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# Making renewable hydrogen cost-competitive

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Policy instruments for supporting green H<sub>2</sub>

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**STUDY**

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**Agora**  
Energiewende



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 **Guidehouse**

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# Making renewable hydrogen cost-competitive

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### STUDY

Making renewable hydrogen cost-competitive:  
Policy instruments for supporting green H<sub>2</sub>

### ON BEHALF OF

Agora Energiewende  
Anna-Louisa-Karsch-Straße 2 | 10178 Berlin  
T +49 (0)30 700 14 35-000  
F +49 (0)30 700 14 35-129  
www.agora-energiewende.org  
info@agora-energiewende.org

### WRITTEN BY

Guidehouse Energy Germany GmbH  
Albrechtstraße 10c | 10117 Berlin  
T +49 30 72621410  
https://guidehouse.com/  
matthias.schimmel@guidehouse.com

### PROJECT LEAD

Matthias Deutsch  
matthias.deutsch@agora-energiewende.de

### AUTHORS

Matthias Schimmel, Pia Kerres,  
Korinna Jörling, Corinna Klessmann,  
Jonas Schröder (all Guidehouse),  
Martin Altrock, Christine Kliem,  
Charlotta Maiworm und Simon Hillmann (all BBH),  
Matthias Deutsch, Philipp D. Hauser,  
Oliver Sartor (all Agora Energiewende)

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### WITH CONTRIBUTIONS FROM

Gniewomir Flis, Andreas Graf,  
Michaela Holl (all Agora Energiewende)

### RESEARCH SUPPORT

Becker Büttner Held (BBH)  
Lawyers Public Auditors Tax Advisors PartGmbH  
Magazinstraße 15–16 | 10179 Berlin | Germany

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# Preface

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Dear reader,

Hydrogen will be a key enabler of climate neutrality in various sectors. In line with this insight, policy makers in Europe have been actively adopting hydrogen development strategies.

Unfortunately, as clearly acknowledged in the European Commission's 2020 Hydrogen Strategy, renewable hydrogen production is economically uncompetitive today – even with record carbon certificate prices – and is expected to remain uncompetitive until the 2030s. To put it succinctly: there is currently no natural market demand for fully decarbonized hydrogen, nor is such demand anticipated to materialise prior to the end of this decade.

European industrial policy is required to fill this gap – and, in our view, action should be taken quickly

(i.e. as part of the Fit-for-55 Package, and the revision of state aid guidelines).

To better understand hydrogen's policy support needs and their effects, Agora Energiewende and Guidehouse have examined the policy instruments most promising for bridging the cost gap between renewable hydrogen and its fossil counterparts. Based on our findings, in this study we present a policy instrument mix and roadmap designed to catalyse the renewable hydrogen ramp-up.

I hope you find this report both informative and stimulating.

Best regards,

Patrick Graichen  
*Executive Director, Agora Energiewende*

## Key conclusions:

1

**There is a limited set of applications in all sectors that urgently need renewable hydrogen to become climate-neutral.** These applications include steel, ammonia and basic chemicals production in the industrial sector, as well as long-haul aviation and maritime shipping. The power sector needs long-term storage to accommodate variable renewables, and existing district heating systems may require hydrogen to meet residual heat load. Accordingly, renewable hydrogen needs to be channelled into these no-regret applications.

2

**Ramping up renewable hydrogen will require extra policy support that is focused on rapid cost reductions.** While renewable electricity (the main cost component of renewable hydrogen) is already on track to become cheaper, electrolyser system costs also need to be reduced. Cheaper electrolysers will come through economies of scale and learning-by-doing effects; however, predictable and stable hydrogen demand is prerequisite for electrolyser manufacturers to expand production and improve the technology.

3

**CO<sub>2</sub> prices in the 2020s will not be high enough to deliver stable demand for renewable hydrogen, underscoring the need for a hydrogen policy framework.** Even at CO<sub>2</sub> prices of €100 to 200/tonne, the EU ETS will not sufficiently incentivise renewable hydrogen production, making additional policy support necessary for a considerable period of time. Among potential policy options, a general usage quota for renewable hydrogen would not be sufficiently targeted to induce adoption in the most important applications.

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.** Several policy instruments should be deployed in concert to achieve this aim – namely, carbon contracts for difference in industry; a quota for aviation; auctions to support combined heat and power plants; measures to encourage markets for decarbonised materials; and hydrogen supply contracts. These instruments will also need to be complemented by regulations that ensure sustainability, appropriate infrastructure investment, system integration, and rapid renewables growth.



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# MAKING RENEWABLE HYDROGEN COST- COMPETITIVE: POLICY INSTRUMENTS FOR SUPPORTING GREEN H<sub>2</sub>

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Conclusions drawn  
by Agora Energiewende

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# 1 Conclusions

1

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

The path to a climate-neutral Europe will indisputably involve renewable hydrogen. Voices calling for green hydrogen to support decarbonisation have thus been growing ever-more numerous. However, given the high renewables demand entailed by green hydrogen production, is it essential to consider alternative decarbonization options. This is particularly important because in some cases, those alternatives do currently not exist, and are unlikely to be developed in the future, due to the need for specific chemical properties, a high energy density or a potential for long-term energy storage. Based on those considerations, Table 1 categorises each potential usage context as *uncontroversial*, *controversial* or a *bad idea*.

Applications with an **uncontroversial** need for green molecules include steel, ammonia and basic chemicals production in the industrial sector,<sup>1</sup> as well as long-haul aviation and maritime shipping. In addition, the power sector needs long-term storage to accommodate higher variable renewable feed-in, and existing district heating systems may require hydrogen to supply residual heat load.<sup>2</sup>

**Controversial** hydrogen applications may also require renewable hydrogen over the long run, but the extent of this need is unclear today. For example, high-temperature heat can be delivered with electricity in several ways.<sup>3</sup> In transport, the mass production of battery electric vehicles is currently more advanced than hydrogen-based technology for heavy duty vehicles and buses. Nevertheless, hydrogen fuel cell trucks are expected to play a role at ports and in industrial clusters due to synergies with other hydrogen applications.<sup>4</sup>

Finally, using hydrogen is a **bad idea** when the involved energy conversion losses clearly favour proven direct electrification alternatives, e.g. battery-powered cars and light-duty vehicles, or low-temperature heat production for industrial processes and space heating.<sup>5</sup>

Scarce energy infrastructure and financial resources must be allocated, at least initially, to the highest priority and no-regrets usages. Thus, it is important that policy instruments and relevant funding instruments are designed, in a first stage, to prioritise only uncontroversial applications.

1 Agora Energiewende and Wuppertal Institut (2021)

2 Prognos et al. (2021); Ueckerdt et al. (2021); ETC (2021)

3 Agora Energiewende and AFRY (2021); Madeddu et al. (2020)

4 Transport & Environment (2021)

5 Agora Verkehrswende, Agora Energiewende and Frontier Economics (2018); Fh-IEE (2020)

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

Table 1

Green molecules needed?	Industry 	Transport 	Power sector 	Buildings 
<b>Uncontroversial</b>	<ul style="list-style-type: none"> <li>· Reaction agents (DRI steel)</li> <li>· Feedstock (ammonia, chemicals)</li> </ul>	<ul style="list-style-type: none"> <li>· Long-haul aviation</li> <li>· Maritime shipping</li> </ul>	<ul style="list-style-type: none"> <li>· Long-term storage for variable renewable energy back-up</li> </ul>	<ul style="list-style-type: none"> <li>· District heating (residual heat load *)</li> </ul>
<b>Controversial</b>	<ul style="list-style-type: none"> <li>· High-temperature heat</li> </ul>	<ul style="list-style-type: none"> <li>· Trucks and buses **</li> <li>· Short-haul aviation and shipping</li> </ul>	<ul style="list-style-type: none"> <li>· Absolute size of need given other flexibility and storage options</li> </ul>	
<b>Bad idea</b>	<ul style="list-style-type: none"> <li>· Low-temperature heat</li> </ul>	<ul style="list-style-type: none"> <li>· Cars</li> <li>· Light-duty vehicles</li> </ul>		<ul style="list-style-type: none"> <li>Individual buildings</li> </ul>

\* 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).

2

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

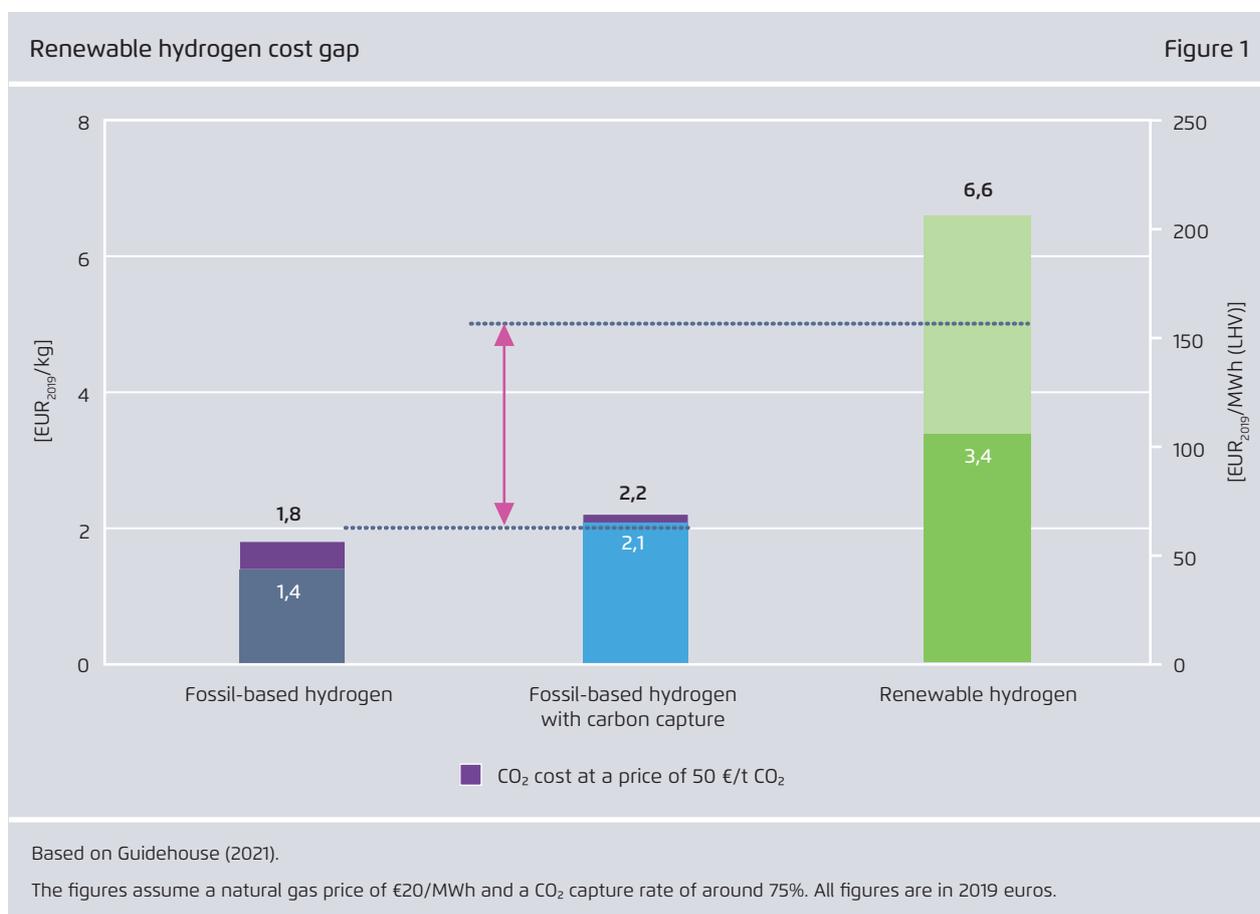
Today, nearly all hydrogen is produced from natural gas, at a cost of €1.40/kg, or €1.80/kg when adding CO<sub>2</sub> costs of approximately €50 per tonne (see Figure 1). Adding costs for carbon capture and storage to avoid 75% of the CO<sub>2</sub> emissions would make fossil-based hydrogen a bit more expensive (€2.20/kg). By comparison, the cost of renewable hydrogen ranges between €3.40 and €6.60/kg. Thus, the average cost gap between fossil-based hydrogen and renewable hydrogen is approximately €3/kg.

While estimates of future global production capacity for renewable hydrogen vary between 33 GW to more

than 90 GW,<sup>6</sup> the extent to which project developers are anticipating higher willingness to pay among customers and/or some form of policy support to bridge the cost gap identified in Figure 1 remains unclear, for in the absence of such support, the economics would not pencil out in most cases.

The cost of renewable hydrogen is primarily determined by: (1) the cost of renewable electricity; (2) the annual operating hours of the electrolyser, or so-called capacity factor; and (3) the electrolyser system costs.

6 IRENA (2021)



**Renewable electricity, the largest single cost component, is already on track to become cheaper.**

Across the globe, auctions held to provide support for solar PV and wind energy have achieved record low results. For example, Saudi Arabia’s PV tender in April 2021 drew a successful bid of 0.0105 USD/kWh.<sup>7</sup> From 2010 to 2019, the global weighted-average levelised cost of electricity (LCOE) produced by utility-scale solar photovoltaics, offshore wind, and onshore wind fell by 82%, 47% and 39%, respectively. These trends are expected to continue.<sup>8</sup> While renewable power demand for hydrogen production could contribute to further cost declines, its overall impact is likely to be marginal, as hydrogen only projected

7 PV magazine (2021)

8 IRENA (2020)

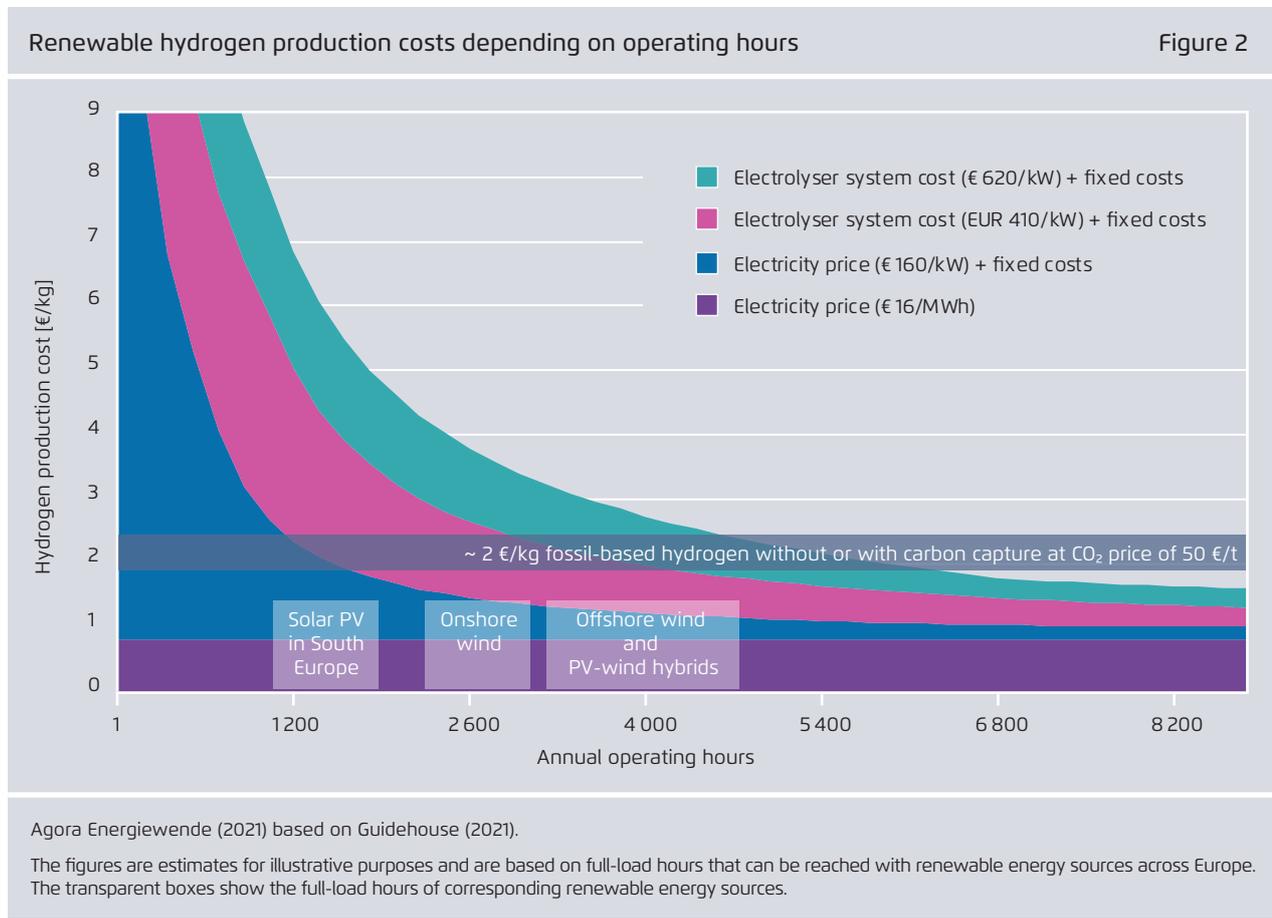
to account for a limited share of global final energy demand (13–24%) in 2050.<sup>9</sup>

**Higher capacity factors will lower the cost of hydrogen**

Electrolysers entail considerable investment costs. Distributing these costs over as many annual operating hours as possible lowers the overall cost of hydrogen production.<sup>10</sup> Figure 2 illustrates this effect for electrolysers at different system cost levels, ranging from €620/kW to 160€/kW. The largest abso-

9 ETC (2021)

10 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<sub>2</sub> and electricity (Guidehouse 2021).



lute decrease in production costs occurs on the left hand side of each curve. By contrast, on the right hand side, a further increase in operating hours has a declining impact on costs. At an electrolyser system cost of €620/kW, more than 5,400 annual operating hours are required to bring production cost below €2/kg, where production breaks even with fossil-based hydrogen – with or without carbon capture – if CO<sub>2</sub> is priced at €50/t. At a system cost of €160/kW, just 1,500 hours is sufficient to hit breakeven. At such low cost levels, electrolysis in Southern Europe based on solar PV alone becomes increasingly attractive.<sup>11</sup>

Beyond the important role played by the cost of renewable power, this capacity utilisation effect shows how hydrogen production costs are mediated not only by upfront investment costs, but also annual hours of operation.

### **The costs of electrolysers will fall given economies of scale and learning-by-doing effects.**

The global production of electrolysers currently stands at some 135 MW per year, with the largest manufacturers having an annual output on the order of 10–20 MW. Increasing the **scale of production** generally induces decreasing costs per unit of production. The manufacturing of 1 GW of capacity per year – a 50 to 100 fold increase in production – would unleash considerable economies of scale, and several companies have announced plans to achieve this objective. Similarly, increasing the size of electrolysis plants from 1 MW (typical today) to 100 MW or higher would considerably cut costs.<sup>12</sup>

**Learning-by-doing** refers to innovation in production, including standardisation, greater specialisation, and improved manufacturing processes. Such innovation can lower the risk perceptions held by project developers and financial institutions, thus

ensuring more favourable financing conditions. Learning-by-doing effects are anticipated to materialise in electrolyser deployment, and learning rate estimates are similar to that of solar PV.<sup>13</sup> Nevertheless, electrolyser cost projections are subject to considerable uncertainties regarding current installed capacity and cost levels, as well as expectable learning rates.<sup>14</sup> This is why Figure 3 shows a large cost range for renewable hydrogen from 2020 to 2030. Accordingly, the cheapest renewable hydrogen may reach cost parity with fossil-based hydrogen in the late 2020s. This assumes a CO<sub>2</sub> price path from €50/t in 2020 to €100/t CO<sub>2</sub> in 2030.

