Electrolyser** system costs

Higher capacity factors will lower the cost of hydrogen

Renewable hydrogen production costs depending on operating hours



Agora Energiewende (2021) based on Guidehouse (2021)

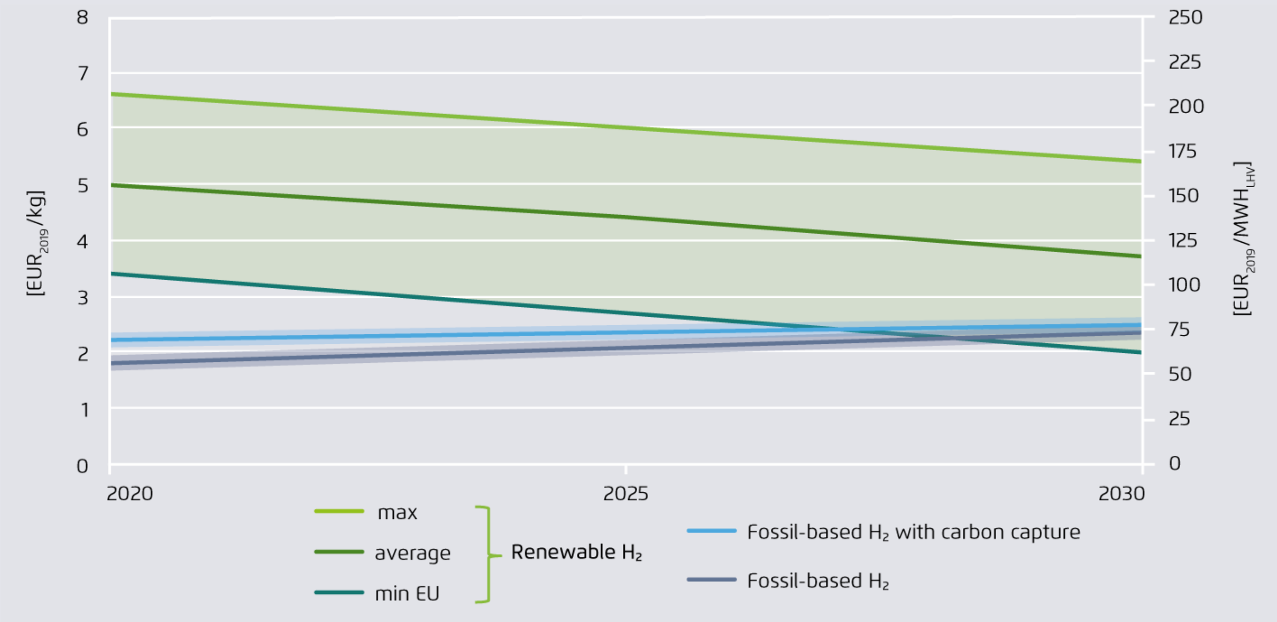
- **Cost of hydrogen can be lowered** by distributing the investment costs over as many annual operating hours as possible

At an **electrolyser system cost** of

- **€620/kW**, **more than 5,400 hours** are required to bring production cost below €2/kg (~ fossil-based H_2 with/without carbon capture)
- **€160/kW**, **just 1,500 hours** is sufficient to hit breakeven – making electrolysis in Southern Europe based on solar PV alone increasingly attractive.
- Note that operating costs would increase disproportionately at more than 5,000 operating hours if electrolysers use **grid electricity** and operate based on market prices for H_2 and electricity.

The costs of electrolysers will fall given economies of scale and learning-by-doing effects, but such deployment will only materialize with predictable and stable hydrogen demand.

Production cost of H_2 and fossil-based H_2 with and without carbon capture



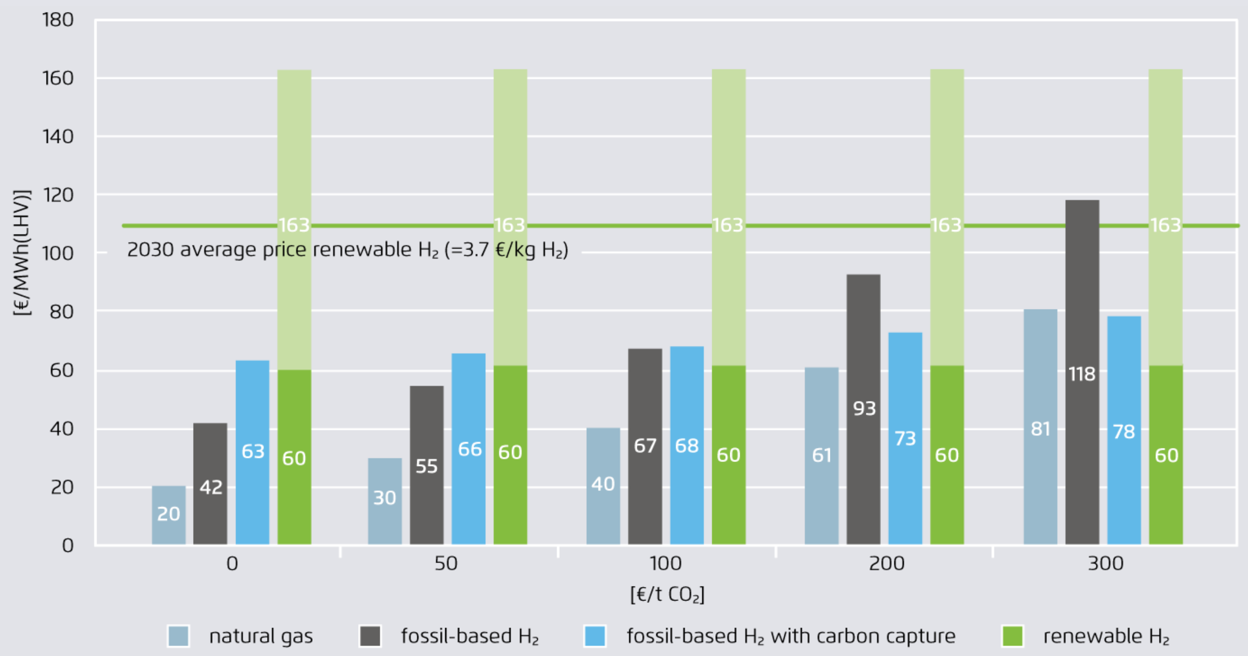
The price range for fossil-based H_2 reflects an implicit carbon price of €50/tCO_2 in 2020 increasing to €100/tCO_2 in 2030. For natural gas, a price of €20/MWh is assumed. The capture rate for fossil-based H_2 with carbon capture is assumed to be around 75%.