Finally, research, development, and demonstration are also relevant for making progress with electrolysis, in part to reduce reliance on scarce materials such as platinum group metals and cobalt.<sup>15</sup>

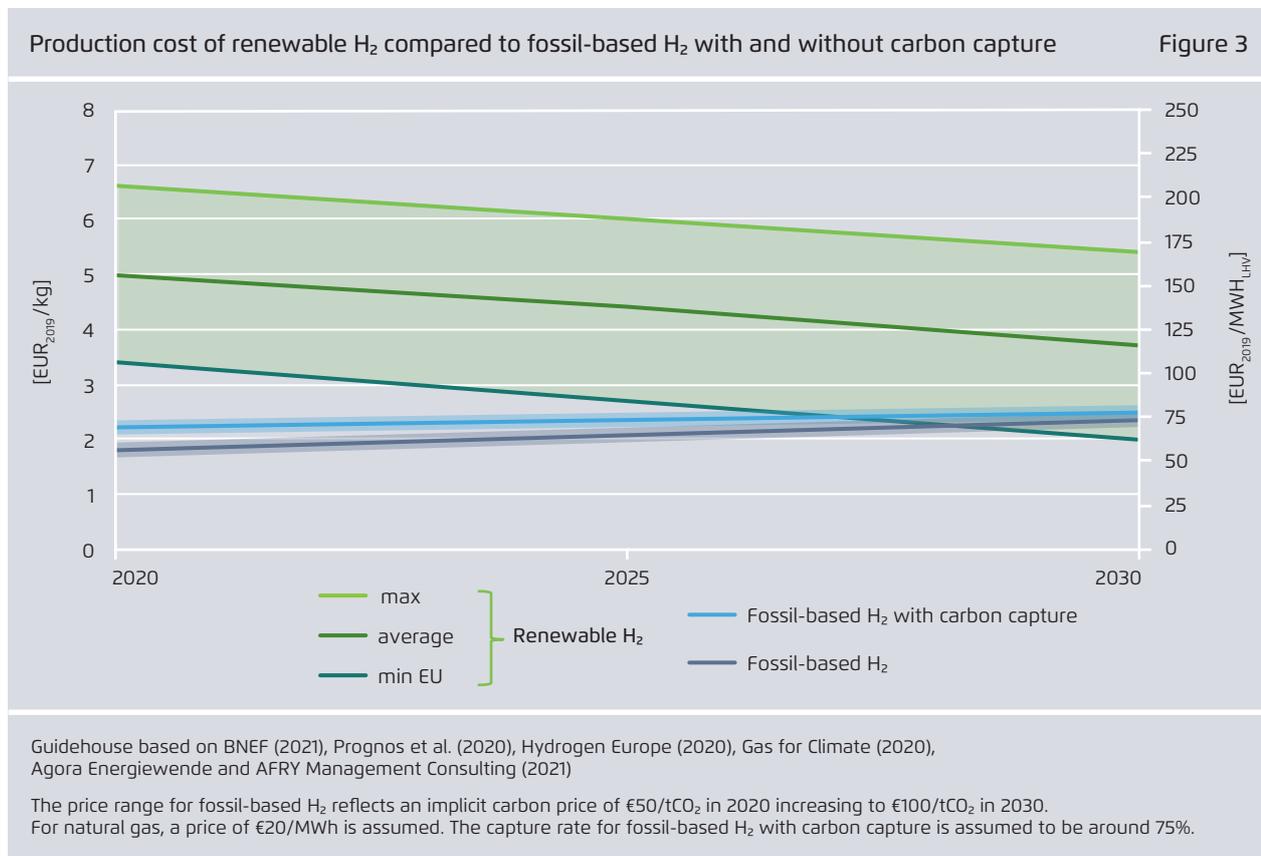
11 Agora Energiewende and AFRY Management Consulting (2021)

12 IRENA (2020); Windpower Monthly (2020)

13 IRENA (2020)

14 These uncertainties largely explain the variance in cost estimates that are being discussed publicly. Some studies compare low-cost electrolysers seen in China versus OECD cost levels (Agora 2019). IRENA (2020) provides an overview of learning rates and uses 18% as a mid-estimate. That is, with each doubling of cumulative electrolyser production, investment costs are expected to decrease by 18%. The chosen starting value is also important. Starting with the existing global capacity of 20 GW of chlor-alkali electrolysers yields much slower cost reductions than starting from lower values (e.g. just 0.2 GW of water electrolysis systems are currently in place). In addition, the available electrolyser technologies and their historic development differ considerably (AEL, PEM, SOEC, AEM).

15 IRENA (2020)



**Such deployment will only materialise with predictable and stable hydrogen demand.**

Electrolyser manufacturers need a predictable pipeline of projects if they are to invest in plants at the GW level. Yet this predictability is only possible through policy support, given the current economic uncompetitiveness of renewable hydrogen. Indeed, large-scale investment in renewable hydrogen cannot take place without support, as there is currently no market for green H<sub>2</sub>, due to significantly cheaper alternatives.

Using taxpayer money to support renewable hydrogen in an era of already strained public budgets will require compelling justifications. In particular, it will necessitate a basic agreement on where to prioritise investment and what kinds of projects are beyond question in terms of their compatibility with the goal of climate neutrality. Therefore, renewable hydrogen needs to be channelled into uncontroversial applications (as outlined above) with high priority. Conversely, a lack of common ground might delay the renewable hydrogen ramp-up, given the integral role of policy support.

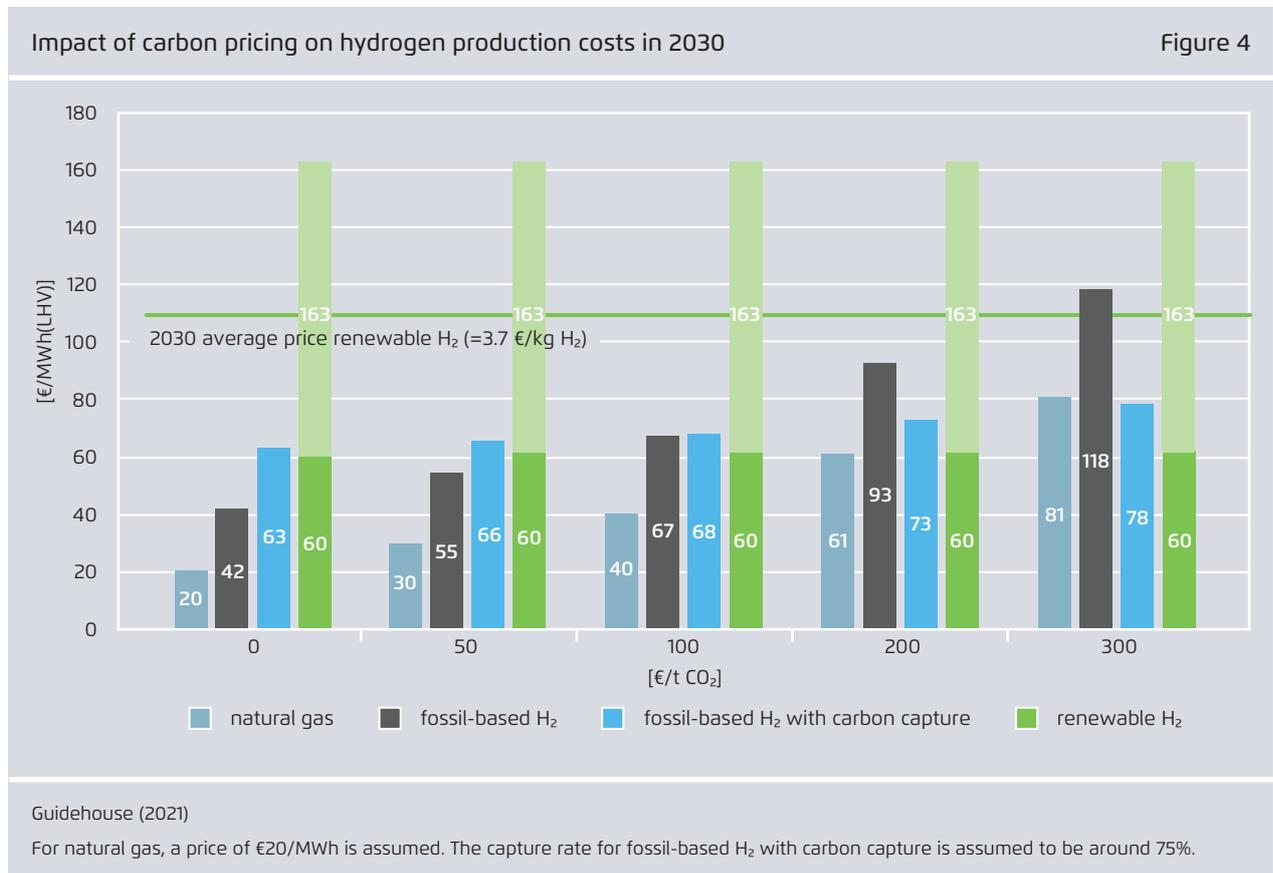
**3 CO<sub>2</sub> prices in the 2020s will not be high enough to deliver a stable demand for renewable hydrogen, reinforcing the need for a hydrogen policy framework.**

Carbon pricing will be a cornerstone of the needed policy framework, and its future role in different sectors is currently being discussed at the EU level.<sup>16</sup> While this framework should be gradually extended to correct price disparities and make fossil fuels more expensive, it is important to acknowledge its limits in the short to medium term.

**Even at CO<sub>2</sub> prices of €100–200/tonne, the EU ETS will not sufficiently incentivise renewable hydrogen production.**

Figure 4 illustrates the impact of carbon pricing on the cost of hydrogen production in 2030 and compares it with natural gas, which in several applications is the default fuel used today. Up to a CO<sub>2</sub> price of around €200/t, natural gas is cheaper than the three forms of hydrogen shown. This contrasts strongly with current EU ETS allowance prices, which ranged from €15/tCO<sub>2</sub> to around €50/tCO<sub>2</sub> in March to May 2021. When renewable hydrogen competes with fossil-based hydrogen, the lowest-cost renewable

16 Agora Energiewende and Ecologic Institute (2021)



hydrogen in 2030 would need CO<sub>2</sub> prices of around €100/t to break even. However, on average, renewable hydrogen technologies would need CO<sub>2</sub> prices of around 300 €/t in 2030 to reach the break-even threshold.

Given the existing challenges surrounding the politics of high carbon prices and rising electricity bills in the EU, it is unlikely that ETS allowance prices will reach such levels anytime soon. And even if sufficiently high carbon prices could be anticipated, one would still have to contend with the potential for carbon leakage and the need for carbon border adjustments.<sup>17</sup>

**Given low EU ETS prices, additional policy support instruments will be needed for a considerable time.**

Until 2030, priority should be given to the market ramp-up of renewable H<sub>2</sub> by bridging the cost gap between fossil energy and renewable H<sub>2</sub>. The design of corresponding instruments should be led by strategic considerations regarding target sectors and applications. For example, European steel producers have entered the global competition for climate-neutral primary steel-making. Enabling the greening of steel via renewable hydrogen will be decisive for making Europe a technology leader for climate-neutral products.<sup>18</sup>

Beyond 2030, H<sub>2</sub> demand and supply should increasingly be organised through a liquid market. In the coming decade, H<sub>2</sub> generation costs will be reduced through cheaper renewable electricity and cheaper

electrolysers. Furthermore, the competing fossil fuels will be more expensive due to higher carbon prices.

**A general renewable hydrogen quota is not sufficiently targeted to induce adoption in the most important applications.**

A general quota that mandates the use of a certain share of renewable hydrogen in all sectors would come with several problems, including issues related to technological compatibility, distribution and efficiency.

First, such a quota would encourage the physical blending of hydrogen with natural gas, which some industries oppose, as they require pure hydrogen.<sup>19</sup> Second, such a quota would be regressive in nature, as lower-income households that rely on gas for heating needs would be disproportionately burdened by higher prices. Third, a quota with initially low hydrogen shares would deliver only negligible greenhouse gas emission savings.<sup>20</sup> Fourth, it would unnecessarily drive the uptake of renewable hydrogen in applications for which other climate-neutral technologies are available, thereby circumventing the necessary strategic reflection on future-proofing infrastructure. That is, it would divert renewable hydrogen from uncontroversial applications that truly require hydrogen to become climate-neutral, as described above.<sup>21</sup> Given these drawbacks, a general gas quota would be unsuitable for catalysing a renewable hydrogen ramp-up.

17 Cf Euractiv (2021a, 2021b), TheOlivePress (2021), 20Minutes (2021). The policy framework also needs to address issues surrounding free ETS allowance allocation. In reality, free allowances distort the effect, as renewable H<sub>2</sub> does not receive any free allowances. If, for example, a conventional steel plant (basic oxygen furnace/blast furnace) switches to hydrogen based-steel making, no more free allowances are granted, further increasing the cost of production (Guidehouse 2021).

18 Agora Energiewende and Wuppertal Institut (2021)

19 The industry dialogue "Gas 2030", hosted by the German Ministry of Economic Affairs and Energy, stressed the importance of gas quality, and identified risks for the industrial demand side arising from blending (BMW 2019).

20 This is due to the lower volumetric energy density of hydrogen relative to natural gas. For example, blending a 5% volume of hydrogen would only displace 1.6% of fossil gas. Also see Figure 2.6 in IRENA (2021) on the relationship between blending, CO<sub>2</sub> emissions and the gas price.

21 Guidehouse (2021)

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.**

In particular, a host of targeted instruments should be deployed in unison to support uptake in industry, transport and the power sector.

### **Carbon contracts for difference will enable European industry to start the transition to climate-neutral products.**

Carbon contracts for difference (CCfD) can facilitate investment in breakthrough technologies. By offsetting the additional operating cost of breakthrough technologies, CCfDs de-risk long-term investment, thus allowing industry to take advantage of natural re-investment cycles to build the climate-neutral industrial hubs of the future. By enabling the production of climate-friendly basic materials, CCfDs can create supply that is necessary to establish the standards and the demand pull that are needed for the development of green lead markets. Another important objective of using CCfDs to kick start the development of industrial plants with flexible demand for renewable hydrogen, not only as an anchor for hydrogen demand, but also as a back-up for the energy sector.

The anticipated funding requirements for CCfDs to support the use of renewable hydrogen can be very large initially. For one green steel plant, CCfD funding requirements can exceed €200 million annually. Several options for cost reduction and recouping outlays exist. To ensure a positive synergy between CCfDs and the carbon price as a lever for minimising CCfD costs, the instrument should be designed as a complement to the reform of the EU ETS and its carbon leakage regime. Further cost reduction can be achieved by designing CCfDs as an insurance mechanism that covers the additional cost of clean production until this cost gap can be addressed by green lead markets or other demand-side instruments. Finally, costs can be reduced by ensuring the gradual

upscaling of renewable hydrogen to support technological innovation and cost reductions.

While these cost reduction strategies must be envisaged as part of the conceptual design of CCfDs, it is also important to establish sustainable financing mechanisms. To ensure the rapid deployment of CCfDs, their costs can initially be covered with general tax receipts or EU ETS revenues. In the medium term however, it is preferable to define solid financing mechanisms that are in sync with the reform of Europe's carbon leakage regime. If a continued use of free allocation is envisaged, this can be complemented with a climate levy on final products that use steel or other potentially GHG intensive basic materials. In the event a carbon border adjustment mechanism (CBAM) is established, cost recovery can possibly be secured by increasing EU ETS auction volumes.<sup>22</sup>

### **A power-to-liquid quota in aviation of 10% by 2030 would deliver clear market signals that Europe intends to import considerable volumes of liquid e-fuels**

Long-distance aviation needs liquid fuels with a sufficiently high energy density. By setting an EU-wide quota of 10% for power-to-liquid products in aviation, demand for e-kerosene would be created, leading to a ramp-up in renewable H<sub>2</sub> and jet fuel production as well as further technological learning. The price premium would be passed on through the airlines to consumers.<sup>23</sup>

22 Agora Industry et al. (2021)

23 To the extent that air travel costs rise, this result would also be consistent with the broader need to moderate demand for air travel – a rapidly growing source of GHG emissions.

The current EU discussion on Sustainable Aviation Fuels is dominated by liquid biofuels, with only marginal attention being devoted to e-fuels derived from renewable hydrogen and sustainable carbon sources.<sup>24</sup> While cost considerations are very relevant today, the effective sustainability potential of e-fuels will be critical as progress toward climate neutrality is made.<sup>25</sup> A 10% PtL quota by 2030 would represent around 70 TWh of e-fuels, the production of which would require some 140 TWh of renewable electricity.<sup>26</sup>

Given this demand volume, the EU would very likely need to import liquid e-fuels to meet the quota by 2030. Such liquids have the advantage of being drop-in alternative fuels, i.e. they are compatible with existing infrastructure and aircraft.

This makes e-liquids very different from hydrogen, for which long-range transport comes at considerable extra cost. Hence, e-fuels lend themselves to importation more naturally than hydrogen. At the same time, major oil companies increasingly feel the pressure to transition to net-zero<sup>27</sup> while oil-export-

ing countries see a future for renewable hydrogen.<sup>28</sup> Those market actors need to receive a clear and early signal that they should prepare for going beyond hydrogen to deliver liquid e-fuels with carbon from sustainable sources. This implies developing and scaling the necessary plants on an aggressive, non-linear growth path extending beyond 2030 to reach climate-neutrality by 2050<sup>29</sup>. The earlier market actors start, the better they will be prepared for the disruption awaiting petroleum markets.

### **Gas power plants need to be 100% hydrogen-ready to back up renewables and meet residual heat load in district heating.**

To have the required hydrogen power plant capacities in place by 2030,<sup>30</sup> a dedicated support instrument is needed. In Germany, for example, a fixed feed-in premium for renewable H<sub>2</sub>-fuelled CHP plants could be tendered under the existing CHP Act. Plants would receive support per unit of electricity generated, covering both the incremental CAPEX as well as the OPEX cost difference between renewable H<sub>2</sub> and natural gas.

24 EPRS (2020)

25 Bioenergy use faces trade-offs with biodiversity and habitat loss (Secretariat of the Convention on Biological Diversity 2014). Regarding climate-neutrality, Bioenergy Carbon Capture and Storage (BECCS) will be important as a negative emissions technology for offsetting any residual emissions that cannot be mitigated. This will require using considerable amounts of bioenergy at central locations in the industrial and power sectors to capture carbon emissions. See Prognos et al. (2021).

26 This could be achieved, for example, by deploying an additional -35 GW of offshore wind turbines that operate with 4000 full-load hours. Major upscaling in offshore wind, however, calls for improved cooperation and offshore wind planning between European member states (Agora Energiewende, Agora Verkehrswende, Technical University of Denmark and Max-Planck-Institute for Biogeochemistry 2020).

27 Financial Times (2021)

28 The Guardian (2021)

29 Note that there are also significant non-CO<sub>2</sub> effects of aviation on climate change that e-fuels alone will not be able to mitigate. According to current knowledge, those effects represent at least half of the total climate change effect of aviation. They would need to be compensated via negative emissions to reach climate-neutrality (Prognos et al. 2021).

30 For Germany, Prognos et al. (2021) assume 2.5 GW of H<sub>2</sub>-fuelled capacities in 2030, generating 8 TWh of electricity and 5 TWh of heat.

### **Scalable green lead markets could help to create a business case for renewable H<sub>2</sub>.**

The use of renewable hydrogen should also be fostered through tools to create markets for climate friendly basic materials. In this respect, different tools can be considered relevant at different time scales. In the short run, CO<sub>2</sub> performance labelling and public procurement can be valuable for creating lead markets. Labels can be used to communicate the necessity of a price premium for recouping investment in new production processes (e.g. based on renewable H<sub>2</sub>). Standards are needed to determine rules for the accounting of embedded emission intensities, e.g. for the hydrogen used during the production of basic materials. In addition, governments can create demand themselves by setting minimum green public procurement requirements for basic materials likely to use hydrogen as an input (such as steel or plastics for construction). In the medium term, labelling tools and public procurement requirements could also lead to demand being scaled up via regulations on embedded carbon in final products, such as vehicles, construction and packaging. Embedded carbon limit policies can also have synergies with other policy priorities, such as incentivising material efficiency, material substitution and reliance on recycled materials. To be effective, the diverse demand side instruments must be compatible with the CCfD as an insurance mechanism for investment on the supply side, as described above.

### **Hydrogen supply contracts can enable competition between production in the EU and abroad.**

Hydrogen supply contracts cover for the difference between the lowest possible renewable H<sub>2</sub> production price and the highest willingness to pay for it in a double auction model. That is, the price gap is identified by one auction on the supply side and one on the demand side.<sup>31</sup> Towards 2030, once H<sub>2</sub> transport infrastructure enables liquid markets, production locations in Germany, Europe and abroad can participate in the auctions. Ideally, the instrument will let those locations compete against each other, together with different modes of transport, be it liquified or compressed hydrogen, ammonia or liquid organic hydrogen carriers, in addition to the less costly hydrogen transport via pipeline.<sup>32</sup>

### **The required policy support for renewable hydrogen at the EU level is anticipated to cost €10-24 billion per year**

Table 2 summarises the annual policy support needed in the industrial, aviation and power sectors in Germany and the EU. Beyond 2030, direct support for renewable H<sub>2</sub> production or consumption should be phased out. In the next decade, the cost gap will be much smaller, and consumers and markets should increasingly shoulder the financing burden.

31 This principle has been proposed by the H<sub>2</sub>Global initiative, supported by the German Federal Ministry for Economic Affairs and Energy, <https://H2-global.de/>.

32 IEA (2019)

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

Table 2

	Support instruments for renewable hydrogen	Billion EUR per year			
		Germany		EU	
		Low	High	Low	High
Demand	Carbon Contracts for the transformation of 33% DE / 50% EU primary steel production capacity to H <sub>2</sub> -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. <u>Cost recovery:</u> 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 <sub>2</sub> -DRI with effective CO <sub>2</sub> -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 <sub>2</sub> and PtL production and further technological learning. A long-term pathway must be towards 100% climate-neutral e-kerosene. <u>Cost recovery:</u> Additional costs are passed on to end-users (aviation passengers)	1.4	1.9	10.3	14
	Support for H <sub>2</sub> -fuelled combined heat and power plants (2025–2035) Support for CHP plants that use green H <sub>2</sub> is tendered under the German CHP Act. Plants receive support per unit of energy generated, covering both the incremental CAPEX as well as the OPEX cost difference between H <sub>2</sub> and natural gas. <u>Cost recovery:</u> Through levies on electricity end consumers (in line with current CHP act) for the initial investments; if the amount increases, budget finance could be considered.	0.3	1.1		
	H <sub>2</sub> quota in gas power plants (from 2035 onwards) A quota takes over once the use of H <sub>2</sub> is established through the support for H <sub>2</sub> -fuelled combined heat and power plants. <u>Cost recovery:</u> Additional costs are passed on to end-users				
	Public procurement (2022-2050) The instrument obliges governments to establish strict sustainability criteria for procurement, thereby creating secure markets for sustainably manufactured products. <u>Cost recovery:</u> Through public budget				
	Labelling of green products (2022–2050) Labelling creates transparency allowing consumers to choose a low-carbon product. <u>Cost recovery:</u> Possible costs for certification and the set-up of the scheme could initially be covered by industry				
	H <sub>2</sub> supply contracts (2022–2030 (phase 1) & 2030–2040 (phase 2)) H <sub>2</sub> supply contracts cover for the difference between the lowest possible renewable H <sub>2</sub> production price and the highest willingness to pay for it in a double auction model. <u>Cost recovery:</u> Through public budget	0.8	5.3		
Supply	Investment aid (2021–2030) The instrument provides CAPEX funding to build electrolyzers. <u>Cost recovery:</u> Multiple options exist, e.g. EU-ETS or Recovery and Resilience Facility				

Sector focus: ■ Industry ■ Transport ■ Power ■ Cross-sector

The costs were calculated using the following price assumptions: low renewable H<sub>2</sub> costs: 60 €/MWh; high renewable H<sub>2</sub> costs: 163 €/MWh; low PtL costs: 202 €/MWh; high PtL costs: 256 €/MWh; natural gas: 20 €/MWh; fossil-based H<sub>2</sub>: 42 €/MWh. \* average annual costs of a portfolio of 10 years CfD contracts, ignoring effect of sequential build up and phase out

based on Guidehouse (2021).

Note that Guidehouse assumes an aviation quota of only 5%. The hydrogen volumes for Germany are based on "Towards a Climate-Neutral Germany by 2045" (Prognos et al. 2021). The cost projection for the CcFd instrument represent alternative and mutually exclusive scenarios with regards to the evolution of Europe's carbon leakage policy.

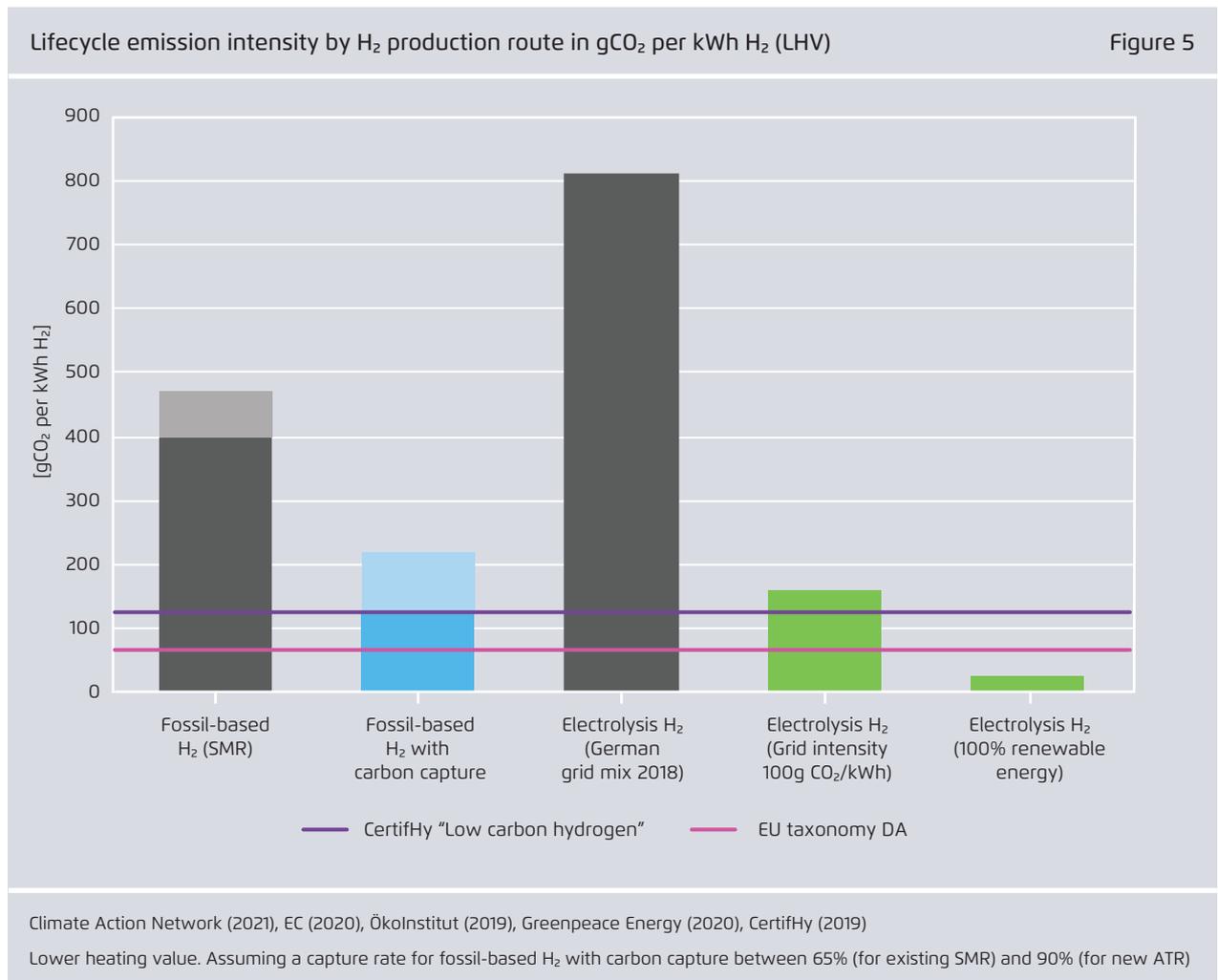
**The instruments need to be complemented by regulation for sustainability and system integration.**

The regulatory approach for H<sub>2</sub> must have strong safeguards to ensure that H<sub>2</sub> delivers the positive climate impacts it promises. Without such controls, there is even a risk of higher GHG emissions from H<sub>2</sub> due to increasing electricity or natural gas consumption.

Figure 5 shows the lifecycle GHG emissions intensity (in gCO<sub>2</sub> per kWh of H<sub>2</sub>) for different types

of H<sub>2</sub>,<sup>33</sup> with the dotted lines representing sustainability thresholds currently under discussion in the context of CertifHy and the Delegated Act on the EU sustainable finance taxonomy. The most sustainable-type is hydrogen generated through electrolysis using 100% renewable energy.

33 Nuclear hydrogen production has not been investigated in this study. The long-term operation of existing nuclear may be a cost-effective option for hydrogen production in some European countries, but new plants do not seem to be a viable option at present, because most of the recent nuclear projects in Europe are already being outcompeted by wind and solar (Prognos 2014, IEA & NEA 2020).



On the other hand, electrolysis that relies on power with a considerable share of fossil fuels, like in Germany today, can lead to very high CO<sub>2</sub> emissions, due to energy conversion losses.

Against this backdrop, we need:

1. **clear criteria** for when H<sub>2</sub> counts as climate neutral;<sup>34</sup>
2. a **roadmap** for applying these criteria, because some sectors, such as industry, are subject to reinvestment cycles that may require different treatment;<sup>35</sup> and
3. **legislation & certification** to translate the criteria and roadmap into binding practice.

Of particular importance for both sustainability and system integration is the siting of electrolyzers. If H<sub>2</sub> production and renewable electricity production are separated by grid constraints, electrolysis actually runs on fossil-based generation that is located nearby – even given compliance with the criteria of additionality and temporal correlation. Moreover, without locational requirements, the risk of new grid congestions would increase across Europe. In Germany, this would increase the risk of a bidding zone split, with increasing electricity prices in the South and decreasing prices in the North. While bidding zones generally reflect current structural congestion in the grid, it seems advisable to specify areas

suitable for H<sub>2</sub> production, thereby avoiding the creation of additional grid congestion in the future.

### **Fossil-based hydrogen with carbon capture does not need additional policy support**

The emission intensity of fossil-based hydrogen with carbon capture is similar to electrolysis, with a grid intensity of around 100 g CO<sub>2</sub>/kWh (as shown in Figure 5). Furthermore, the availability of renewable electricity for H<sub>2</sub> production is currently limited. Given that fossil-based hydrogen with carbon capture is also significantly cheaper, it could be used as a bridge technology, by satisfying and encouraging demand for H<sub>2</sub>, and by supporting associated infrastructure expansion, easing the transition to a fully renewable H<sub>2</sub> economy. Similar to renewable hydrogen, fossil-based H<sub>2</sub> with carbon capture should comply with strict sustainability criteria to ensure that the decarbonisation goals are achievable. These criteria should be ratcheted up, starting at a minimum reduction rate of 70% compared to a fossil benchmark, while also fully accounting for life-cycle emissions that occurred upstream.<sup>36</sup> Once renewable H<sub>2</sub> production costs have sufficiently declined, renewable H<sub>2</sub> will overtake fossil-based H<sub>2</sub> with carbon capture.

34 See discussion surrounding the recast Renewable Energy Directive (RED II).

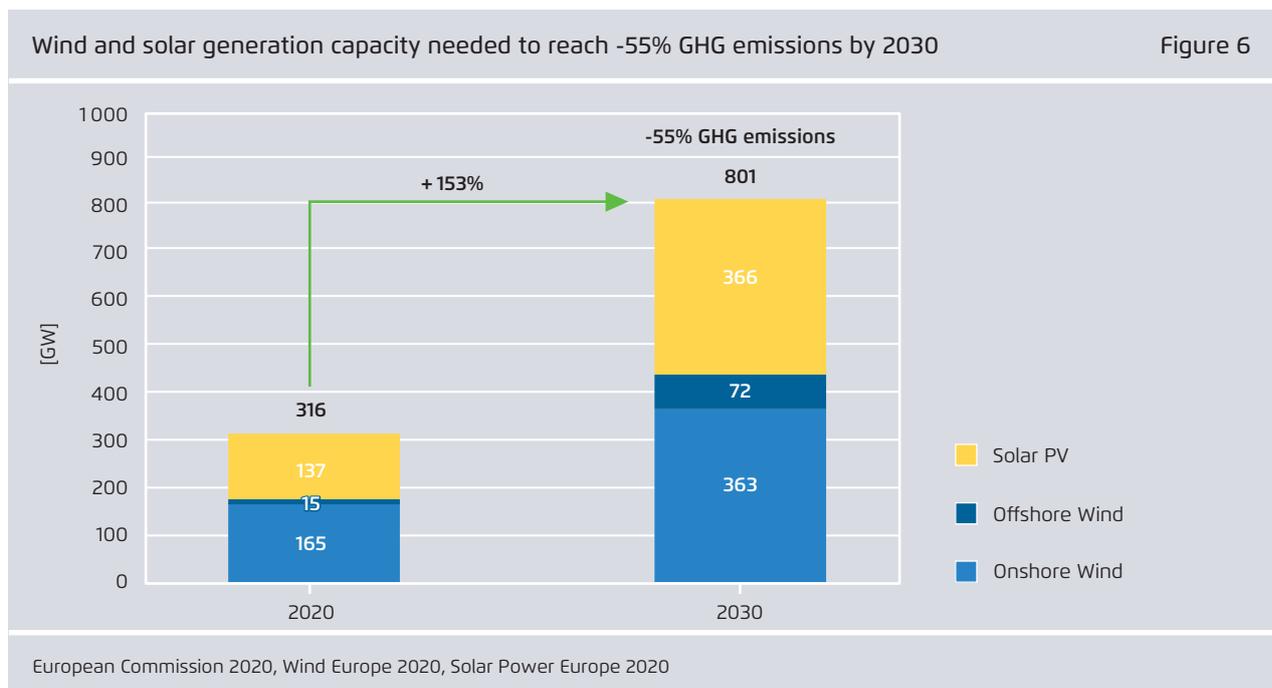
35 The necessity to avoid lifetime extension of conventional CO<sub>2</sub>-intensive assets requires industries to deploy key-low-carbon technologies now, even if the necessary scale and quality of renewable hydrogen is not yet available. In these cases it makes sense to allow for a gradual strengthening of sustainability criteria to allow for a smooth upscaling of hydrogen production capacities. Clearly, the application of renewable hydrogen criteria will also need to ratchet up in due time to ensure compatibility with climate-neutrality over the long term.

36 To be consistent with the objective of climate neutrality, any residual emission, however, would need to be offset by negative emissions, further increasing the total cost of fossil-based H<sub>2</sub> with carbon capture. As avoiding 100% of lifecycle emissions from production of fossil-based H<sub>2</sub> with carbon capture is unrealistic, the long-term goal should be to replace natural gas with biomethane to generate negative emissions and significantly increase renewable H<sub>2</sub> production.

**Renewable hydrogen needs major additional renewable energy deployment.**

The pace of renewable hydrogen expansion will largely depend on the growth in renewable energy sources. While the aggregated capacity of solar PV, offshore and onshore wind amounted to 316 GW in the EU in 2020, a more than 150% increase by 2030 is needed to reach 801 GW and to reduce GHG emissions by 55% relative to 1990. Hydrogen ambitions beyond the COM Impact Assessment may even require greater renewable energy expansion.

To be sure, the large-scale deployment of renewable hydrogen represents a massive and in some ways unprecedented challenge for the energy transition. The uncertainties linked to such a large-scale challenge should not be underestimated. Yet they should impress upon us the need to prioritise the uptake of hydrogen to uncontroversial, no-regret applications. Indeed, while necessary for the broader energy transition, renewable H<sub>2</sub> may remain a scarce resource in the future, due to potential political, economic or technical constraints to its expansion.





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# MAKING RENEWABLE HYDROGEN COST- COMPETITIVE: POLICY INSTRUMENTS FOR SUPPORTING GREEN H<sub>2</sub>

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Study conducted by Guidehouse

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## Executive Summary

All **climate neutrality scenarios** show a long-term **need for renewable hydrogen** (H<sub>2</sub>), with demand mostly concentrated in industry, the power sector and some areas of transport (e.g. aviation and maritime). Several European countries and the European Union (EU) have adopted H<sub>2</sub> policies and strategies over the past two years. Germany and the EU have also pledged substantial funds to support the market uptake of renewable H<sub>2</sub> (see section 1). Against this backdrop, we outline the building blocks of a regulatory architecture for encouraging a renewable H<sub>2</sub> economy in Germany and the EU. The described measures aim to facilitate the rapid, predictable, and efficient growth of H<sub>2</sub> supply and demand in a manner that contributes to the goal of climate neutrality. We also address interrelationships between support policies at the EU and national levels.

Up to 2030, a priority should be placed on the market ramp-up of renewable H<sub>2</sub> by bridging the cost gap between renewable H<sub>2</sub> and fossil-based alternatives. Over this decade, it will also be important to encourage H<sub>2</sub> demand in subsectors that lack other decarbonisation options, such as steel and chemicals. However, as renewable hydrogen production is still very expensive, **supply-side interventions** may also be needed (see section 2.2).

We recommend implementation of the following **demand-side policy instruments**:

- In the industrial sector, a Carbon Contracts for Difference (CCfDs) would help to facilitate investment in renewable H<sub>2</sub> by defraying additional operating costs (see factsheet A.1). This instrument could be financed with a climate surcharge (see factsheet A.8).
- In the aviation sector, an EU-wide quota for e-kerosene of 5% by 2030 should be considered (see factsheet A.4).

- In the power sector, support for H<sub>2</sub> as a CHP fuel source could be integrated into the tendering system under the German CHP Act (see factsheet A.3).
- Green lead markets would help to create a business case for investing in renewable H<sub>2</sub>. In this regard, we recommend a labelling system for climate-friendly basic materials (see factsheet A.6) and green public procurement (see factsheet A.7).

While carbon pricing supports renewable H<sub>2</sub>, carbon prices up to 2030 are unlikely to trigger significant renewable hydrogen demand. Also, current EU ETS rules discourage hydrogen investment in certain industries, as investment means relinquishing allowances.

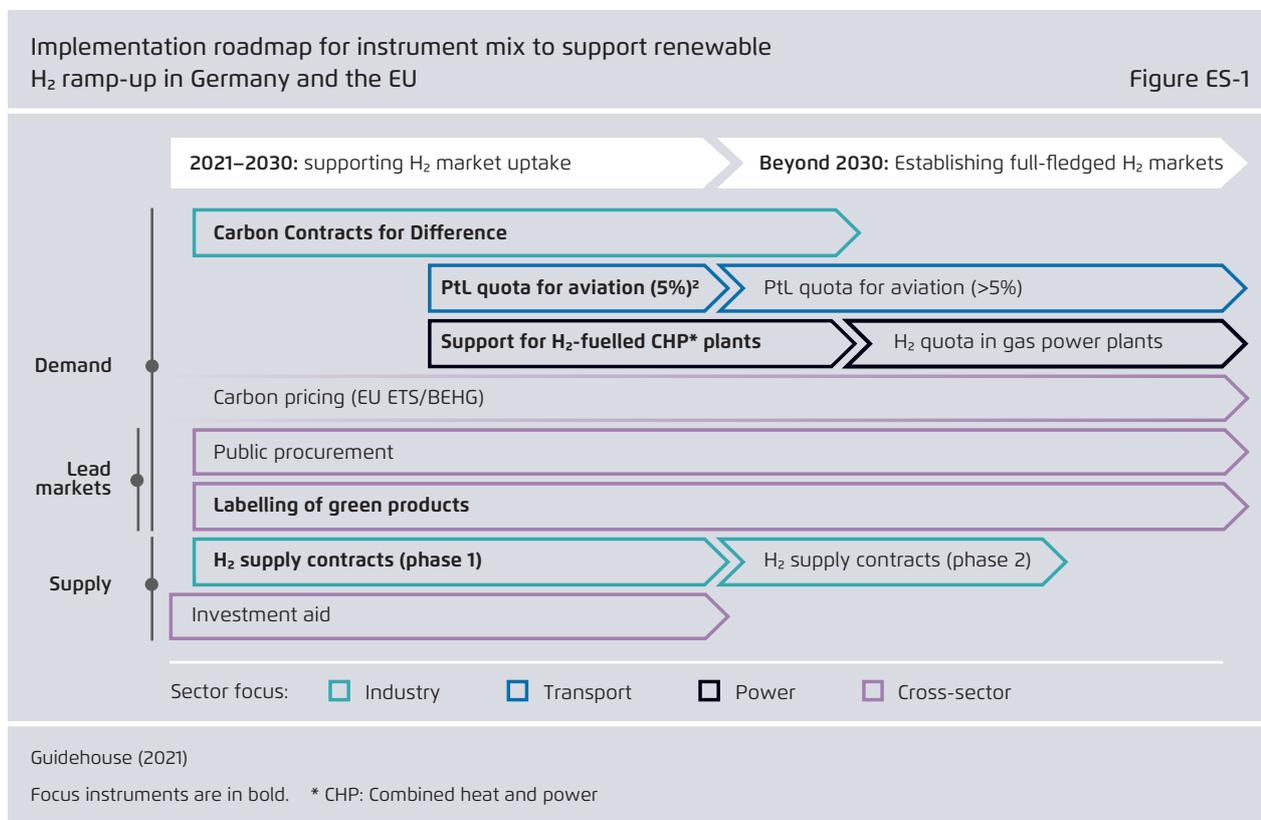
In this way, demand-side policies must be coordinated with coherent supply-side interventions to address the still very high cost of renewable H<sub>2</sub> production. The supply market for renewable H<sub>2</sub> is in its infancy at the moment. This market will need to be rapidly expanded to achieve the targets set forth by the German and EU H<sub>2</sub> strategies.

We recommend the following supply-side policy instruments:

- Investment aid to support the deployment of electrolyzers.
- Exemption from electricity taxes and levies to reduce the cost of electricity.<sup>1</sup>
- H<sub>2</sub> supply contracts to cover the price gap for qualified renewable H<sub>2</sub> demand in the German industry sector (see factsheet A.2).

Supporting the early years of the H<sub>2</sub> ramp-up will be expensive, meaning that attention must be paid to the fair allocation of support costs (see section 2.3).

<sup>1</sup> This instrument was legally implemented in Germany in January 2021.



Beyond 2030, direct support for renewable H<sub>2</sub> production or consumption should be phased out (see section 3). As the cost gap to fossil alternatives will be much smaller after 2030, the cost of supporting renewable hydrogen should be increasingly passed to market actors.

Figure ES-1 summarises the various instruments that can be used to support renewable H<sub>2</sub> and a proposed timeline for their implementation. However, measures to encourage the growth of supply and demand will not be enough. As

2 We propose the introduction of an EU-wide quota for sustainable aviation fuels (SAF) of at least 10%, with a sub quota of at least 5% for e-kerosene by 2030. The quota should be reviewed in 2025 and, if feasible, be increased to 10% by 2030. Note that a share of 10% e-kerosene (as mentioned in the Agora conclusions) is at the upper bound of technologically feasibility given no prior industrial scale production. Even reaching a 5% PtL quota would require significant efforts.