Guidehouse (2021) based on BNEF (2021), Prognos et al. (2020), Hydrogen Europe (2020), Gas for Climate (2020), Agora Energiewene & AFRY (2021)

- There is **nothing automatic** about those cost reductions. Someone needs to pay the learning curve.
- Electrolyser manufacturers need **predictable pipeline** of projects to invest in GW plants
- Yet this predictability is only possible through **policy support**, given the current economic uncompetitiveness of renewable hydrogen.
- Using taxpayer money to support renewable hydrogen needs **basic agreement** on where to prioritise investment.
- Therefore, renewable hydrogen needs to be channelled into **uncontroversial applications**.
- Conversely, a lack of common ground might **delay** the renewable hydrogen ramp-up, given the integral role of policy support.

CO_2 prices in the 2020s will not be high enough to deliver a stable demand for renewable hydrogen, reinforcing the need for a hydrogen policy framework.

Impact of carbon pricing on hydrogen production costs in 2030



For natural gas, a price of €20/MWh is assumed. The capture rate for fossil-based H_2 with carbon capture is assumed to be around 75%

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- **Carbon pricing** will be a cornerstone of the needed policy framework but is has its **limits** in the short to medium term.
- Even at CO_2 prices of **€100–200/t**, the EU ETS will not sufficiently incentivize renewable hydrogen production.
- Given low EU ETS prices, **additional policy support** instruments will be needed for a considerable time
- A general renewable hydrogen **quota is not sufficiently targeted** to induce adoption in the most important applications and comes with further problems related to technological compatibility, distribution and efficiency.
- Therefore, we need **other policy instruments**.

A policy framework to ramp up the market for renewable hydrogen should initially target the applications where hydrogen is clearly needed and a no-regret option.

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Overview of needed policy support for renewable H_2 in Germany and the EU

Support instruments for renewable hydrogen	Billion EUR per year			
	Germany		EU	
	Low	High	Low	High
Carbon Contracts for the transformation of 33% DE / 50% EU primary steel production capacity to H_2-DRI with current free allocation regime (2022–2035/2040) The instrument facilitates investments in breakthrough technologies. By offsetting the additional operating cost of breakthrough technologies, a CCfD de-risks long-term investments. Cost recovery: Through climate levy or EU-ETS revenues	1.1*	2.7*	4.1*	10.2*
CCfD for the transformation of 33% DE / 50% primary steel production capacity to H_2-DRI with effective CO_2-price gradually increasing from 50€/t (2021) to 90€/t in 2040	0*	1.6*	0*	6.1*
PtL quota for aviation (2025-2030 (10%) & 2030–2050 (increase to 100% by 2050)) By setting an EU-wide 10% quota in aviation, demand for e-kerosene is created, leading to a ramp-up in renewable H_2 and PtL production and further technological learning. A long-term pathway must be towards 100% climate-neutral e-kerosene. Cost recovery: Additional costs are passed on to end-users (aviation passengers)	1.4	1.9	10.3	14

...

The cost projection for the CCfD instrument in line 1 and 2 represent alternative and mutually exclusive scenarios with regards to the evolution of Europe's carbon leakage policy. Note that Guidehouse assumes an aviation quota of only 5%. See the report for a more comprehensive overview of policy support instruments.