**sustainability** is the primary motivation for using H<sub>2</sub>, strong safeguards should be adopted to ensure renewable H<sub>2</sub> has a positive climate impact (see section 4). Without such safeguards, reliance on H<sub>2</sub> could induce even higher GHG emissions, due to increased electricity demand or higher natural gas consumption. Clear definitions for renewable and climate-neutral H<sub>2</sub> must also be established. The criteria developed in this regard could be applied in a gradualistic, sector-specific manner, to avoid stifling market ramp-up. In the long-term, however, all H<sub>2</sub> production must become climate-neutral.

Well-functioning infrastructure and markets are indispensable components of an effective regulatory architecture, as they unite supply and demand. Accordingly, coherent European-wide standards for H<sub>2</sub> transport, cross-border trade, and third-party access to H<sub>2</sub> networks will represent an essential foundation for the emerging H<sub>2</sub> economy.

However, renewable H<sub>2</sub> is not the only option for enabling the growth of an H<sub>2</sub> economy. As the volume of renewable electricity capacity that can be devoted to H<sub>2</sub> production is currently limited, renewable H<sub>2</sub> is currently almost three times more expensive than its fossil-based alternatives. In this way, the production of **fossil-based H<sub>2</sub> using carbon capture** could serve as a bridge technology, by satisfying and encouraging demand for H<sub>2</sub>, and by supporting associated infrastructure expansion, easing the transition to a fully renewable H<sub>2</sub> economy.



# 1 Introduction: The role of H<sub>2</sub> in reaching climate targets

## 1.1 H<sub>2</sub> in climate neutrality scenarios

Over five years have elapsed since the signing of the Paris Agreement, and the pressure to decarbonise remains immense. The EU has raised its climate ambition and the pace of decarbonisation significantly in recent years. As part of its Green Deal, the European Commission has proposed achieving **climate neutrality by 2050**. The European Climate Law enshrines this commitment, setting forth an intermediate 55% reduction target for 2030, compared to 1990 levels. This is a significant increase from the previous 2030 target of 40% (European Commission 2021a, 4/21/2021).

Following a recent decision by Germany's highest court, the Climate Protection Act of 2019 will be revised to target a GHG emissions reduction of 65% in relation to 1990 by 2030 (previously, the target was 55%) (Bundesregierung 2021b, 2021a). The Act will also set a new target year for climate neutrality – 2045, instead of 2050.

To achieve climate neutrality, **all sectors of the economy need to decarbonise**. In some sectors, such as buildings or passenger transport, this could entail direct electrification, e.g. through heat pumps and electric vehicles. In others, such as steel, chemicals or long-distance air travel, electrification is not an option over the short- to mid-term. Here, **renewable hydrogen (H<sub>2</sub>) and its derivatives<sup>3</sup> represent the foundation of a long-term solution**. This is because renewable H<sub>2</sub> can be used to decarbonise sectors and applications that are resistant to electrification.

3 Whenever in the context of this paper we speak of hydrogen (H<sub>2</sub>) we always mean renewable H<sub>2</sub> and its derivatives, such as ammonia or carbon-containing molecules, unless specified otherwise.

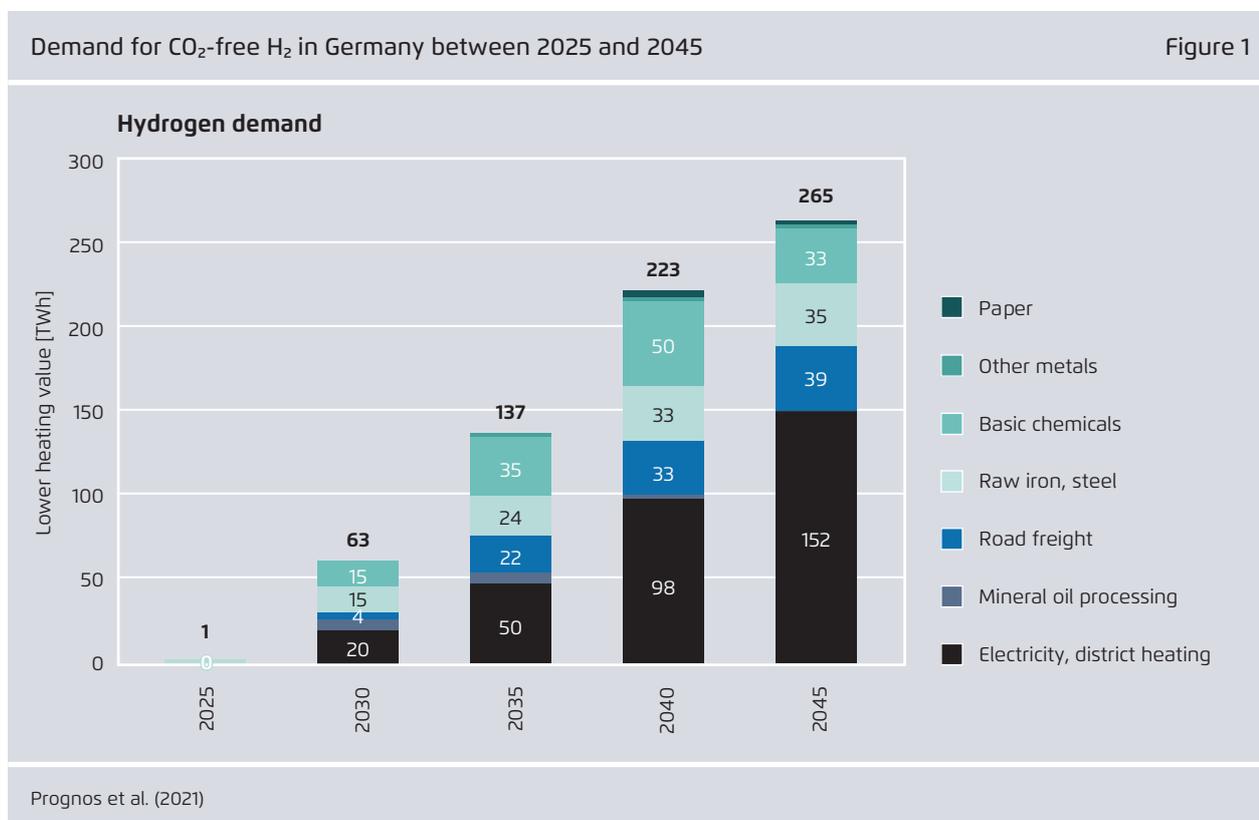
All climate neutrality scenarios<sup>4</sup> show a long-term need for renewable H<sub>2</sub> from an end-use perspective (Dena 2018; BDI 2018; Gas for Climate 2019; Fraunhofer IPA and Fraunhofer ISE 2018; Prognos et al. 2021; Öko-Institut 2020; European Commission 2020a). However, from a systems perspective, renewable H<sub>2</sub> is also needed in countries that have limited renewable energy potential. As certain regions – including South America, the Middle East, Australia, and North Africa – have abundant renewables potential, these regions could become exporters of renewable H<sub>2</sub> to net energy importing countries such as Germany (Jensterle et al. 2019).

The study "Towards a Climate-neutral Germany by 2045" (Prognos et al. 2021) shows that in light of the more ambitious climate targets for 2030, **significant amounts of renewable H<sub>2</sub> may already be needed by the end of this decade**. According to the study, Germany will need around 60 TWh of CO<sub>2</sub>-free H<sub>2</sub> by 2030,<sup>5</sup> partly to run power stations and combined heat and power (CHP) plants, and partly to supply the basic materials industry.<sup>6</sup> In industry, H<sub>2</sub> will mainly be used for the direct reduction of iron ore for low-carbon steel production, for the generation of process steam, and as a raw material for basic chemicals. In the electricity sector, H<sub>2</sub> will be used to fuel gas-fired power plants, in order to generate electricity when there is residual demand and to supply heat to district heating networks. Towards

4 This list includes -95% scenarios which only approach climate-neutrality without dealing with the last 5% of GHG emissions. We do not refer to any of the -80% scenarios, which are implicitly included.

5 Excluding fossil-based hydrogen.

6 The basic materials industry is made up of businesses engaged in mining and metal refining, chemical products, and forestry products.



2045, renewable H<sub>2</sub> will become increasingly important as a secondary energy carrier, as a transport fuel and as feedstock for industry. Specifically, renewable H<sub>2</sub> will be used to run power plants, CHP plants<sup>7</sup> and heating stations; to fuel road freight; and to produce basic chemicals, steel, ferrous alloys, and some other materials (see Figure 1). Demand will increase to around 265 TWh, of which around two-thirds (169 TWh) will be imported. In addition, electricity-based fuels and renewable naphtha – totalling 158 TWh – will have to be imported. CO<sub>2</sub>-neutral Power-to-Liquid (PtL) fuels will be used in shipping and aviation and, to a much smaller extent, in road transport. Renewable naphtha is needed for industrial materials that recycling cannot provide.

<sup>7</sup> CHP plants fuelled with H<sub>2</sub> will need to cover the residual heat load in district heating that remains after all other sources of renewable heat and recycled waste heat have been tapped. In the long run, the most important contribution will come from large-scale heat pumps (Prognos et al. 2021).

**Currently, renewable H<sub>2</sub> is very expensive** – too expensive for widespread use (IRENA 2020a, 2020b; BMWi 2020). Experts agree that public support, including a solid cost recovery model, is needed to scale up the H<sub>2</sub> economy. Over the short term, renewable H<sub>2</sub> could replace existing fossil-based H<sub>2</sub> use, e.g. for desulphurisation or hydrogenation. Over the long-term, refining is likely to decrease, redirecting the renewable H<sub>2</sub> to other sectors (Prognos et al. 2020, section 3.2.6; Agora Energiewende and AFRY Management Consulting 2021).

## 1.2 H<sub>2</sub> policies and strategies

To achieve climate neutrality, countries need to simultaneously ramp up renewable H<sub>2</sub> supply and demand. A dedicated policy framework can ensure that renewable H<sub>2</sub> is quickly produced in increasing quantities. The two main cost drivers of renewable H<sub>2</sub> are the price of renewable electricity and the capital

expenditures for electrolysers. With the cost of renewable technologies rapidly decreasing, the operational costs for H<sub>2</sub> production are anticipated to fall in the future. To ensure this trend continues, the cost of renewable power should be considered when adopting an H<sub>2</sub> policy framework. However, mechanisms to ensure the affordability of renewable power have not been incorporated into the regulatory architecture proposed here. The second driver – the cost of electrolysers – will only fall with large-scale electrolyser deployment. Therefore, the adopted policy framework will be particularly important for driving down electrolyser costs. With the increasing deployment of renewable H<sub>2</sub> technologies, economies of scale and technical improvements will trigger cost reductions (IRENA 2020a, section 4.2). A multitude of countries and the EU have published **H<sub>2</sub> policies and strategies** over the last two years (IEA 2019; IRENA 2020b). In June 2020, the German government adopted its national H<sub>2</sub> strategy, which sets forth measures to promote the production and use of renewable H<sub>2</sub> (BMW<sub>i</sub> 2020).<sup>8</sup> In July 2020, the European Commission published an H<sub>2</sub> strategy for climate neutrality in Europe, which has a strategic focus on developing renewable H<sub>2</sub> and supporting its future uptake (European Commission 2020c, 2020c, p. 5).

**Funding** is a key factor for the rapid uptake of renewable H<sub>2</sub>. The German government has launched an extensive economic stimulus program as a response to the COVID-19 pandemic. The program earmarks €7 billion for national H<sub>2</sub> projects and €2 billion for international projects linked to the national H<sub>2</sub> strategy (BMF 2020). As part of its funding pledge, the German government is in the process of setting up a tendering system for the international production of renewable H<sub>2</sub> (BMW<sub>i</sub> 2020). The system, called H<sub>2</sub>Global, aims to cover the cost difference between, on the one hand, H<sub>2</sub> and its derivatives produced outside the EU, and, on the other, the highest available

offtake price in Germany. The lowest possible production price and highest readiness to pay will be discovered in two-phase auctions (for supply and demand). The gap to market clearing will be paid by public funds through an intermediary entity (H<sub>2</sub>Global 2021). The national H<sub>2</sub> strategy is also promoting industry investment in electrolysers (BMW<sub>i</sub> 2020). The EU, for its part, has launched the Next Generation EU (NGEU) package as a response to the COVID-19 pandemic. The package has a climate spending target of 30% (European Commission 2021e). The NGEU provides grants and loans to Member States, which they can use for various purposes, including investment in renewable H<sub>2</sub>. Furthermore, the EU supports renewable H<sub>2</sub> through the EU Innovation Fund.

The **EU emissions trading system** (EU ETS) is another important policy tool for supporting the uptake of renewable H<sub>2</sub>. The EU ETS sets a CO<sub>2</sub> emission allowance cap for the energy, industrial, and aviation sectors. Phase 4 of the EU ETS, which started in 2021, aims to accelerate investment in decarbonisation by increasing the pace of annual allowance reductions and reinforcing the Market Stability Reserve<sup>9</sup> (European Commission 2021b). In addition to this EU-wide policy, Germany's Fuel Emissions Trading Act (BEHG) established an emissions trading system for heating and transport; trading was launched at the start of 2021 (BMJV 2019). At sufficiently high prices, these policies place significant pressure on companies to decarbonise, e.g. by investing in renewable H<sub>2</sub> technologies. However, the free allocation of emissions certificates under the EU ETS is a barrier to hydrogen use in industry, as companies forego emission certificates when they switch to hydrogen-based technologies.

8 The strategy specifies that fossil-based H<sub>2</sub> with carbon capture may play a role in a transition phase, while only renewable H<sub>2</sub> is considered sustainable in the long term.

9 The Market Stability Reserve was introduced to address the surplus of emission allowances. In the short term, the surplus risked undermining the orderly function of the carbon market. Over the long term, it could have affected the ability of the ETS to meet more demanding emission reduction targets cost-effectively. The Market Stability Reserve improves the system's resilience to major shocks by adjusting the supply of allowances to be auctioned.

The larger **legislative framework** for energy and climate policy is also changing. By June 2021, the European Commission will review and, where necessary, propose revisions to all relevant European legislation, including in particular the Renewable Energy Directive (RED), the EU ETS Directive, and the Energy Efficiency Directive (EED). This “Fit for 55” package aims to achieve a 55% reduction in GHG emissions by 2030 and climate neutrality by 2050 (European Commission 2021c; Agora Energiewende and Ecologic Institut 2021). Experts anticipate the promotion of renewable H<sub>2</sub> to be a feature of the proposed amendments. The European Commission’s agenda for 2021 also foresees the legislative revision of the third energy package for gas, which will alter the common rules in the market for natural gas and the conditions for accessing natural gas supply networks (European Parliament 2021). Legislative changes related to gas infrastructure could have significant effects on the use of renewable H<sub>2</sub> in the EU. In addition, the European Climate Law, which will enshrine the goals of the European Green Deal into law, is slated for near-term adoption. As an additional measure, the EU is expected to revise its guidelines on state aid for environmental protection and energy, which may have important implications for how renewable H<sub>2</sub> can be promoted by national governments.

### 1.3 The aims and structure of this report

The current political ambition and funding pledges in the area of renewable H<sub>2</sub> underline the need for a coherent regulatory framework for hydrogen – both in Germany and the EU. This report thus outlines the potential building blocks of a regulatory architecture that supports renewable H<sub>2</sub> and its derivatives in Germany and the EU. While the report provides many recommendations that are geared to the German context, its key findings are also relevant at the European level. The recommendations are based on a literature review, our own analysis, and on expert workshops.

The sections of this report present regulatory strategies that can ensure a reliable, efficient and sustainable ramp-up of H<sub>2</sub> in the energy system up to 2030. The report also provides a high-level outlook beyond 2030. It should be noted that the dates are only indicative and mainly serve for political orientation.

In collaboration with Agora Energiewende, the project team selected eight promising policy instruments. The instruments are a mixture of existing, planned and new instruments. The appendix provides details on each instrument, and places a focus on implementation, to show initial steps for establishing the described regulatory architecture. In addition, the report refers to other instruments that already exist or are slated for implementation in Germany or at the EU level.

**Section 2** focuses on the ramp-up of the H<sub>2</sub> market up to 2030. During this phase, a primary goal should be to leverage available funding to stimulate the expansion of electrolyser manufacturing capacities. At the same time, demand markets need to be developed. The aim of this section is to show how the cost gap between renewable H<sub>2</sub> and fossil-based H<sub>2</sub> or natural gas can be bridged using policy instruments (an important prerequisite for market-driven ramp-up). We also highlight additional demand-side measures that are required.

**Section 3** discusses the period after 2030, when a focus should be placed on establishing more mature markets. In contrast to the previous phase, support payments (subsidies) will be phased-out, while still ensuring continued market growth. The report also presents policy instruments for this phase. The period after 2040 is not investigated in detail in this report.

The regulatory architecture that is adopted will require not only support instruments but also regulations pertaining to infrastructure and a broader enabling framework. While the enabling framework

will not necessarily have a direct impact on supply and demand, it will nevertheless be essential for the proper function of H<sub>2</sub> markets. Adequate infrastructure, the efficient integration of H<sub>2</sub> into the larger energy system, and the existence of international standards are all essential enabling conditions. These conditions are addressed in **sections 4 and 5**.

**Section 6** focuses on the role of fossil-based H<sub>2</sub> with carbon capture as a bridge technology. While renewable H<sub>2</sub> is rather costly today, more affordable fossil-based H<sub>2</sub> with carbon capture could be used to satisfy and encourage demand for H<sub>2</sub> and support associated infrastructure expansion, thus crucially undergirding the growth of the renewable H<sub>2</sub> economy.



## 2 Supporting H<sub>2</sub> use towards the 2030 target

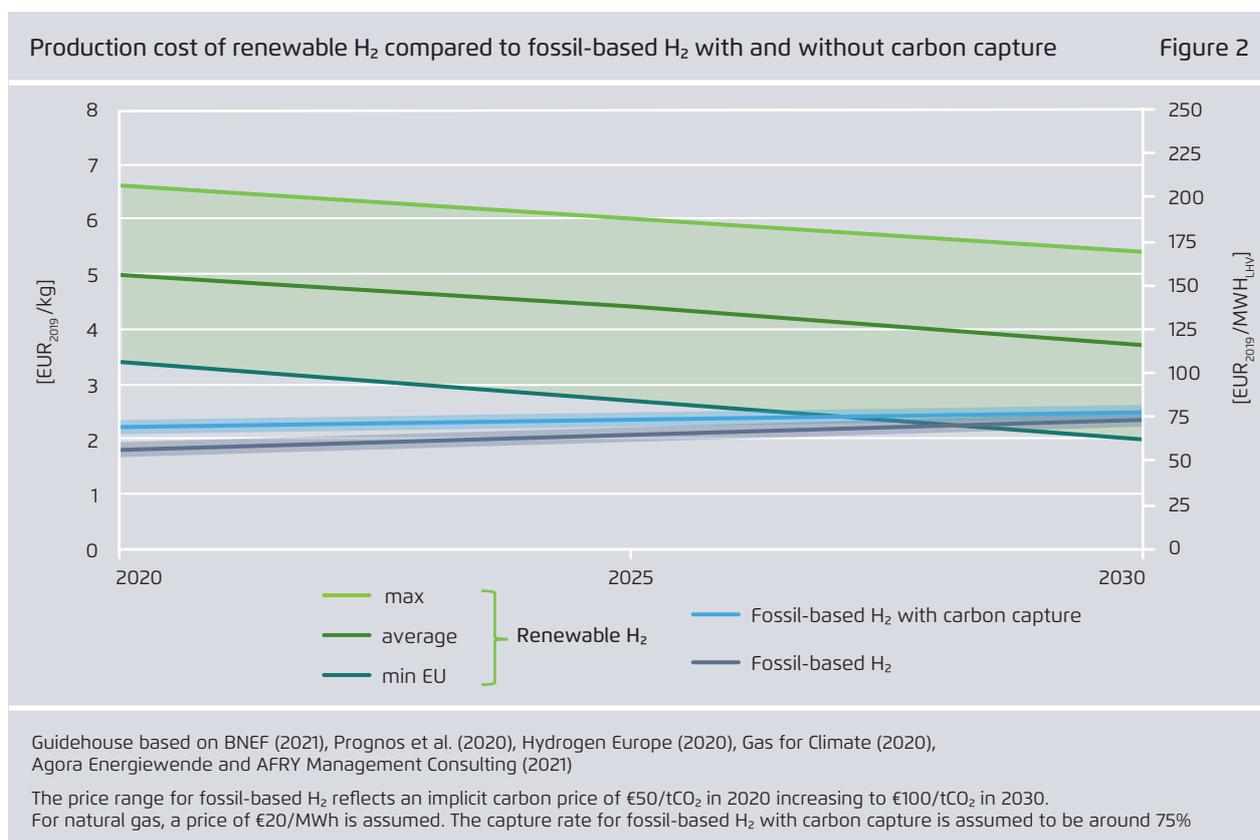
### 2.1 Political priorities up to 2030

The EU and multiple Member States have recently published H<sub>2</sub> strategies, including specific targets for 2030. While certain aspects of these strategies are divergent based on specific national circumstances, four overarching priorities should be considered both at the EU level and in Germany when developing a regulatory architecture for renewable hydrogen.

Firstly, priority should be given to **ramping up the market for renewable H<sub>2</sub> by bridging the cost gap to competing energy sources**. Expanding installed electrolyser capacity will accelerate the technology learning curve. Experience from other technologies suggests that prices will decrease as economies of scale increasingly apply. This could lower the key

barrier to renewable H<sub>2</sub> uptake – namely, the price gap to alternatives. Renewable H<sub>2</sub> is significantly more expensive than its fossil counterparts (see Figure 2).<sup>10</sup> Recent development projects show renewable H<sub>2</sub> costs of €100–€200/MWh. By contrast, fossil-based H<sub>2</sub> with carbon capture costs roughly €60/MWh, and fossil H<sub>2</sub> costs roughly €42/MWh.

10 The renewable H<sub>2</sub> 2020 range is based on BNEF (2021), Prognos et al. (2020), Hydrogen Europe (2020) and Gas for Climate (2020). The 2030 range is based on Prognos et al. (2020) and Agora Energiewende and AFRY Management Consulting (2021). The price range for fossil-based H<sub>2</sub> reflects an implicit carbon price of €50/tCO<sub>2</sub> in 2020 increasing to €100/tCO<sub>2</sub> in 2030. For natural gas, a price of €20/MWh is assumed. The capture rate for fossil-based H<sub>2</sub> with carbon capture is assumed to be around 75%.



Lower prices will be of high importance, as significant renewable H<sub>2</sub> volumes will already be needed in 2030 to achieve climate targets (see section 1.1). Accordingly, targeted policy instruments are needed to bridge this cost gap (as discussed in more detail in section 2.2).

Secondly, a **priority should be given to H<sub>2</sub> use in sectors with limited decarbonisation alternatives.**

Renewable H<sub>2</sub> demand from sectors and applications that could electrify directly should not be incentivised. In an efficient scenario for the energy system of 2050, just a few applications rely on renewable H<sub>2</sub> (see section 1.1). In the short term, some other applications might also use renewable H<sub>2</sub> or its derivatives as stop-gap solutions, but this comes at the risk of delaying investment in more suitable climate-neutral technologies.

Thirdly, **the cost of supporting H<sub>2</sub> market growth should be shared in a fair and transparent manner.**

The total expenditures that will be needed to bridge the above-mentioned cost gap are high. Providing for a viable cost recovery model is thus extremely important (see section 2.3). Additional levies on the general cost of electricity paid by end customers should be avoided, as this would discourage sector coupling while also creating misalignment between those who pay for renewable H<sub>2</sub> and those who benefit from it.

Fourthly, **the creation of new distortions in the power system must be avoided.**

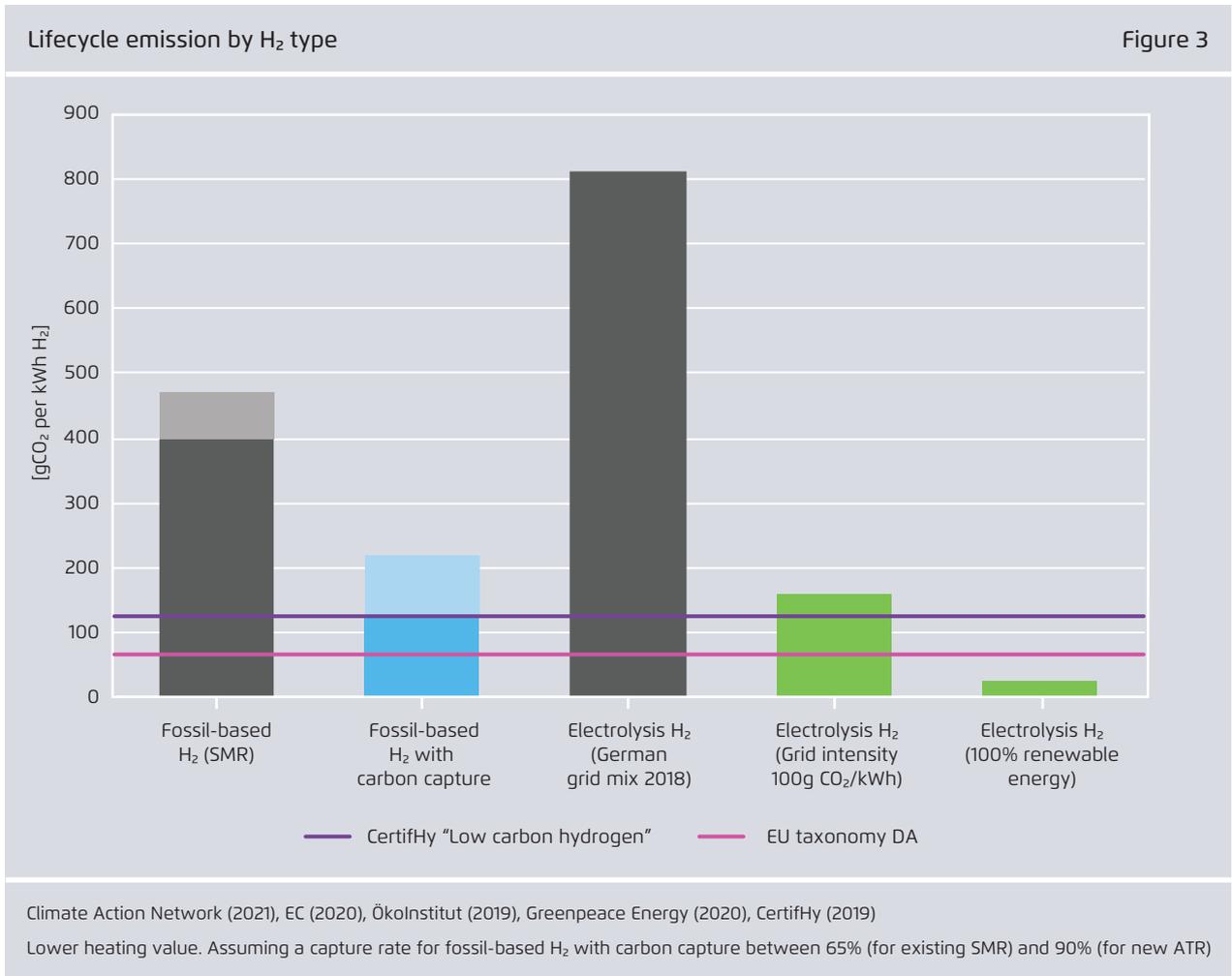
In the long-term, it is crucial that electrolyzers are optimised from the perspective of overall system efficiency, rather than the interests of individual operators. In an optimally functioning system, renewable H<sub>2</sub> should provide flexibility to the system, alleviate network constraints, and rely on renewable electricity that would have been curtailed otherwise. By 2045, Germany is projected to have 50 GW of electrolyser capacity (Prognos et al. 2021). These electrolyser capacities will have significant impacts on the German and European power systems. Achieving the desired level of operational flexibility in the electrolyser fleet by 2030 may be difficult,

however. Some technologies in the renewable H<sub>2</sub> economy are fairly new at the industrial scale – for instance, polymer electrolyte membrane (PEM) electrolysis. Operators may need to gain experience with running these technologies in a flexible way before fully subordinating them to an operational regime that emphasises system health. The priority up to 2030 should thus be to “do no harm”. In other words, while H<sub>2</sub> technologies may not provide significant benefits to the power system early on, we should ensure they don’t aggravate problems, e.g. by augmenting electricity demand during low renewable energy feed-in or grid congestion. Additional considerations regarding market integration and infrastructure are discussed in section 5.

## 2.2 Instruments to achieve market uptake of H<sub>2</sub>

H<sub>2</sub> is already used today on a large scale, mainly in refining and in ammonia and methanol production. Germany consumes some 55 TWh of H<sub>2</sub> each year; across the EU, annual consumption stands at 340 TWh (BMW<sub>i</sub> 2020; Gas for Climate 2021). However, virtually all of this H<sub>2</sub> is produced using fossil fuels such as natural gas, which generates significant GHG emissions (IEA 2019). We refer to this type of H<sub>2</sub> as ‘fossil-based’ H<sub>2</sub>. It is produced mainly through steam methane reforming (SMR). A cleaner version is ‘fossil-based H<sub>2</sub> with carbon capture’, which is also produced using fossil fuels, but the generated carbon emissions are captured and stored. The most sustainable type of H<sub>2</sub> is ‘renewable H<sub>2</sub>’, which is generated through electrolysis using 100% renewable energy.<sup>11</sup> Figure 3 shows the lifecycle emissions intensity of five different H<sub>2</sub> types (in gCO<sub>2</sub> per kWh H<sub>2</sub>). The two H<sub>2</sub> types on the left are produced using SMR, while the three H<sub>2</sub> types on the right are produced using electrolysis. The threshold criteria for sustainable hydrogen are currently under

11 Some lifecycle emissions for renewable hydrogen still occur related to upstream renewable electricity generation

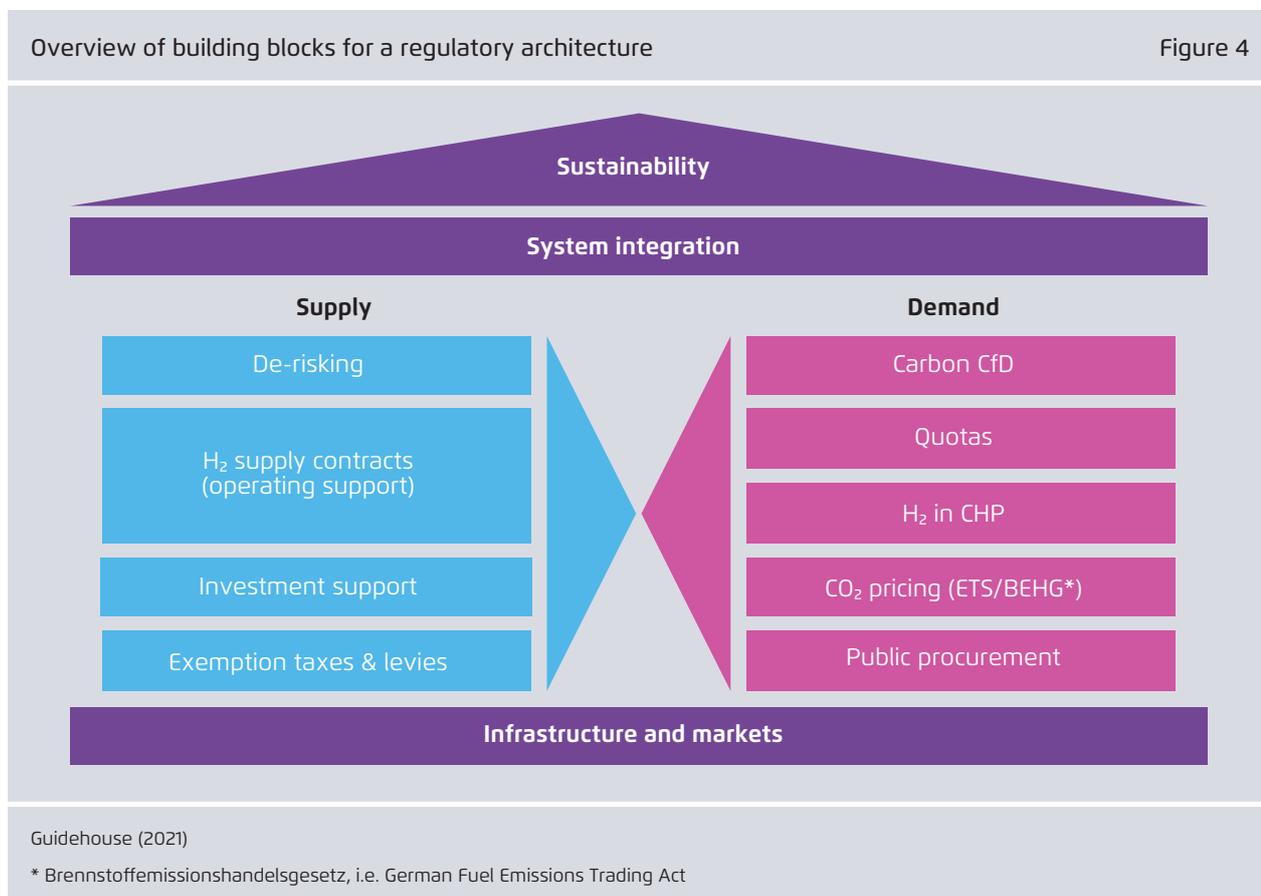


discussion. This is reflected by the dotted lines, which show emissions associated with competing standards (namely, the criteria set forth by CertifHy<sup>12</sup> and the Delegated Act on the EU Sustainable Finance Taxonomy). Additional discussion on H<sub>2</sub> sustainability by type is provided in sections 4 and 6.

Given the established use of H<sub>2</sub> in the industrial sector, industry is well-positioned to become a lead market for renewable H<sub>2</sub>. However, for successful market uptake, policy instruments are required to

reduce and ultimately close the cost gap between renewable H<sub>2</sub> and its fossil-based alternatives. Policy instruments on the demand side are needed to introduce H<sub>2</sub> to applications that really need it, for instance the industry applications mentioned in the beginning of this section. As production costs are still very high, however, demand-side instruments may not be sufficient, making supply-side interventions necessary. In the following, we discuss both domains of policy intervention – supply and demand – and possible policy instruments.

12 CertifHy was initiated at the request of the European Commission and financed by the Fuel Cell and Hydrogen Joint Undertaking to establish an EU-wide Guarantee of Origin scheme for Green and Low Carbon H<sub>2</sub>



However, instruments to encourage renewable hydrogen supply and demand are not enough. Rather, there is a need to adopt a holistic regulatory approach that also addresses sustainability, system integration, infrastructure and markets (see Figure 4). Well-functioning infrastructure and markets are indispensable for uniting supply with demand. Accordingly, they have a foundational role (as discussed in section 5). By contrast, sustainability and system integration are ‘overarching’ aspects that unite and provide purpose to the various regulatory measures; they are the ‘roof’ under which the measures are subsumed. Sustainability and system integration are discussed in greater detail in section 4.

### 2.2.1 Supply-side instruments

The market for renewable H<sub>2</sub> is still in its infancy, as production is currently confined to some smaller pilot projects (Gas for Climate 2021). Accordingly, available

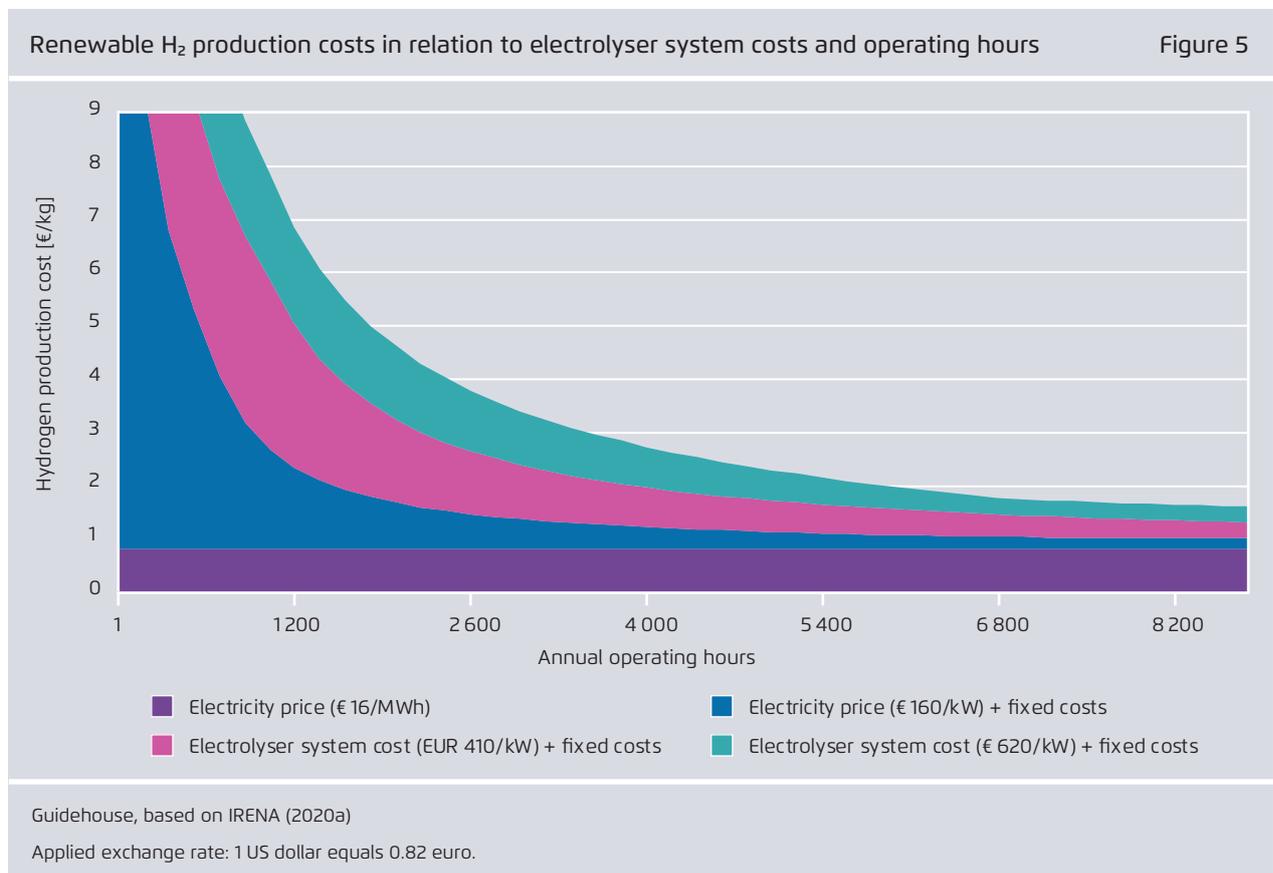
supply would need to be rapidly expanded to achieve the targets set out in the aforementioned H<sub>2</sub> strategies. The EU’s H<sub>2</sub> strategy aims to achieve at least 40 GW of electrolyser capacity by 2030 (European Commission 2020c). The German H<sub>2</sub> strategy, by contrast, has a target of 5 GW of electrolyser capacity by 2030 and an additional 5 GW by 2035 if possible (BMW<sub>i</sub> 2020).

The large-scale production of renewable H<sub>2</sub> is currently unattractive to investors, as the cost of producing renewable H<sub>2</sub> significantly exceeds that of fossil-based alternatives. The production cost of H<sub>2</sub> depends on several factors, including electrolyser capital expenditures, the technical efficiency of conversion, annual operating hours,<sup>13</sup> the cost of stack replacement, and the procurement cost of renewable

13 Also known as the ‘capacity factor’.

electricity (IRENA 2020b). Figure 5 shows production costs in relation to annual operating hours as a function of different electrolyser investment cost levels, ranging from €160/kW to €620/kW, and assuming a constant low electricity price of €16/MWh. As shown in the figure, the cost of renewable H<sub>2</sub> production varies significantly across operating hours. At low operating hours, the production costs are extremely high. The constant electricity price used in the figure aims to underscore the relevance of operating hours as a price driver. However, if electrolysers use grid electricity and operate based on market prices for H<sub>2</sub> and electricity, the situation would be different, as operating costs would increase disproportionately at higher operating hours. Consequently, operators may want to restrict operating hours, e.g. to no more than 5,000 hours per annum. As the volatility of electricity prices increases, this relationship becomes more important.

The most important influenceable factor for achieving cost-competitive production is the cost of the electrolyser system. A cheap electrolyser only needs to run 1,000 hours per annum to achieve cost-competitive production, while the most expensive electrolyser needs to run around four times as long. In this way, dedicated policy instruments should be adopted to encourage electrolyser cost reductions. The European Commission expects electrolysers to become significantly less expensive by 2030 (European Commission 2020c). Stacks are also expected to become very cheap as production becomes increasingly automated. The cost of producing electricity from renewable sources has fallen steadily and is expected to decrease further in the future. This cost decline is treated as exogenous, as the pace of renewables expansion will not be impacted by progress in electrolyser deployment.



Various supply-side measures can help to make H<sub>2</sub> more competitive by decreasing costs, including investment aid, tax exemptions, and de-risking instruments. **Investment aid** could finance the capital costs (CAPEX) for electrolyzers. At the EU level, the Innovation Fund supports innovative low-carbon technologies (such as electrolyzers) with revenues from the EU ETS. Furthermore, the German H<sub>2</sub> strategy aims to support the switchover to hydrogen in the industrial sector by providing funding for investment in electrolyzers (BMW<sub>i</sub> 2020). Indeed, multiple options for incentivising investment are available, including the EU ETS and Recovery and Resilience Facility. However, investment aid is not enough, as the final price of renewable H<sub>2</sub> is largely dependent on the cost of feedstock electricity, as shown in Figure 5.