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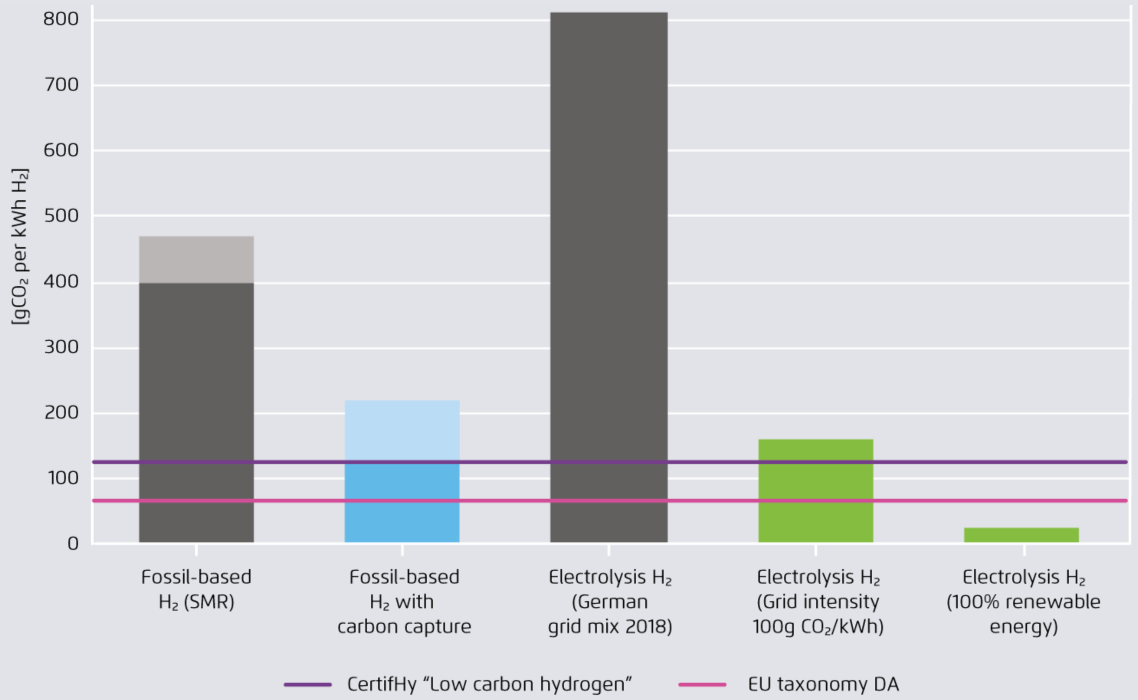
- → **Carbon contracts for difference (CCfD)** will enable European industry to start the transition to climate-neutral products.
- → A **power-to-liquid (PtL) quota** in aviation of 10% by 2030 would deliver clear market signals that Europe intends to import considerable volumes of liquid e-fuels
- → **Gas power plants** need to be 100% H_2-ready to back up renewables and meet residual heat load in district heating
- → Scalable **green lead markets** could help to create a business case for renewable H_2
- → **H_2 supply contracts** can enable competition between production in the EU and abroad.
- → The required **policy support** for renewable H_2 at the EU level is anticipated to cost **€10-24 bn p.a.**

The instruments need to be complemented by regulation for sustainability and system integration.

Lifecycle emission intensity by H_2 production route in gCO_2 per kWh H_2 (LHV)



LHV. Assuming a capture rate for fossil-based H_2 with carbon capture between 65% (for existing SMR) and 90% (for new ATR)

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Hydrogen from electrolysis…

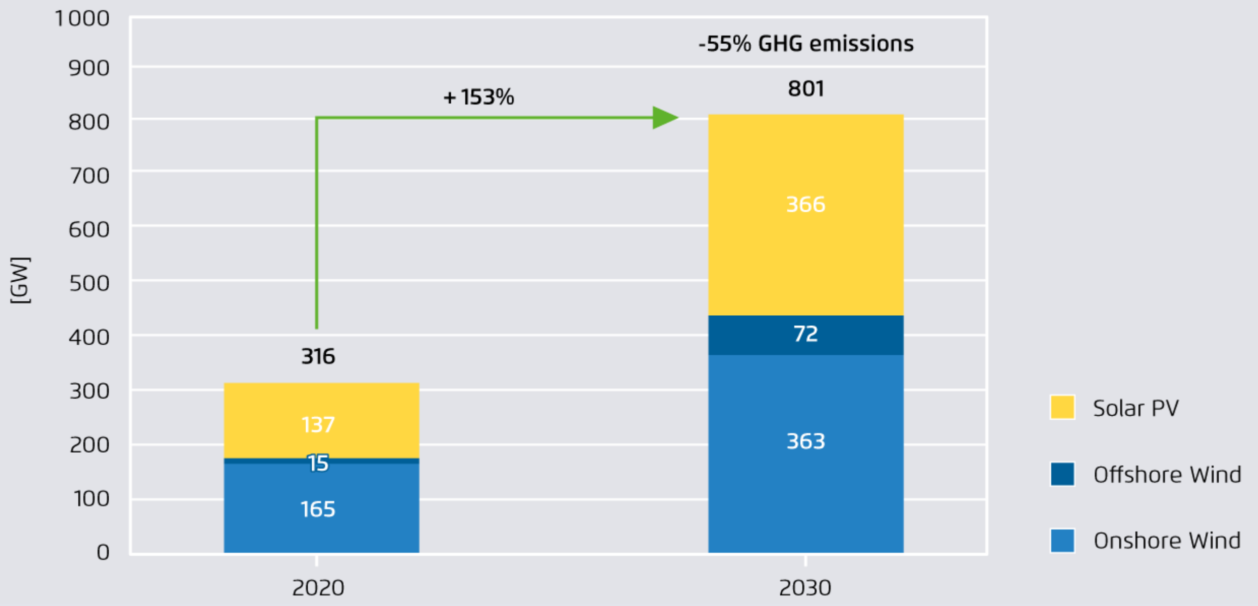
- → is **most sustainable** with 100% RES
- → can lead to **high CO_2 emissions** otherwise
- → needs **clear criteria** for climate neutrality and a roadmap for applying the criteria (industry may require different treatment)
- → needs **appropriate siting** for sustainability and system integration, given grid constraints

Fossil-based hydrogen with carbon capture…

- → has similar **emission** intensity as electrolysis with grid intensity of 100g CO_2/kWh
- → does **not need** additional policy support
- → should comply with strict **sustainability** criteria
- → criteria should be **ratcheted up** (climate-neutrality would require negative emissions)

Renewable hydrogen needs major additional renewable energy deployment.