The **exemption of electrolyzers from taxes and levies** would decrease the cost of electricity, which is the largest component of operating costs (OPEX). In Germany, taxes and levies account for around half of the electricity price paid by end customers (BDEW 2021). The EEG levy alone accounts for almost a third of the electricity price. According to the latest revision of the EEG Act, companies producing renewable H<sub>2</sub> with RES are partially exempt from paying the EEG levy (up to 30 MWh/a) (BMJV 2017). Furthermore, if an industrial facility or product contributes to grid stability, it is fully exempt. The applicability of this exemption to electrolyzers would depend on the defined requirements for renewable H<sub>2</sub> production. However, any reductions to these price components would still not suffice to make H<sub>2</sub> production cost-competitive. The planned decrease in the EEG levy is also problematic, as it will reduce the steering effect of the instrument (Tagesspiegel 4/7/2021; BMW<sub>i</sub> 10/15/2020).

**De-risking instruments** to reduce financing costs can significantly lower necessary investment outlays. Renewable H<sub>2</sub> projects may be subject to a wide variety of risks, including political, regulatory, counterparty, exchange rate, and liquidity risks.

Lowering these risks reduces cost of capital, thus making the renewable H<sub>2</sub> cheaper. Any policy instrument that closes the cost gap to fossil fuels or that creates reliable demand could be considered a de-risking instrument. Policy instruments with a long-term perspective generally have a higher de-risking potential than others. Instruments that are not dependent on public budget allocations, such as quotas, are also considered to have a higher de-risking potential, particularly when the political commitment to future budget allocations is uncertain (Gas for Climate 2021). Government guarantees to cover the risk of default in the final stages of a technology's development can also be viewed as a financial de-risking instrument (Agora Energiewende and Wuppertal Institut 2021).

The instruments outlined above can help to reduce the cost gap to fossil-based alternatives. However, they are unable to fully close this gap. **H<sub>2</sub> supply contracts** that provide support for both production and demand could be harnessed to address the remaining cost discrepancy (see factsheet A.2). This instrument would cover the price gap between renewable H<sub>2</sub> and fossil alternatives in the German industrial sector. The support provided to each plant would be granted as a fixed euro amount per tonne of H<sub>2</sub>. The special feature of this instrument is that it would cover both the supply and demand sides of the market. Under the proposed instrument, the price gap is identified in a two-stage auction, one for supply, and one for demand. The producer offering the lowest price and the offtaker with the highest willingness to pay would be awarded financial support for a certain time period. The instrument would be introduced in two phases. In the first phase, H<sub>2</sub> transport infrastructure would not be widely available, so H<sub>2</sub> supply contracts would be tied to fixed delivery locations within Germany, leading to decentralised supply and demand. However, once H<sub>2</sub> transport infrastructure is sufficiently developed to enable a liquid market (towards 2030), production locations in Germany and internationally would be allowed to compete in the auctions. The annual cost of policy support for this

instrument within Germany is estimated at between €0.8 and €5.3 billion. While this instrument can facilitate the uptake of H<sub>2</sub> in applications that really need it, it cannot guarantee such uptake will occur. Hence, demand-side instruments are also crucial for encouraging demand in the desired sectors.

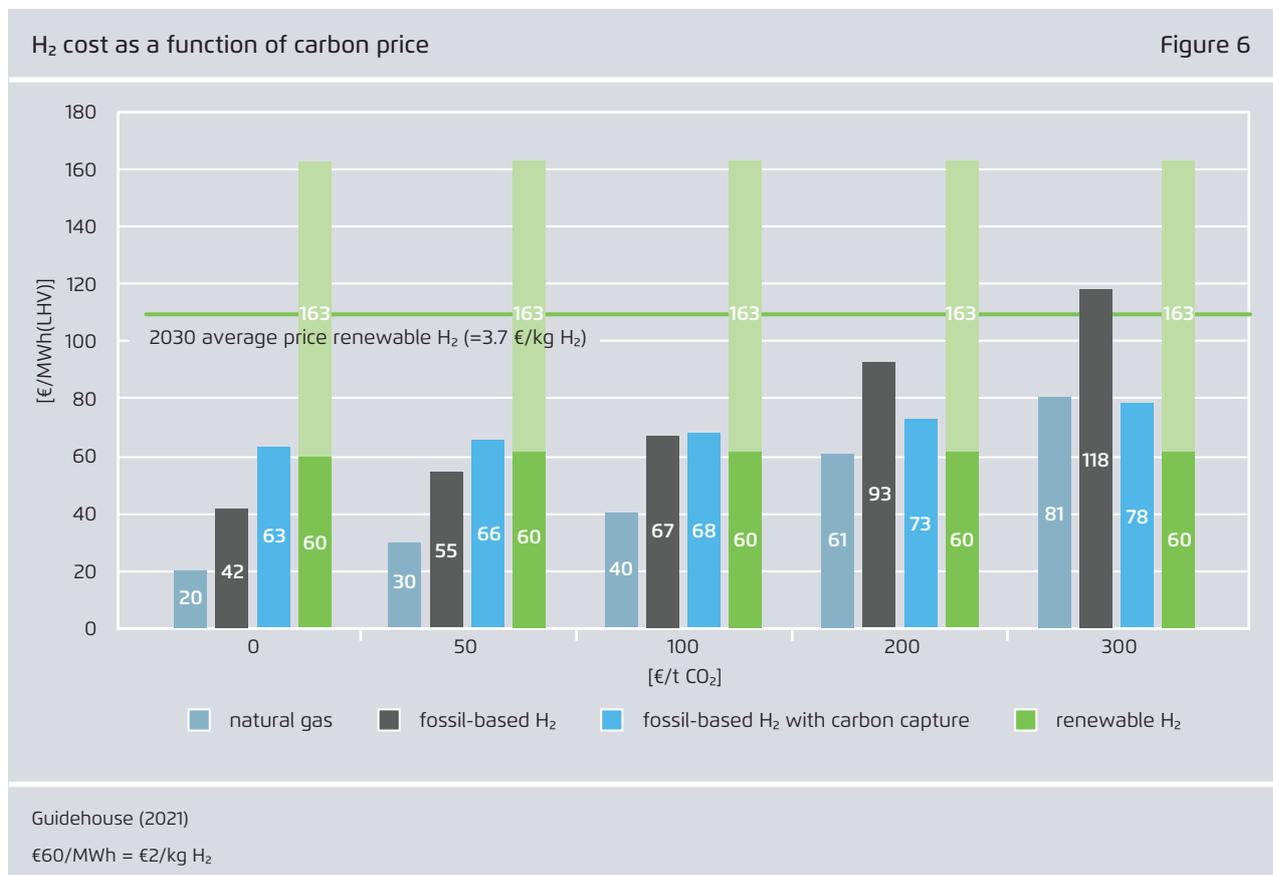
**2.2.2 Demand-side instruments**

On the demand side of the market, a focus should be placed on creating demand for H<sub>2</sub> in applications that truly need it while production is being ramped up.

One important instrument for promoting demand is **carbon pricing**. Carbon pricing makes fossil fuels increasingly expensive. This, in turn, triggers cost-efficient GHG abatement measures, including greater efficiency or a reliance on alternative fuels (e.g. electrification or biomass). However, when carbon pricing is not sufficient for cutting emissions

in areas of application in which H<sub>2</sub> needs to be employed, carbon pricing can help to close the cost gap between renewable H<sub>2</sub> and its fossil counterparts.

At current prices, carbon pricing alone is not enough, however. EU ETS allowance prices ranged from €15/tCO<sub>2</sub> to over €50/tCO<sub>2</sub> between March 2020 and May 2021. The German BEHG has a similar price level (€25/tCO<sub>2</sub>, but set to increase to €55/tCO<sub>2</sub> by 2025). This is too small to close the cost gap in any area of application (see Figure 6). Renewable H<sub>2</sub>, natural gas, and fossil-based H<sub>2</sub> without and with carbon capture react differently to increasing carbon prices. The large price range shown for renewable H<sub>2</sub> in the figure is a reflection of divergent market expectations and variance in the underlying renewable energy potential. For reference purposes, we use €3.7/kg as the average expected price for renewable H<sub>2</sub> in 2030.



As anticipated carbon prices over the short term will be excessively low, sector-specific policies are needed to encourage rapid uptake of renewable H<sub>2</sub>.<sup>14</sup> In the **industrial sector**, Carbon Contracts for Difference (CCfDs) would be a suitable tool. The primary aim of this instrument is to facilitate investment in breakthrough technologies. By offsetting the additional operating cost of novel technology, CCfDs can de-risk long-term investment (see factsheet A.1). The funding requirements for CCfDs can be very large. Indeed, estimates place the funding required to convert one third of German primary steel production to H<sub>2</sub> at €1.1–€2.7 billion per annum. The equivalent estimate for converting half of EU production is €4.1–€10.2 billion per annum (under the current free allocation regime). Several options for cost recovery exist. Initially, the instrument could be financed from general taxes receipts or EU ETS revenues. A climate surcharge on final products (e.g. steel) could generate dedicated funding for sector-specific CCfDs. More information on cost recovery is included in section 2.3. Quotas for low-carbon (e.g. hydrogen-based) products or for renewable energy use (including renewable H<sub>2</sub>) represent another potential instrument for the industrial sector not analysed further in this report.

In the **aviation sector**, a PtL quota would create strong demand for renewable H<sub>2</sub>. The aviation sector, especially long-distance air travel, has few alternatives for decarbonisation. Accordingly, e-kerosene production must be upscaled as quickly as possible. Setting an EU-wide quota would create investment security for a ramp-up of renewable H<sub>2</sub> and jet fuel production. It would also send a strong signal internationally, as quota fulfilment would require international imports as a supplement to domestic production inside the EU. E-kerosene can

be easily transported and is therefore the ideal H<sub>2</sub> derivative for imports (see factsheet A.4). The price premium could be passed on to consumers by airlines. We propose the introduction of an EU-wide quota for sustainable aviation fuels (SAF) of at least 10% by 2030, as well as a sub-quota of at least 5% for e-kerosene. The e-kerosene quota should be reviewed in 2025 and, if feasible, increased to 10% by 2030. Note that a 10% e-kerosene share is considered the upper bound of technological feasibility given that the technology has not yet been developed at the industrial scale. Even reaching a 5% PtL quota would require significant efforts. The annual cost of a 5% e-kerosene quota is estimated at between €0.7–€1 billion for Germany<sup>15</sup> and €5.2–€7 billion for the EU.<sup>16</sup>

In the **power sector**, the study "Towards a Climate-neutral Germany by 2045" foresees 2.5 GW of H<sub>2</sub>-fuelled capacities in 2030, generating 8 TWh of electricity and 5 TWh of heat (Prognos et al. 2021). To have the required capacities in place by 2030, a dedicated support instrument is needed. A fixed feed-in premium for new renewable H<sub>2</sub>-fuelled CHP plants could be tendered under the existing CHP Act (see factsheet A.3). Plants would receive support per unit of energy generated, covering both the incremental CAPEX as well as the OPEX cost difference between renewable H<sub>2</sub> and natural gas. The annual cost of policy support for this instrument is estimated to range from €0.3 to €1 billion for Germany. It is important to note that this instrument is driven by the power sectors' need for dispatchable generation. Heat production is a side benefit, and will only be needed to cover the residual heat load (see info box below).<sup>17</sup> Support under the CHP Act is currently

14 Our discussion of instruments is not fully comprehensive, as additional instruments, including measures to promote the use renewable H<sub>2</sub> and its derivatives in the maritime sector, will also be required.

15 Based on 91 TWh of kerosene demand.

16 Based on 667 TWh of kerosene demand.

17 This is the remaining load after all other available sources of renewable heat and recycled waste heat have been tapped. In the long run, the most important contribution will come from large-scale heat pumps (Prognos et al. 2021).

financed through levies on final consumers. This system could also be used to finance upfront investments; as an additional source of funding, carbon tax revenues could be considered.

### H<sub>2</sub> in the power sector: How soon?

While assessments diverge on how soon the integration of H<sub>2</sub> in the power sector will be required, experts agree that the transition will need to be well-prepared. History has shown that the adoption of new energy technologies is often delayed by unforeseen technical challenges. This underscores the need for early piloting to prepare the ground for large-scale adoption. Moreover, backup solutions for power generation and district heating need to be explored. Various other factors may lead to delays in the transition to H<sub>2</sub>, including:

- Limited output capacity among manufacturers, planners, engineers and utility providers.
- The restricted time window for CHP construction or retrofit, outside the winter heating period.
- The time required to plan and implement heating grids for climate neutrality (the efficient utilization of hydrogen condensing technology demands modular and distributed solutions).

Finally, climate neutrality by 2045 implies faster H<sub>2</sub> integration in CHP production. Overall, the transformation towards H<sub>2</sub> use in CHP plants will take time, and will require early signaling to relevant stakeholders (Prognos 2021).

Lastly, the government could create demand itself, by buying green. **Green public procurement** obligations could have a significant impact on market demand. As public authorities across the EU spend around 14% of GDP (around €2 trillion per

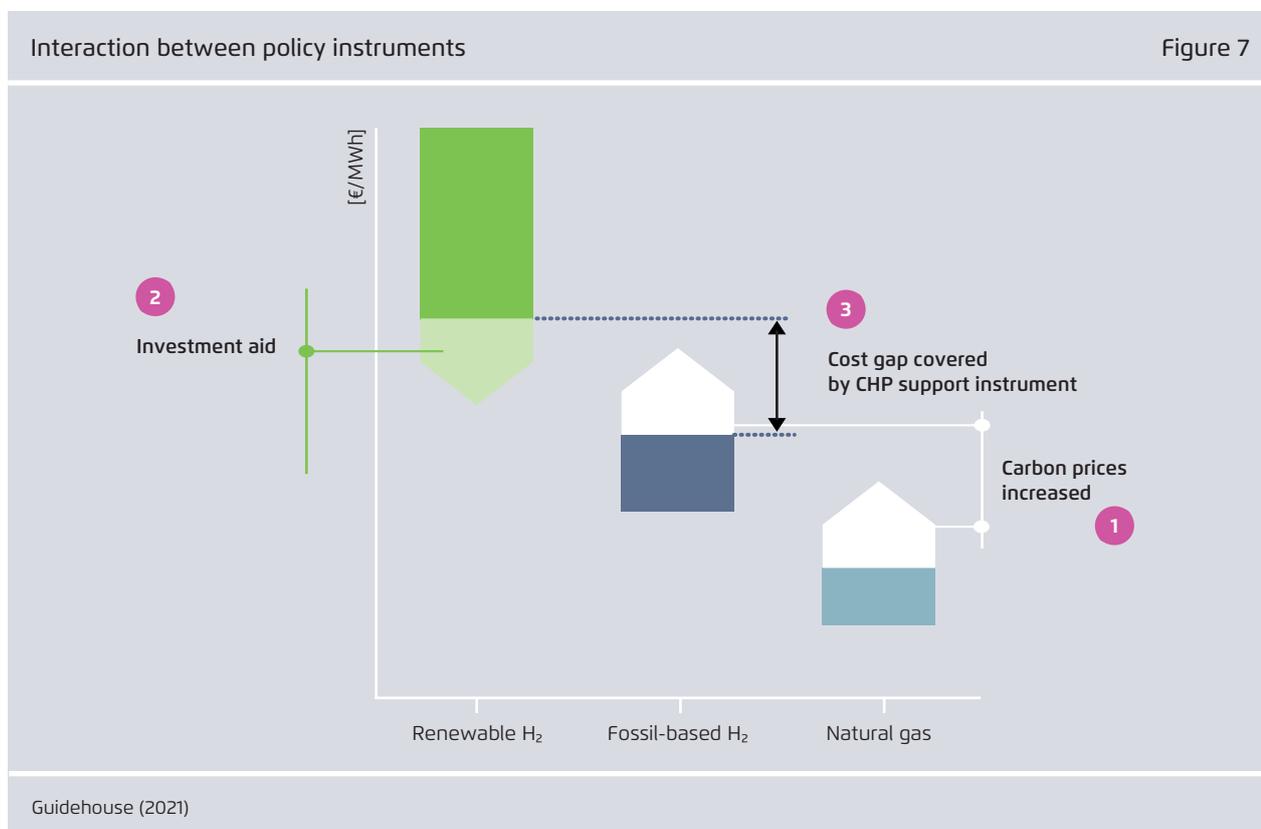
year) on the purchase of services, works and supplies, public procurement criteria could be leveraged to shape production conditions for various products, including steel, cement and vehicles (see factsheet A.7) (Agora Energiewende and Wuppertal Institut 2021).

Instruments that create demand across the board may lead to inefficient short-term allocation of renewable H<sub>2</sub> and negative long-term lock-in effects. Hence, instruments like a **general H<sub>2</sub> quota** may not be implemented. (see factsheet A.5).

### 2.2.3 Interaction between supply and demand instruments

The overall aim of the adopted regulatory framework should be to augment and harmonise supply and demand while also avoiding excessive subsidisation, including double subsidies. Accordingly, the interactive effects between different support instruments must be taken into account. As shown in Figure 7, supply and demand interventions have cumulative effects. Individual development projects may qualify for several support instruments – and the instruments may be needed in combination to make the project financially viable. In the example below, the EU ETS makes natural gas procurement more expensive for a CHP plant. Combined with this, investment aid makes renewable H<sub>2</sub> production less expensive. The remaining cost gap to fossil-based alternatives could then be covered in a third step with a support instrument for H<sub>2</sub>-based CHP plants (as described in factsheet A.3). A similar graph could be drawn for hydrogen use in the aviation sector.<sup>18</sup>

18 The feasibility of introducing investment aid for e-kerosene in combination with a usage quota for the aviation sector will hinge on the European Commission's judgment as well as changes being considered to state aid guidelines in the area of environmental protection and energy.



In the regulatory architecture we propose, several instruments have overlapping or interactive effects. Carbon Contracts for Difference (CCfDs) and H<sub>2</sub> supply contracts both seek to promote renewable H<sub>2</sub> consumption by industry. Insofar as both instruments are in place, it would be necessary to restrict eligibility to just one of these instruments, to avoid impermissible double subsidy.

Furthermore, interactions may arise between the labelling instrument for green lead markets and other instruments such as public procurement. Here, we find a mutually beneficial interaction, as governments would benefit from the increased transparency provided by labels, while increased public spending on green products would foster the development of green lead markets and business models based on renewable H<sub>2</sub>.

Thus, while interactions between support instruments may be intended and beneficial for closing the cost gap to fossil alternatives, policymakers need to

be aware of such interactions, and avoid over-subsidising certain projects. Over-subsidy can be avoided through adequate monitoring of market activity, in addition to the targeted adjustment of regulatory provisions when problems are identified. In general, market-driven schemes, such as auctions, have proven best-suited for avoiding the pitfall of over-subsidisation.

### 2.3 Relationship between policies in Germany and the EU

This report focuses on policies that will enable H<sub>2</sub> uptake in Germany and the EU. Some of these policies are designed for implementation at the EU level, while others are specific to Germany. Despite this focus on Germany, the principles underlying the described policy instruments could be used to establish a regulatory architecture for hydrogen in other European countries.

The adoption of policies within the EU is generally subject to the **principle of subsidiarity**. In the case of EU Directives, for instance, the broader regulatory framework is set by the EU, and then adapted to national circumstances by Member States. Ideally, this means that policies, regulations, funding support at the European and Member State levels should complement each other.

The complex relationship between these two levels of governance may lead to some inconsistency over the short- to medium-term. With a view to H<sub>2</sub>, there is a possibility of **temporary misalignment and overlapping regulations**. For example, different product definitions for renewable H<sub>2</sub> are currently emerging, as Germany is introducing an exception to the EEG levy for H<sub>2</sub> plants that uses a different definition from that which can be expected from the RED II Delegated Act on sustainability criteria for electricity consumption by electrolysers. This misalignment is expected to dissolve once the RED II Delegated Act is adopted, as Germany and other Member States will most likely amend their criteria at that point in time. Similarly, overlapping regulation in the case of a renewable fuel quota for the aviation sector, as such regulations might be introduced with different degrees of ambition and permissible fuel types at the German and EU levels. While Germany has already decided to introduce a PtL quota, the EU is pondering a quota for Sustainable Aviation Fuels (SAF), including biokerosene. Should both quotas be introduced, market actors would need to fulfil the stricter obligation. Such misalignment can lead to inefficiencies and should ideally be avoided. However, we generally expect that such issues will be temporary in most cases.

The current funding landscape for H<sub>2</sub> related projects is quite diverse and will likely become more complex as additional Member States introduce funding schemes that complement those available at the European level. As a result, **project developers may become overwhelmed by the complexity of the funding landscape**. In particular, this may place an

excessive administrative burden on project developers, as demonstrated by past experience with funding schemes for renewable energy. As a result, project developers may not apply to the best-suited scheme for their project, or fail to take advantage of assistance altogether. This is a particularly relevant issue when it comes to inadmissible double support, i.e. when support from one scheme precludes support from another.

The problems posed by initially divergent and partially misaligned policy provisions at the EU and national levels may be of marginal concern **so long as regulatory harmonisation is achieved over the long term**. Such harmonisation, especially when it comes to sustainability criteria, will be essential for establishing a liquid and efficient H<sub>2</sub> market over the long term.

A certain level of heterogeneity between Member States in the area of H<sub>2</sub> policies and regulations will perhaps be unavoidable. Some Member States will act as **first movers** as they strive for technological leadership (e.g. Germany, the Netherlands). Other countries will be late adopters, benefiting from the innovation of first-movers.