Wind and solar generation capacity needed to reach -55% GHG emissions by 2030



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- **Pace of renewable H_2 expansion** will largely depend on the growth in renewables
- **801 GW wind and solar PV** are needed by 2030 to reduce GHG emissions by 55% relative to 1990, according to the European Commission's Climate Target Impact Assessment.
- **Hydrogen ambitions** beyond the COM's Impact Assessment may even require greater renewable energy expansion.

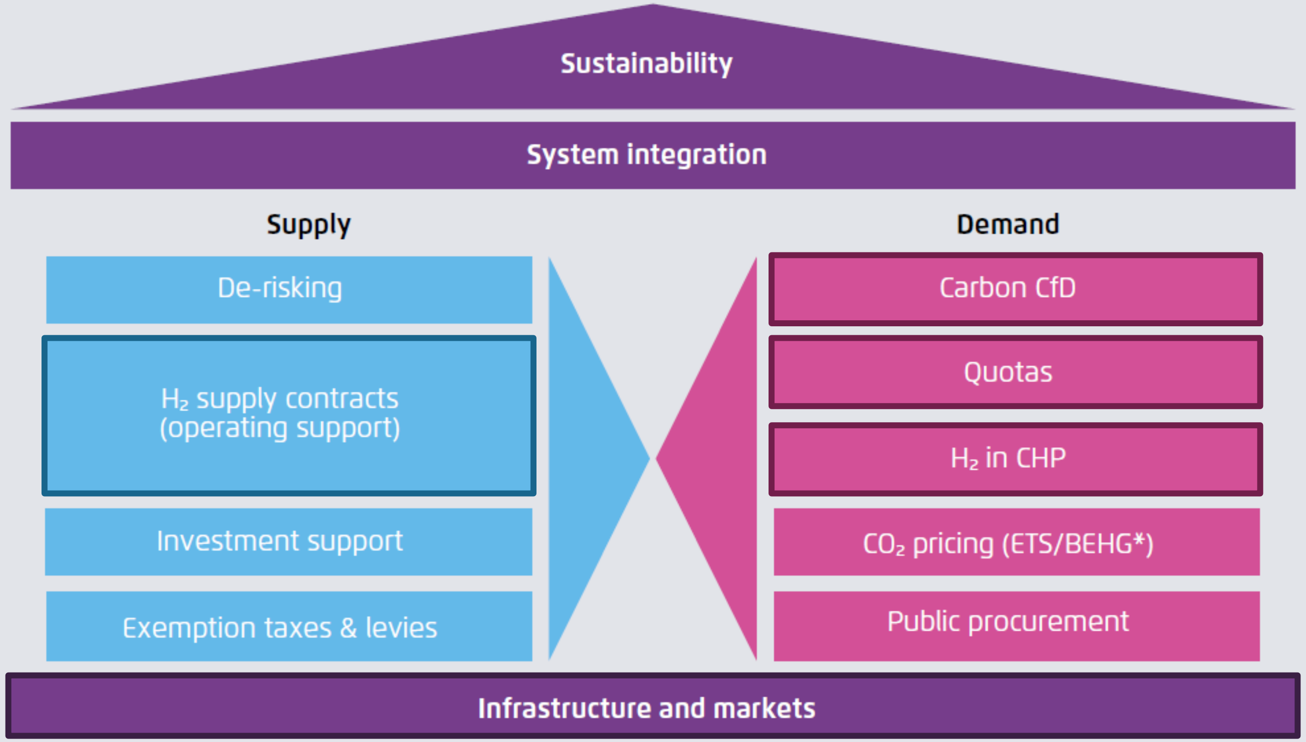
Key conclusions

1	There is a limited set of applications in all sectors that urgently need renewable hydrogen to become climate-neutral.
2	Ramping up renewable hydrogen will require extra policy support that is focused on rapid cost reductions.
3	CO_2 prices in the 2020s will not be high enough to deliver stable demand for renewable hydrogen, underscoring the need for a hydrogen policy framework.
4	A policy framework to ramp up the market for renewable hydrogen should initially target the applications where hydrogen is clearly needed and a no-regret option.

Study conducted by Guidehouse

Regulatory architecture –
Building blocks of a hydrogen economy

Enabling ramp-up in demand and supply of renewable H2 requires, next to policy instruments, an accompanying architecture of support



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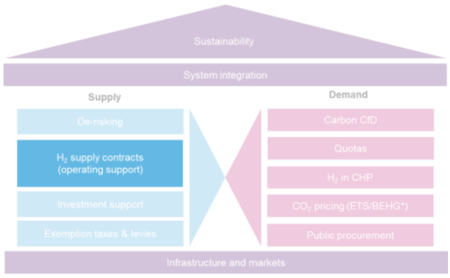


H_2 supply contracts – bridging the cost gap

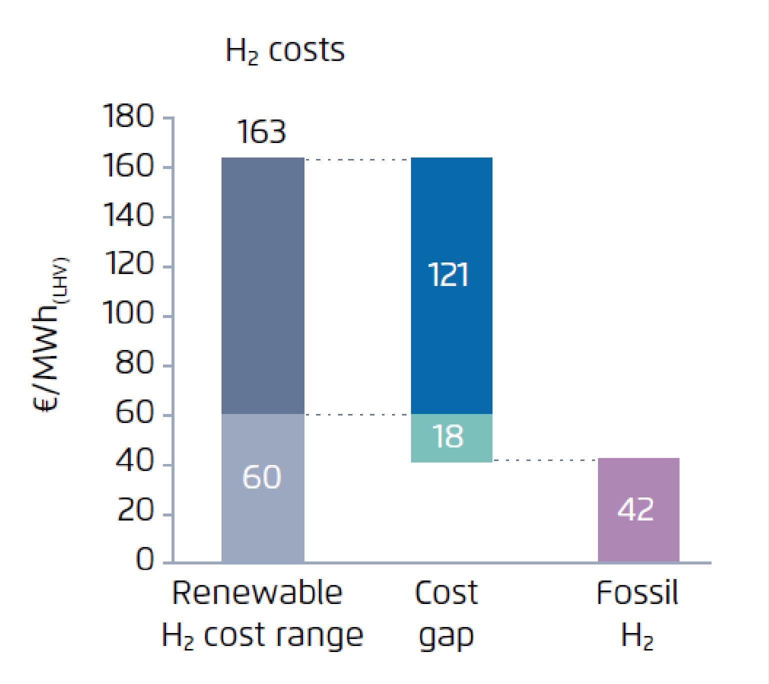
Goal: Cover for the difference between the lowest possible renewable H_2 production cost and the highest willingness to pay in a double auction model.

Design: H_2 supply contracts pay for defined time spans a fixed premium in EUR/t H_2. An intermediary entity administers the public funds to cover the difference. The instrument's focus is on the (German) industry sector.

Timing: In the **short term** (towards 2030), H_2 supply contracts must be tied to a fixed delivery location within Germany (integrated projects). In the **long term** (beyond 2030) the goal is to buy hydrogen from producers and sell it to end users via auctions.

Legal analysis: The instrument is in principle legally feasible. The instrument qualifies as state aid since the funds are from tax revenues. It must therefore be notified with the European Commission. Due to civil law regulations, the contractual period should be limited to 5, maximum 10 years.

Supporting H_2 imports with €0.8 bn to €5.3 bn year year can cover the difference between supply and demand effectively



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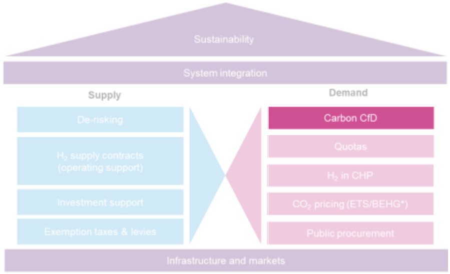


Carbon Contracts for Difference (CCfDs) – de-risiking breakthrough technologies

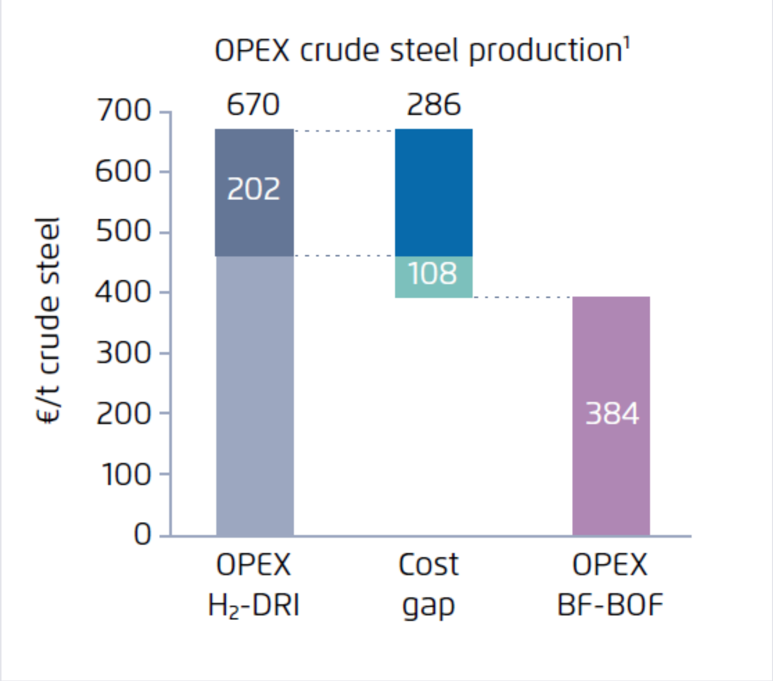
Goal: Facilitate investments by industry in breakthrough technologies by compensating the difference between the effective CO_2 price (EU-ETS) and the mitigation costs of a breakthrough technology.

Design: A CCfD can be awarded to industry on a project-by-project basis or in a competitive auctioning scheme. If the awarded party sells its product as green against a premium that remunerates the implied emission reduction, no funding is paid. A **labelling** of climate-friendly basic materials could incentivise off-takers to pay that premium, thereby creating **green lead markets**.

Timing: First CCfDs will start in 2022. With H_2 becoming cost competitive, increasing CO_2-prices and the development of green lead markets, the instrument can likely be phased out in the late 2030s.

Legal analysis: Legal feasibility depends on the specific design. A state aid notification would need to carried out. The CCfD must be designed in such a way that overfunding is avoided. The contract duration must therefore be limited from the outset and the tenders must be equipped with maximum bid limits. Due to the permissible aid intensities, 100% of the eligible costs can only be funded through tenders.