## 2.4 Allocating the cost of support instruments

The described support instruments for encouraging growth in H<sub>2</sub> supply and demand entail significant costs. When it comes to the societal distribution and recovery of these costs, certain basic principles should be considered. First, there should be transparency regarding the true cost levels and how burdens are being shared. Whenever reasonable, costs should be allocated to those who actually use the goods and services requiring renewable H<sub>2</sub>. On the other hand, society as a whole will benefit from the establishment of H<sub>2</sub> markets, as this will support climate protection while also creating new opportunities for value creation and shared prosperity. Some broader sharing of costs thus appears justified, at least early on.

Refinancing option	Distributional fairness	Potential financing volume	Ability to implement soon	Cost transparency	Potential need for exemptions (e.g. industry)
Public budget	+	+	+	+	/
Power levy	-	+	+	+	+
Climate surcharge	+	+	-	+	-
Obligation (e.g. quota)	-	o	+	-	+
Green lead markets	+	-	o	+	/

+ High  
o Medium  
- Low  
/ Not applicable

Guidehouse (2021)

In the following, we present several options for recovering the costs associated with our recommended policy instruments (see Table 1).

One cost-recovery option is to use general funds from the **public-sector budget**. This would provide access to large sums of money over the short-term. Furthermore, costs would be automatically distributed in a socially equitable manner, given the progressive nature of the tax regime. One caveat is that broad allocation along these lines could lead to an unfair cost-benefit distribution over the long-term. Using public budgets could also result in ‘stop and go’ funding, e.g. due to budget cuts or freezes.

A second option is to use **power levies**, such as the German EEG levy<sup>19</sup> or CHP levy. Alternatively, fuel or gas levies could be used. Levies are an established mechanism for financing climate protection measures. In general, levies have the advantage of assured funding (no budget freezes or exhausted funds), and

they also target the right consumers. However, this option also has disadvantages. Levies are generally more difficult to implement legally. In addition, they tend to place disproportionate burdens on lower-income households, leading to negative distributional effects. Energy-intensive industries may need exemptions (as with the EEG levy). Last but not least, direct electrification measures (which are preferred due to their efficiency) are disadvantaged by power levies, due to higher electricity prices.

A third option is to apply a **climate surcharge** to CO<sub>2</sub>-intensive products (such as steel, aluminium, cement and plastics), thus making those products more expensive for consumers (see factsheet A.8) (Agora Energiewende and Wuppertal Institut 2021). This incentivises material efficiency and substitution. However, in contrast to the previous two options, such a surcharge would represent a completely new instrument with a complex set-up, thus requiring some time to generate a significant funding stream.

Yet a fourth option would be to implement **usage obligations** (rather than support payments). Instruments such as quotas would force the obligated

19 The 2021 amendment to the EEG determined that the EEG levy is partially funded by the federal budget, thus requiring it to be capped. The abolishment of the EEG levy over the mid-term is currently under discussion.

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parties, e.g. fuel suppliers, to cover H<sub>2</sub> usage costs. The obligated parties would then be expected to pass along cost increases to end consumers. Obligations usually have a greater impact on lower-income individuals than the wealthy, leading to negative distributional effects. The instrument would also require robust standards and transparent, clearly understandable certification.

A fifth option is to establish **green lead markets**. This option would rely on the willingness of households and businesses to pay a premium for climate-friendly products based on renewable H<sub>2</sub>. Example products include cars, flights, plastic packaging, and construction materials. Establishing lead markets for green products could play an important role for companies to adopt corresponding business models. A **labelling system for climate-friendly basic materials** is an important prerequisite for green lead markets (see factsheet A.6). Furthermore, green labels are likely to be most effective in combination with other instruments, such as carbon limits on final products (CISL and Agora Energiewende 2021). If carbon limits on products were adopted, producers would need to provide evidence of compliance, e.g. via CO<sub>2</sub> pass-

porting of input emissions. Labels can also be used to communicate the necessity of charging a price premium (e.g. to finance new production processes based on renewable H<sub>2</sub>). In this way, a labelling system can support the ramp up of renewable H<sub>2</sub> production and the development of green lead markets, in part by allowing the costs of market development to be passed along to consumers. As the initial demand-side pull will not be sufficient to justify investment in renewable hydrogen capacity, the use of additional instruments, such as CCfDs, may be necessary. Furthermore, **green public procurement** is an additional option for encouraging green lead markets, as public entities have significant buying power, allowing them to become an influential driver of demand for green products (see factsheet A.7).

The establishment of green lead markets and a green labelling system would yield distinct benefits, as they would foster market transparency while also capturing funding from those who are willing to pay a price premium. However, they are not sufficient unto themselves to trigger the necessary scope of transformation, and should thus be viewed as supplements to other funding and support options.



### 3 Beyond 2030: Long-term strategies to support H<sub>2</sub>

In the period up to 2030, a policy focus should be placed on enabling the market uptake of H<sub>2</sub>, which requires decisive government support. Beyond 2030, H<sub>2</sub> supply and demand should be increasingly governed by a well-functioning and liquid market.

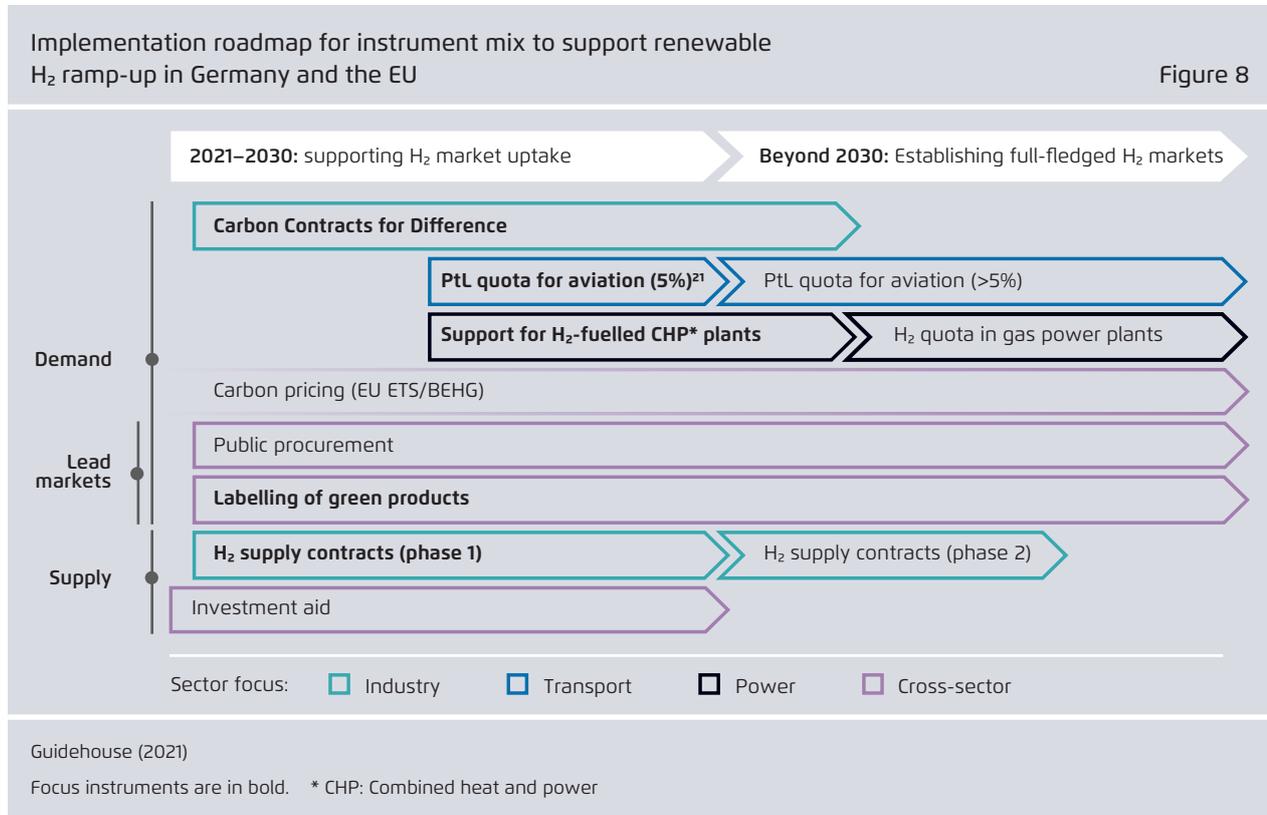
This shift will be made possible through evolving market conditions and associated regulatory changes. By 2030, H<sub>2</sub> generation costs will be significantly lower, thanks to declines in the cost of renewable electricity and electrolyser technology. At the same time, the competing fossil fuels will become more expensive due to higher carbon prices.<sup>20</sup> As a result of these developments, **the cost gap will be reduced**. In some applications, where renewable H<sub>2</sub> competes directly with fossil-based H<sub>2</sub>, the cost gap may even be eliminated entirely. However, a persistent gap can be anticipated when it comes to direct competition between renewable H<sub>2</sub> and natural gas, or renewable H<sub>2</sub> and conventional jet fuel. Therefore, policies to support the renewable H<sub>2</sub> market will still be needed.

Figure 8 shows how the focus of policy intervention can be anticipated to change over time. While CCfDs should be adopted as soon as possible, e.g. in 2022, as renewable H<sub>2</sub> becomes more cost competitive after 2030, this instrument can likely be phased out. The CHP instrument could be introduced

around 2025 to address predicted support needs in the power sector. However, this instrument could be replaced by a renewable H<sub>2</sub> quota for gas power plants once coal-based electricity generation has ended. (Otherwise, a shift in market share from gas to coal could result.) Carbon prices are likely to remain too low over the near term to have a decisive impact (see section 2.2.2). In the 2030s, however, rising carbon price levels could make an important contribution to closing the renewable H<sub>2</sub> cost gap.

In the 2030s, direct support for renewable H<sub>2</sub> production and consumption should be phased out and other instruments such as quotas should be used. This policy shift would make sense from a **funding perspective**. After a decade of subsidy from public budgets, it should be possible to rely on market actors to close the cost gap. This can be done by increasing forms of regulation that require consumers and producers to bear costs, e.g. a PtL quota for aviation (see factsheet A.4) or green public procurement. Eventually, lawmakers could introduce additional quotas (e.g. a renewable H<sub>2</sub> quota for gas plants), or strengthen carbon limits for products (e.g. plastics, cement). In addition, the market could be supported by households and businesses willing to pay a premium for green products (see factsheet A.6 and section 2.3).

20 For example, according to Prognos, Öko-Institut and Wuppertal-Institut (2021), the EU ETS price could rise to €52/tCO<sub>2</sub> in 2030 and €80/tCO<sub>2</sub> in 2045.



21 We propose the introduction of an EU-wide quota for sustainable aviation fuels (SAF) of at least 10%, with a sub quota of at least 5% for e-kerosene by 2030. The quota should be reviewed in 2025 and, if feasible, be increased to 10% by 2030. Note that a share of 10% e-kerosene (as mentioned in the Agora conclusions) is at the upper bound of technological feasibility given no prior industrial scale production. Even reaching a 5% PtL quota would require significant efforts.

## 4 Ensuring sustainability and system integration

Sustainability is the primary motivation for developing renewable H<sub>2</sub> technologies. Accordingly, H<sub>2</sub> regulations must have strong safeguards to ensure positive benefits for the climate. Without such safeguards, reliance on H<sub>2</sub> could induce even higher GHG emissions, due to increased electricity demand or higher natural gas consumption.

Three steps are required from a regulatory perspective. Each step is described in more detail in the coming sections. Specifically, policymakers must:

1. **Define clear sustainability criteria for climate-neutral H<sub>2</sub>.** The setting of long-term standards will involve complex technical issues. Furthermore, questions pertaining to system integration will arise, as the effects of renewable H<sub>2</sub> production need to be considered in the context of the broader, interconnected energy system.
2. **Develop a roadmap for the adoption of sustainability criteria.** Not all criteria may be practical from the start, and some sectors may need special treatment.
3. **Establish legislation and a certification system** in order to translate the sustainability criteria and roadmap into binding practice.

### 4.1 Defining sustainability criteria

By definition, renewable H<sub>2</sub> is hydrogen manufactured using renewable energy (European Parliament; European Council 2018). The production of hydrogen requires large amounts of electricity, due to conversion losses. Furthermore, when the input electricity is not from renewable sources, H<sub>2</sub> production creates higher emissions, rather than emissions savings (Öko-Institut 2019). Accordingly, it is crucial to **define criteria for renewables-based electrolysis**, despite the complexity of this issue.

The recast Renewable Energy Directive (RED II) foresees three methods for demonstrating the use of renewable electricity when an electrolyser produces renewable H<sub>2</sub> for the transport sector (European Council and European Parliament 2018):

- The electrolyser consumes the renewables share of the grid mix. In combination with the requirement to save at least 70% GHG, this is only possible in countries with almost fully decarbonized electricity systems, for instance Norway or Iceland.
- The electrolyser operates in a ring-fenced system with a direct connection to dedicated renewables generation.
- The electrolyser consumes 100% renewable electricity from the grid.

The last case – **the sourcing of renewable electricity from the public grid** – is the most complex case to define, because electricity delivered through the grid does not have any renewable attributes *per se*. RED II introduces three criteria for grid electricity to count as renewable in the transport sector. These criteria could be adopted for other sectors (possibly in modified form). The criteria are designed to encourage the system integration of additional electrolysers.

**Additionality** means that renewable electricity consumed by electrolysis would not have been produced had there been no H<sub>2</sub> production. This criterion only applies when the H<sub>2</sub> producer wants to claim fully renewable electricity input. In the absence of this criterion, electrolysis would ‘steal’ renewable energy from other end users (e.g. households), forcing them to fall back on non-renewable energy. H<sub>2</sub> producers could be obliged to ensure the deployment of additional renewable capacities by financing new assets outside existing support schemes (European Council and European Parliament 2018; Global Alliance Powerfuels 2020b) or by making a financial contribution to the respective support scheme. This

could warrant allocating the additional costs for new renewable capacity to the sector responsible for additional renewable electricity demand.<sup>22</sup> In order to maintain a consistent level of ambition and ensure RES additionality at the system level, renewable energy targets in the EU would have to be adjusted to reflect the increase in renewable electricity demand attributable to H<sub>2</sub> production. However, such an increase in the RES target would require adjustments to the Governance Regulation and might be difficult to agree on by Member States. Such RES target additionality would, however, be needed to ensure a positive effect of the additionality criterion on the overall GHG balance.

Second, **temporal correlation** between H<sub>2</sub> production and renewable electricity feed-in will need to be assured. This means that electrolysis should only take place when adequate renewables generation is occurring – otherwise, electrolysis will be sourcing non-renewable electricity from the grid. Adherence to this criterion is also important from the perspective of system integration. There are several options for defining temporal correlation:

- A.** Renewable H<sub>2</sub> electrolysis may only take place during hours when the renewable asset that is contracted through a power purchase agreement is generating electricity. This provides a tangible connection between green electricity and renewable H<sub>2</sub>, but ignores the larger issue of system integration.
- B.** Electrolysis may only take place when the power mix in the grid has a high renewables share. This would largely ensure that electrolysis is operated on a system-friendly schedule. As an alternative to this RED II provision, electrolysis could be correlated to times when the grid mix has a low GHG emissions coefficient. This, however, would strongly favour countries with high nuclear shares, and not necessarily reflect high RES shares. At the

same time, it would create challenges for countries with remaining significant fossil generation, such as Germany. In both cases, the precise threshold level would be crucial. If the permissible renewables share or GHG emission coefficient is too strict, electrolysis will become uneconomical, due to low utilization. On the other hand, a lenient threshold would mean running electrolysis when the fossil-fuel share in the power mix is high.

- C.** Electrolysis may only take place during a limited number of hours per year (e.g. 2,000 or 4,000 hours). Assuming that electricity prices are lowest during times of high renewables generation, H<sub>2</sub> producers would be incentivised to operate during high renewables feed-in, as with option B above. However, this option raises questions concerning how to best determine and justify a suitable number of operating hours. As with option B, the number of hours would need to be very low in countries with low renewables shares.

The issues surrounding how to define temporal correlation can be partially resolved by looking at additionality and temporal correlation as mutually interdependent. If there is no additionality, temporal correlation would need to ensure that only fully renewable electricity is sourced from the grid, i.e. setting the threshold in option B to 100%. This would lead to a utilisation of under 10% and preclude economical electrolysis. Having a strong additionality requirement in place, on the other hand, would mean that temporal correlation does not need to hinge on the renewables share alone (i.e. the marginal power plant may not always be renewable). This would allow for softer thresholds in option B or C, as long as the requirements induce flexible electrolyser operation that is adjusted to the respective threshold. In principle, flexible electrolyser operation could also be induced by other instruments or market signals (as has been discussed in relation to markets for flexibility services).

Finally, **geographic location** needs to be considered when electrolysis source electricity from the grid.

<sup>22</sup> In cases where both renewable H<sub>2</sub> support and renewable electricity support are paid from government budgets, this difference would blur.

If H<sub>2</sub> production and renewable electricity feed-in are located in separate grid areas with limited transmission capacity between them, electrolysis may actually depend on fossil-based generation, despite compliance with the criteria of additionality and temporal correlation. This issue is also highly relevant for system integration. Without location criteria, the risk of new grid congestion would increase across Europe. In Germany, this would increase the risk of a bidding zone split, with increasing electricity prices in the South and decreasing prices in the North.<sup>23</sup> While bidding zones generally reflect structural congestion in the grid, it seems highly advisable to specify areas suitable for H<sub>2</sub> production, thereby avoiding the creation of new grid congestion in the future.

One open question concerns the extent to which sustainability requirements and system integration should be regulated jointly when it comes to temporal correlation and the geographical siting of H<sub>2</sub> production. One option would be to require proximal location only to the extent necessary for renewable assets (e.g. through bidding zones). Accordingly, system integration issues such as grid congestion and optimal capacity siting would need to be addressed by other policies. Another option would be to regulate both aspects jointly, e.g. H<sub>2</sub> sustainability criteria would include granular geographic requirements for electrolysers, to avoid new grid bottlenecks. For instance, one could require electrolysers to be located in designated areas close to renewable production centres (see above).

Electricity is not the only aspect in need of consideration when defining the climate-neutrality of H<sub>2</sub>-based fuels. Indeed, the production of renewable H<sub>2</sub> derivatives such as methane, methanol and liquidhydrocarbons require **carbon feedstocks**.

If these carbon feedstocks are not climate-neutral, the net GHG savings could be minimal or non-existent. As a result, various methods of defining “carbon-neutral carbon atoms” have been defined:

Over the long term, the only sustainable carbon sources are **direct air capture** (DAC) and carbon from sustainable **biomass**. A strict requirement would be to limit carbon feedstock for green electricity-based fuels to these sources.<sup>24</sup> However, bio-based sources are scarce and DAC is inefficient and expensive (Global Alliance Powerfuels 2020a).

As a supplement to DAC and bio-based carbon, one could allow carbon sourcing from **process emissions that are hard to abate** – for instance, from cement kilns. In this regard, the double counting of emission reduction credits would need to be prevented. The cement kiln, for instance, would need to report emissions if the renewable fuel user were to report abatement.

Finally, one could permit **any carbon source**, so long as the emissions are accounted properly. For example, one could capture CO<sub>2</sub> from a coal power plant and count it as climate-neutral carbon feedstock as long as the coal plant has cancelled an ETS certificate. This would be the most efficient option in the short term due to the abundance of large CO<sub>2</sub> emitters across Europe. It would, however, require incentives for DAC to be employed and scaled – for example, through a rising mandatory share of DAC (Transport & Environment 2021).

If fossil-based H<sub>2</sub> with carbon capture is to play a role in the H<sub>2</sub> economy, a separate set of criteria is needed to ensure sustainability. This is addressed in section 6.

23 The German government has developed a package of measures with a time schedule for the reduction of domestic structural network congestion. See the following link for more information: [https://www.bmwi.de/Redaktion/EN/Downloads/a/action-plan-bidding-zone.pdf?\\_\\_blob=publicationFile&v=6](https://www.bmwi.de/Redaktion/EN/Downloads/a/action-plan-bidding-zone.pdf?__blob=publicationFile&v=6)

24 Some even argue that carbon from biomass should be excluded due to sustainability concerns (Transport & Environment 2021).

## 4.2 Developing a roadmap for criteria adoption

It may not be necessary to stringently apply all of the criteria presented in section 4.1 from the very start. Instead, **softer requirements** could be imposed during the **initial few years** or until a **defined minimum capacity** has been reached. This would help to facilitate the technology ramp-up, particularly against the backdrop of an initially high cost gap. It would also take into account the time needed to plan and construct new renewable energy plants. Also, some H<sub>2</sub> technologies are new at an industrial scale (see section 2.1), and may need flexible conditions early on. Lastly, the impact of H<sub>2</sub> production on the overall energy system and total GHG emissions will be rather small in the early years. Softer requirements that entail "somewhat less renewable" H<sub>2</sub> at the outset would thus have minimal consequences for climate policy overall.