Enabling breakthrough technologies in industry requires funding in Germany between €1.1 and €2.7 bn for Germany and €4.1-€10.2 bn for the EU



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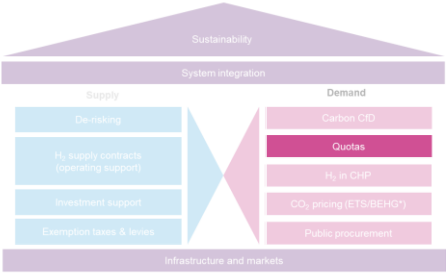


PtL quota for aviation – putting aviation on track to net-zero

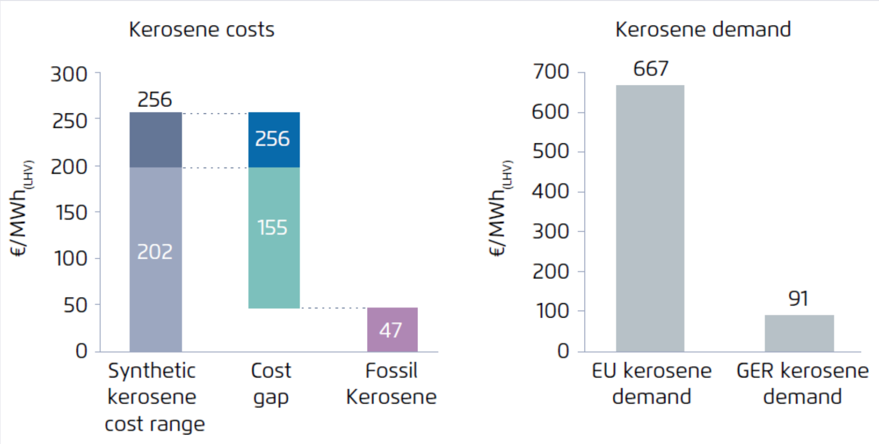
Goal: A PtL quota in the aviation sector creates demand for e-kerosene, a H_2 derivative.

Design: A sustainable aviation fuel (SAF) quota of at least 10% is implemented with a sub quota for PtL of at least 5%, to be reviewed in 2025, and, if feasible, increased to at least 10%. **Obligated parties** are all kerosene distributors for aviation in the EU. The price premium could be passed on through the airlines to consumers.

Timing: The quota obligation can only start a few years after its announcement, e.g. in 2025. PtL and other SAFs must cover 100% of kerosene by 2050. The PtL quota must therefore increase in coordination with a quota for SAFs.

Legal analysis: The instrument is in principle legally feasible. Non-European producers must be granted market access. The quota must be technically achievable and place no undue burden on obligated parties to fulfill the principle of proportionality. It may be challenged if the quota covers only e-kerosene and excludes bio-based kerosene.

Putting aviation on track could lead to costs at EU level between €5.2-€7 bn per year and in Germany to costs between €0.7-€1 bn per year



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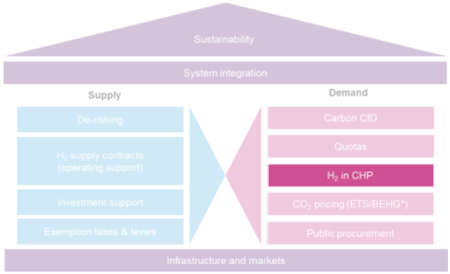


Support for H_2-fuelled CHPs – providing flexibility to the power system

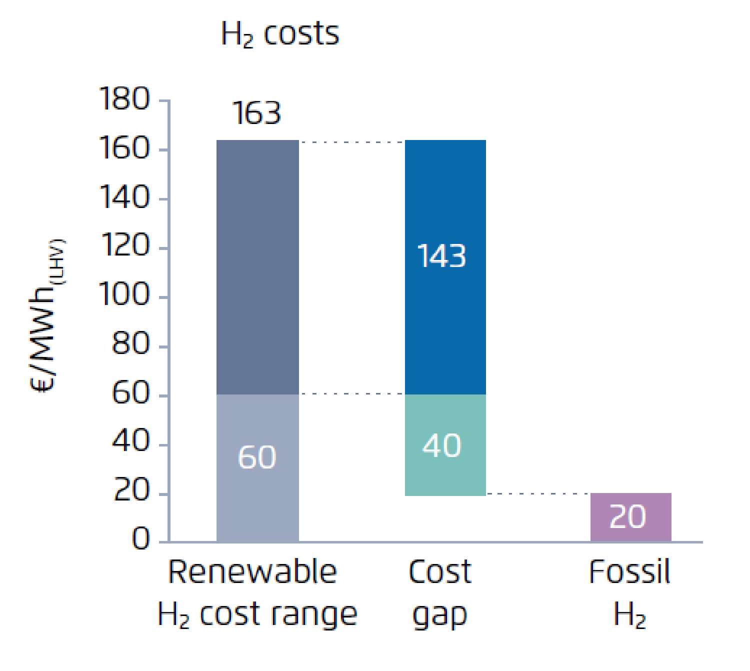
Goal: Plants receive a fixed feed-in-premium per unit of electricity generated, covering both the incremental CAPEX as well as the OPEX cost difference between using H_2 instead of natural gas, thereby incentivising the use of H_2.

Design: Awarded CHP plants are required to physically consume pure H_2. This means that they need to be located close to electrolysers or H_2 networks. To ensure that the supported capacities are used as a flexible source, **operating hours** should be limited to around 3000 hours p.a. System-friendly dispatch is incentivised through electricity spot market prices.

Timing: This instrument could be introduced in the next legislative term and be replaced by a H_2 quota in gas plants once coal-based electricity generation has stopped.

Legal analysis: Support should be regulated and conducted separate from tendering under sec. 8a KWKG. The operating hours may be adapted to simplify the integration in the KWKG or allow stronger orientation towards building capacity. The total duration of support is not specified, but rather refers to the depreciation period.

Flexible electricity supply requires renewable H_2, amounting to funding of €0.3 to €1.1 bn per year



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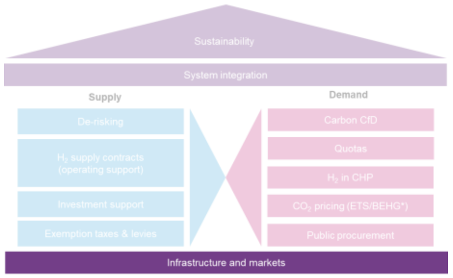

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Labelling of green products – establishing green lead markets

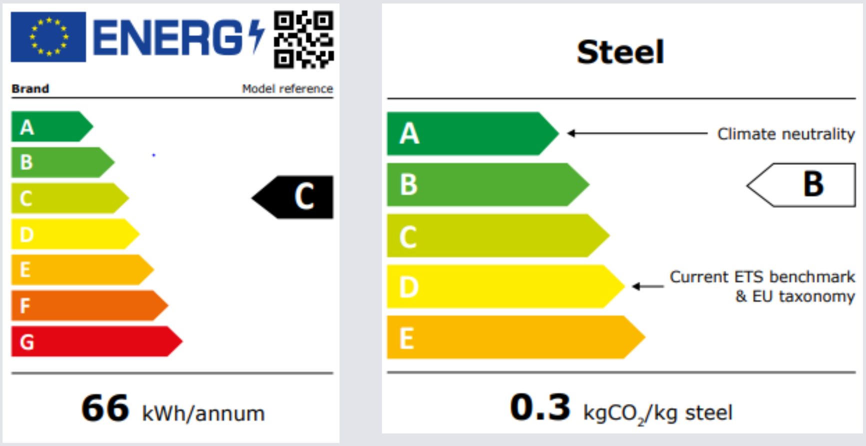
Goal: The goal is to refinance investments in new production processes based e.g. on renewable H_2.

Design: Labels are likely to be most effective in combination with other instruments, such as **carbon limits on final products**. As the initial demand-side pull will not be enough to justify investments in H_2 technologies, additional instruments such as a **CCfD** may be required. The labelling is mandatory for the covered **scope**, i.e. basic materials, which may include steel, basic chemicals, and cement. Additional costs are passed on to the consumer via the final products.

Timing: The label could be introduced as soon as possible and kept thereafter. It should be complimented by additional supply-side policies.

Legal analysis: A legal basis for the introduction of the label is required. For implementation at EU level, integration into the Ecodesign Directive may be considered. The idea of a label may also be addressed in the context of the RED III. Alternatively, a new regulation may be considered. For reasons of proportionality or appropriateness, it would be necessary to gradually introduce the necessary measures to create transparency and establish quality standards.

Copying the Energy Performance Rating Labels model (left) to make **material CO_2 performance rating labels**



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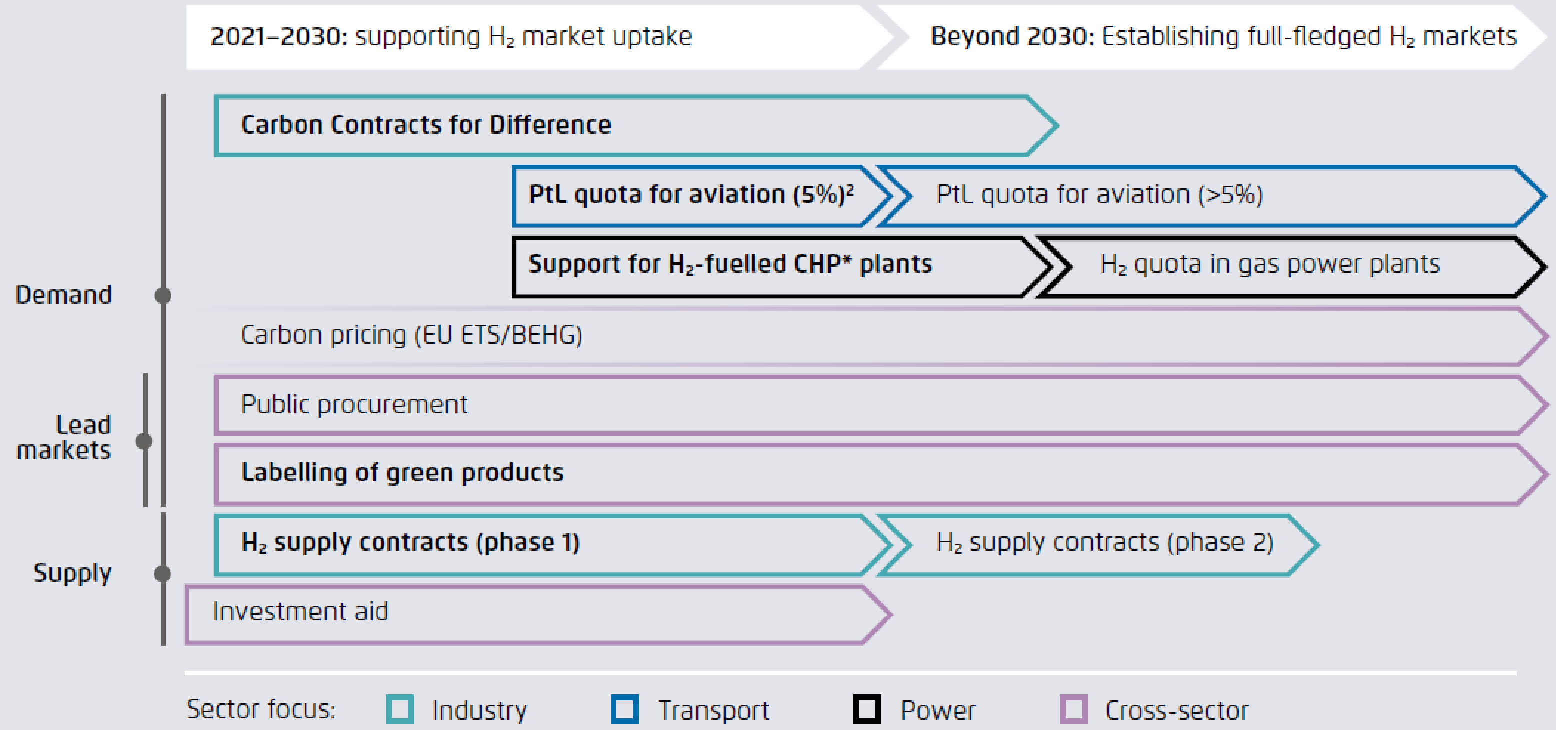
A regulatory roadmap towards a liquid hydrogen market

Different policy instruments require different timelines



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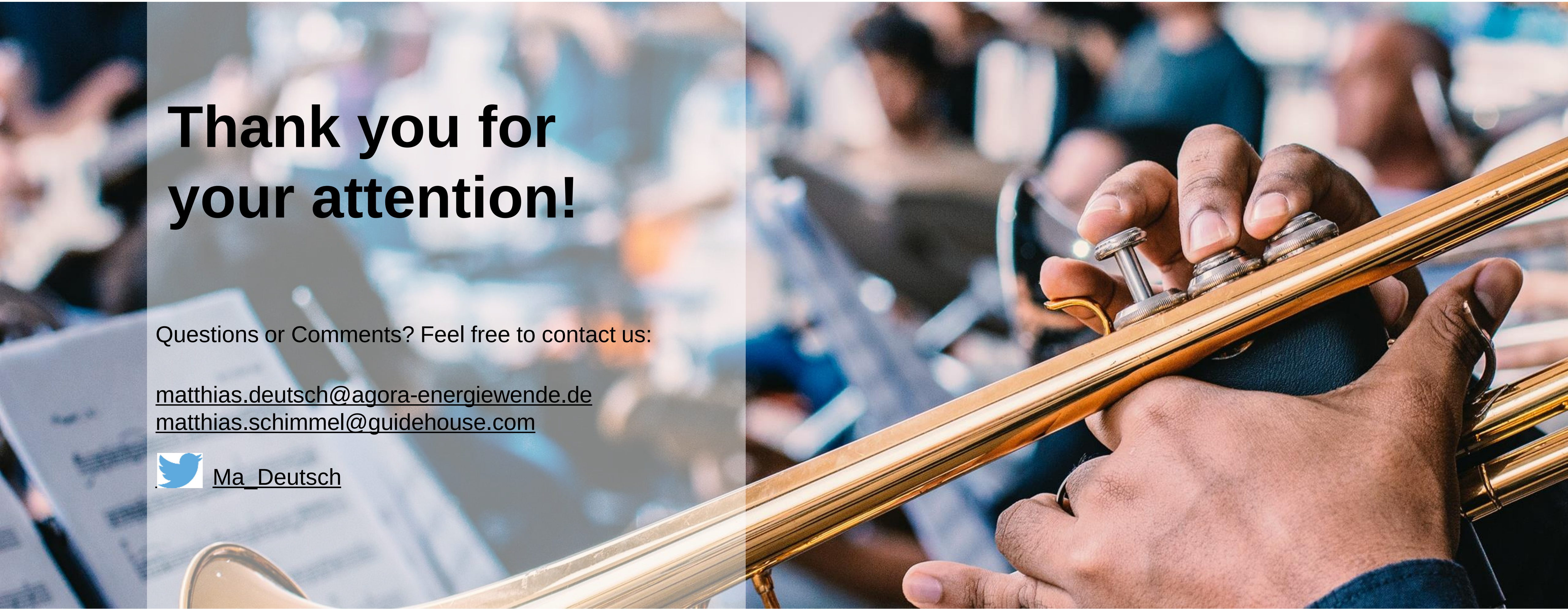

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Questions or Comments? Feel free to contact us:

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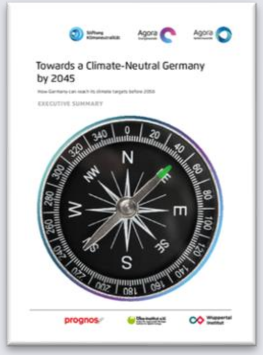
Ma_Deutsch

Publications on climate-neutrality, hydrogen and industry

No-regret hydrogen: charting early steps for H_2 infrastructure in Europe	Towards a climate-neutral Germany by 2045	Breakthrough strategies for climate-neutral industry in Europe	A Clean Industry Package for the EU	The future cost of electricity-based synthetic fuels
				
> full study	> summary (EN) > full study 2050 (DE)	> summary	> full study	> full study > PtG/PtL calculator
> data appendix > webinar	> data appendix 2050 (DE)		> slide deck > webinar	> slide deck > webinar