The gradually tightening of requirements, **differentiated by sector**, should be considered. For example, the transport sector should be able to fulfil strict criteria early on, as energy prices in the sector (e.g. for gasoline) are already high. This eases the pass through of higher costs for strict renewable H<sub>2</sub> compliance. In addition, Power-to-X (PtX) fuels for transport can be imported more easily than pure H<sub>2</sub> (the latter of which is needed, for example, in the industrial sector). Meanwhile, energy prices for gas or coal are much lower for industry, and the pass through of additional costs to customers is often not possible, insofar as product price levels are determined by global commodity markets. More lenient criteria for the industrial sector in an early phase could thus be an important catalyst for a technology switch, despite industry's lower ability to pay in comparison to transport. However, divergent requirements between sectors could negatively impact transparency, and may cause additional regulatory burdens.

Applying softer requirements at the outset in some sectors must not distract from the fact that over the

**mid- to long-term, all H<sub>2</sub> must be climate-neutral**, in line with the criteria discussed in section 4.1. Otherwise, H<sub>2</sub> would fail to serve its primary purpose – that is, to enable climate neutrality. In this way, softer application of the criteria in some sectors or as part of specific support schemes must be seen as a temporary exception. As a result, fossil-based H<sub>2</sub> with carbon capture may need to be eliminated in the future, insofar as the criteria mentioned in section 4.1 are technically unattainable.

## 4.3 The legislative process

Legislation to define renewable H<sub>2</sub> criteria is already under development (for instance, the Delegated Acts pursuant to RED II Art. 27 and 28, and an ordinance pursuant to EEG §93 in Germany). To define when an investment is sustainable, a Delegated Act from the EU Sustainable Finance Taxonomy will soon be published (European Commission 2021d). There are also definitions from private actors, such as CMS 70 from TÜV SÜD. With the large-scale production of renewable and fossil-based H<sub>2</sub> using carbon capture just getting off the ground, additional standards that build on European definitions and requirements are expected to emerge in the coming years.

While it may be expedient to have different standards for renewable H<sub>2</sub> over the near term (see section 4.2 above), over the mid-term, a uniform and strict definition of renewable H<sub>2</sub> is needed to ensure the liquidity of H<sub>2</sub> markets (see section 5.2). At the same time, the excessive proliferation of definitions and market standards depending on the end-use sector or country would lead to market fragmentation and impede later harmonisation. Accordingly, the European H<sub>2</sub> strategy explicitly mentions the need to create harmonised European H<sub>2</sub> standards (European Commission 2020c).

The adoption of such standards will enable certification schemes that verify the renewable nature of H<sub>2</sub> (see also factsheet A.6). Since 2014 the CertifHy

project has been working to develop a European H<sub>2</sub> certification and guarantee of origin scheme. While the adoption of CertifHy is likely, different types of schemes may also emerge.



## 5 Regulating infrastructure and markets

### 5.1 Hydrogen infrastructure

Hydrogen infrastructure can fulfil two purposes – first, to connect renewable H<sub>2</sub> suppliers to demand, and second, to provide for H<sub>2</sub> storage. One option for **transporting and storing** H<sub>2</sub> is to build new, dedicated supply networks.<sup>25</sup> Alternatively, existing natural gas infrastructure can be retrofitted for renewable H<sub>2</sub>. Existing gas infrastructure<sup>26</sup> could provide **storage capacity** of 1,200 TWh, equivalent to three months of natural gas demand in the EU at current levels (Hydrogen Europe 2019). Ultimately, the H<sub>2</sub> infrastructure in place will need to accommodate renewable H<sub>2</sub> supply changes attributable to weather fluctuations, and provide for inter-seasonal storage (Agora Energiewende and AFRY Management Consulting 2021). H<sub>2</sub> supply networks can also offer support services to the power system, including frequency response, voltage control, reserve power, and seasonal storage.

The EU H<sub>2</sub> strategy expects that **initial infrastructure** needs will be limited, as demand will be met directly at the site of consumption or close by (European Commission 2020c). Similarly, the Gas for Climate Initiative, led by ten European gas transport companies,<sup>27</sup> expects that regional networks will form around demand and supply hubs or clusters, so-called “hydrogen valleys” (European Hydrogen Backbone

2021). Dedicated H<sub>2</sub> infrastructure would have transport capacities far outstripping expected renewable H<sub>2</sub> demand. Agora Energiewende and AFRY Management Consulting (2021) have identified “no-regret corridors” for early H<sub>2</sub> pipelines, based on demand from hard-to-abate industrial sectors. Focusing on no-regret infrastructure would reduce the risk of over-dimensioned infrastructure (Agora Energiewende and AFRY Management Consulting 2021). **Up to 2030**, the European Commission expects that a need for EU-wide logistic infrastructure will emerge. In its strategy, the European Commission thus proposes a pan-European backbone and network of H<sub>2</sub> refuelling stations. Gas for Climate has forecasted an initial 11,600 km pipeline network by 2030, which would connect the H<sub>2</sub> valleys (European Hydrogen Backbone 2021). The infrastructure would be further expanded in two stages over the following decade, stretching in all directions by 2040 with a length of almost 40,000 km (European Hydrogen Backbone 2021).

The **financing requirements** for infrastructure development are significant. One approach is to bring H<sub>2</sub> infrastructure under a regulated regime, e.g. a jointly regulated asset base, where dedicated H<sub>2</sub> infrastructure would be cross subsidised by natural gas grid users. Alternatively, infrastructure development could be supported by the general budget. Lastly, the new H<sub>2</sub> infrastructure could be financed through an H<sub>2</sub> levy, subsidised by users connected to the H<sub>2</sub> grid. However, consumers benefitting from H<sub>2</sub> pipelines cannot be expected to bear the full cost of developing dedicated H<sub>2</sub> infrastructure. At the early stage of development, financial support will be essential to ensure adequate incentives for investment. In the following stage, when the number of users has grown but is still small, there is still a substantial risk to the business case if one important user were to exit the market. Expecting investors to bear this risk would entail a higher cost of capital.

25 We understand this as pipeline infrastructure. It is not clear that sea-borne hydrogen transportation will be required at a European scale (Agora Energiewende and AFRY Management Consulting 2021).

26 In Belgium, Denmark, France, Germany, the Netherlands, Sweden, Switzerland and the Czech Republic

27 ‘Gas for Climate: a path to 2050’ is a group of ten leading European gas transport companies (DESFA, Enagás, Energinet, Fluxys, Gasunie, GRTgaz, ONTRAS, Open Grid Europe, Snam, Swedegas, and Teréga) and two renewable gas industry associations (Consorzio Italiano Biogas and European Biogas Association).

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## 5.2 Market design

The European Commission is expected to revise the third energy package for gas in 2021, altering the common rules in the market for natural gas and the conditions for access to natural gas transmission networks (European Parliament 2021). In the revised package, an emphasis should be placed on **aligning definitions and setting European-wide standards** for H<sub>2</sub> transport. Among other things, legislators should: provide a definition for renewable H<sub>2</sub>; harmonise terms used to describe different types of gases (see section 4.3); and set uniform gas quality standards, including purity and contaminant thresholds. With a view to energy storage, the European Commission should expand on the current definition to ensure that power-to-gas/power-to-H<sub>2</sub> is not limited to an energy storage function from the perspective of the electricity market. This could be achieved by e.g. defining its role in sectoral integration and sector coupling (Hydrogen Europe 2019). Ultimately, the policy framework should ensure compatibility between the dedicated H<sub>2</sub> networks that take shape in individual Member States.

Secondly, the revision should create conditions that enable **cross-border trade**. A uniform EU-wide Guarantees of Origin system for gas that governs renewable H<sub>2</sub> and other low-carbon and renewable gases would allow end users to buy specific types of H<sub>2</sub> across the EU, irrespective of their location, thereby encouraging cross border trade. Laying this groundwork for an EU-wide market for renewable and low-carbon H<sub>2</sub> would improve the business case for hydrogen investment, in part by strengthening demand signals.

Lastly, the revision should establish basic rules for **third-party access to transport grids and for a clear legal and organizational separation between H<sub>2</sub> producers and H<sub>2</sub> grid operators ('unbundling')**. This is an important issue, as grid-bound networks are generally natural monopolies that require regulation to prevent anti-competitive behavior or excessive profit taking. In this way, the initial H<sub>2</sub> regulatory framework should reduce the risk of distortions to the internal energy market while also setting rules for objective, transparent and non-discriminatory access to grid infrastructure. This will furnish clarity about conditions for business, thus lowering perceived investment risks.

## 6 Fossil-based H<sub>2</sub> with carbon capture as a bridge technology

### 6.1 The role of fossil-based H<sub>2</sub> with carbon capture

The previous sections of this report provided policy recommendations for how to support the development of renewable H<sub>2</sub> markets. However, renewable H<sub>2</sub> is not the only option for enabling the growth of an H<sub>2</sub> economy. From a sustainability standpoint, reliance on renewable H<sub>2</sub> is essential over the long term and preferable over the short term.<sup>28</sup> However, the volume of renewable electricity capacity that can be devoted to H<sub>2</sub> production is currently limited. As a result, renewable H<sub>2</sub> is currently almost three times more expensive than its fossil-based alternatives (see Figure 2). The support costs that would be required to immediately close the cost gap between renewable H<sub>2</sub> and these alternatives would be enormous and far exceed the already significant funding pledges made by the German government and the European Commission (see section 1.2). Accordingly, the EU H<sub>2</sub> strategy recognizes **the need for the gradual increase of supply and demand as well as the development of necessary grid infrastructure** (European Commission 2020c).

Against this backdrop, **fossil-based H<sub>2</sub> that relies on carbon capture could be used** to satisfy and encourage demand for H<sub>2</sub> while also furnishing a basis for the implementation of the policy support measures outlined in the foregoing discussion. Importantly, fossil-based H<sub>2</sub> using carbon capture should not be understood as a substitute for renewable H<sub>2</sub>, but rather as a supplement to renewable H<sub>2</sub> production.

In this way, the production of fossil-based H<sub>2</sub> using carbon capture could serve as a bridge technology, by satisfying and encouraging demand for H<sub>2</sub>, and by supporting associated infrastructure expansion, easing the transition to a fully renewable H<sub>2</sub> economy.

Fossil-based H<sub>2</sub> with carbon capture is currently **significantly cheaper** than renewable H<sub>2</sub>. In 2021, renewable H<sub>2</sub> production costs stand at €100/MWh to €200/MWh, while fossil-based H<sub>2</sub> with carbon capture costs between €48/MWh and €78/MWh (excluding CO<sub>2</sub> costs), depending on the technology (see Figure 2). Fossil-based H<sub>2</sub> with carbon capture can function as a transition fuel for decarbonisation, paving the way for the gradual phase-out of natural gas (e.g. in primary steel making) or fossil-based H<sub>2</sub> (e.g. in refineries or ammonia production). Once renewable H<sub>2</sub> production costs have declined enough, renewable H<sub>2</sub> production can overtake fossil-based H<sub>2</sub> with carbon capture. The BLUE-GREEN scenario by Agora Energiewende and AFRY Management Consulting (2021) indicates a transition from fossil-based H<sub>2</sub> production to electrolysis between 2030 and 2050. Gas for Climate expects this fuel switch to take place shortly after 2040 and to continue accelerating up to 2050 (Gas for Climate 2020).

Fossil-based H<sub>2</sub> with carbon capture can **support system integration** by operating as back-up to variable renewable H<sub>2</sub>. Fossil-based H<sub>2</sub> with carbon capture can complement an initially variable supply of renewable H<sub>2</sub> that results from the relative scarcity of renewable energy in the system, a fact that will lead to a restriction of full load hours for H<sub>2</sub> electrolysis. Renewable H<sub>2</sub> production is also dependent on the availability of renewable electricity. The main sources of renewable energy in the EU today are wind and solar PV (i.e. intermittent sources). Fossil-based H<sub>2</sub> with carbon capture can smooth fluctuations in

28 In addition, installations that produce fossil-based H<sub>2</sub> with carbon capture can later use biomethane instead of fossil methane, i.e. bio CCS, as feedstock, leading to negative emissions, or climate-positive H<sub>2</sub>.

variable supply. Fossil-based H<sub>2</sub> with carbon capture can also play a role when electrolysis does not make sense (e.g. because of very high prices). While fossil-based H<sub>2</sub> with carbon capture may therefore displace renewable H<sub>2</sub> from the market at certain times, as the greening of the electricity sector continues, renewable H<sub>2</sub> can be expected to completely supplant fossil-based H<sub>2</sub>.

The EU's existing fleet of H<sub>2</sub> production plants can be retrofitted with carbon capture and storage (CCS), rapidly **scaling up the supply of fossil-based H<sub>2</sub> with carbon capture** (Gas for Climate 2020). The renewable energy sources used to produce renewable H<sub>2</sub> need to be additional. By contrast, fossil-based H<sub>2</sub> with carbon capture can be produced using already existing assets. Steam methane reforming (SMR) and autothermal reforming (ATR) are currently the most widely used production processes for fossil-based H<sub>2</sub>. Both can be combined with CCS, thereby reducing GHG emissions. The **demand side** is initially "colour-blind"; using fossil-based H<sub>2</sub> with carbon capture would thus not cause a lock-in effect on the demand side. In many applications, renewable and fossil-based H<sub>2</sub> with carbon capture can be used interchangeably. An exception is ammonia production, as CO<sub>2</sub> is needed to synthesize urea. Using fossil-based H<sub>2</sub> with carbon capture to serve a share of growing hydrogen demand would be important for two reasons: First, H<sub>2</sub> use needs to be ramped up now in order to meet mid- and long-term climate goals. Second, consumers need assurance that enough H<sub>2</sub> can be supplied to invest in new technologies. Fossil-based H<sub>2</sub> with carbon capture can provide that assurance while renewable H<sub>2</sub> production is being expanded.

Reliance on fossil-based H<sub>2</sub> with carbon capture can also **kick-start the infrastructure development** needed for renewable H<sub>2</sub>. Newly constructed, CAPEX-intensive H<sub>2</sub> pipelines need to have sufficient diameter for increasing H<sub>2</sub> volumes over the mid- to long-term. To encourage the more rapid amortisation of investment costs, the pipelines should be utilised to

the greatest extent possible. The importation of fossil-based H<sub>2</sub> with carbon capture could function as a "base load" of H<sub>2</sub> in the network, which would reduce the marginal costs that renewable H<sub>2</sub> would have to price in.

Fossil-based H<sub>2</sub> with carbon capture will be either **imported or produced locally**. No large-scale fossil-based H<sub>2</sub> with carbon capture production sites currently exist in the EU. This will soon change, as several CCS projects have been given the Projects of Common Interest (PCI) label by the European Commission. This label is a pre-requisite for access funding from the Connecting Europe Facility (CEF). CO<sub>2</sub> storage is an essential part of fossil-based H<sub>2</sub> with carbon capture. Most CO<sub>2</sub> storage projects are planned around the North Sea, as depleted gas fields provide storage sites. So far, only two basins in the North Sea, off the coast of the Netherlands and Norway, have received official permits for CO<sub>2</sub> storage (Gas for Climate 2020). Fossil-based H<sub>2</sub> with carbon capture could thus be produced close to CO<sub>2</sub> storage sites and then exported to consumers, e.g. in Germany.

CCS has long been a taboo in Germany due to it being framed as a decarbonisation solution for coal-fired power plants. However, the discussion has shifted and now CCS is seen as a necessity for capturing process emissions<sup>29</sup> in sectors such as cement. Bioenergy with CCS (BECCS) also needs CO<sub>2</sub> infrastructure. **BECCS** will be needed to produce negative emissions, thereby helping to achieve climate targets (Prognos et al. 2020). Using CCS to produce fossil-based H<sub>2</sub> with carbon capture can also be an important element of technology learning for the needed BECCS. Hence, infrastructure for **CO<sub>2</sub> transport** needs to be built. This will create

29 Process emissions include GHG emissions from chemical transformation of raw materials and fugitive emissions. These processes are iron and steel production, cement production, petrochemical production, and nitric acid production, among others.

opportunities for the production of fossil-based H<sub>2</sub> with carbon capture in Germany and elsewhere. Domestic storage of CO<sub>2</sub> is outside the scope of current discussion in Germany. Thus, while production could take place in Germany (as is foreseen, for example, in the Get H<sub>2</sub> Nukleus project<sup>30</sup>), the captured CO<sub>2</sub> would be transported and stored abroad.<sup>31, 32</sup> In such a case, clear guidelines and regulations would need to be established to properly account for exported CO<sub>2</sub> and to assign liability for possible leakage from storage sites.

30 See the project website here:  
<https://www.get-h2.de/en/get-h2-nukleus/>

31 The London Protocol is a global agreement which regulates dumping waste at sea. On October 11th the parties to the London Protocol agreed on allowing temporary use of the changes to the protocol from 2009 which allow export of CO<sub>2</sub> for the purpose of storage offshore. The amendment from 2009 will formally be implemented when 2/3 of the parties of the protocol have ratified it nationally. See the following link for more information: <https://www.regjeringen.no/en/aktuelt/viktig-milepal-for-co2-prosjekt-nadd/id2673809/>

32 The CCS Directive defines the transport phase of CCS as 'the network of pipelines, including associated booster stations, for the transport of CO<sub>2</sub> to the storage site'. This definition is important because it does not mention the possibility of shipping CO<sub>2</sub> between the capture facility and storage site. Exclusion of shipping means operators engaged in CO<sub>2</sub>-shipping for the purposes of CCS would interrupt the monitoring and reporting obligations and break the value chain of CCS endorsed by the CCS Directive. It follows that transport operators engaging in CO<sub>2</sub>-shipping for CCS would not be required to obtain an emissions permit, comply with MRV procedures or surrender allowances for greenhouse gases (GHG) emissions. Where the monitoring and reporting obligations are not met, the EU ETS will not allow capture operators to claim CO<sub>2</sub> was successfully stored. Operators would remain liable to subtract emission allowances for CO<sub>2</sub> permanently stored because the CCS activities would not conform to the requirements of the CCS Directive. Any amount of CO<sub>2</sub> captured and transported by ship for CCS would be added to the installation's total CO<sub>2</sub> emissions. See here for more information: <https://blog.sintef.com/sintefenergy/ccs/the-liability-regime-for-co2-shipping/>

Another argument that speaks in favor of the short-term addition of fossil-based H<sub>2</sub> with carbon capture is its **lower GHG emissions** compared to compared to fossil-based H<sub>2</sub> or natural gas or even electrolytic H<sub>2</sub>, at least if the whole energy system is considered<sup>33</sup> (see Figure 3). It would thus initiate the needed decarbonisation. The German H<sub>2</sub> strategy identifies fossil-based H<sub>2</sub> with carbon capture as carbon-neutral on balance (BMW<sub>i</sub> 2020). Depending on the CO<sub>2</sub> capture technology and the use of natural gas or H<sub>2</sub> as thermal fuel, capturing and storing the CO<sub>2</sub> enables the abatement of direct emissions in H<sub>2</sub> plants (both SMR and ATR) by 60% to 95% (Gas for Climate 2020). In principle, there are no technological reasons why CCS cannot reach close to 100% abatement, but a capture rate in excess of 90% significantly escalates costs (CEPS 2019). Furthermore, in some industrial processes, past experience has even failed to achieve 90% capture rates. In addition to the capturing of CO<sub>2</sub>, methane emissions are an important factor. The European Commission adopted the EU Methane Strategy in 2020, which seeks to address upstream methane emissions occurring during the production and transport of natural gas. A legislative proposal will be deliberated in 2021. Fossil-based H<sub>2</sub> with carbon capture should comply with strict **sustainability criteria** to ensure that decarbonisation goals are achievable. Sustainability criteria should be ratcheted up, starting at a minimum reduction rate of 70% compared to a fossil-based alternative, while fully accounting for life-cycle emissions that occurred

33 Even in cases where accounting rules allow to relate H<sub>2</sub> electrolysis to exclusively renewable energy generation assets, the fact that alternative uses such as the substitution of fossil fuel generation or other direct electrification measures would reduce GHG emissions at a similar or higher level than H<sub>2</sub> uses must be accounted for. Expanding the volume of renewable H<sub>2</sub> and reducing the GHG emissions of the energy system will depend on the expansion of renewable energy generation to satisfy electricity needs for direct and indirect electrification alike.

upstream.<sup>34</sup> To be consistent with the objective of climate neutrality, any residual emissions, however, would need to be offset with negative emissions, further increasing the total cost of fossil-based H<sub>2</sub> with carbon capture. As avoiding 100% of life-cycle emissions from the production of fossil-based H<sub>2</sub> with carbon capture is unrealistic, the long-term goal should be to replace natural gas with biomethane to generate negative emissions<sup>35</sup>, as well as to significantly increase renewable H<sub>2</sub> production.

## 6.2 Policy framework for fossil-based H<sub>2</sub> with carbon capture

Fossil-based H<sub>2</sub> with carbon capture is mentioned in both the German and the EU H<sub>2</sub> **policy strategies** as an important transition fuel. The European H<sub>2</sub> strategy states that the “retrofitting of existing fossil-based H<sub>2</sub> production with carbon capture should continue to reduce greenhouse gas and other air pollutant emissions in view of the increased 2030 climate ambition” (European Commission 2020c). However, the German strategy clarifies that only renewable H<sub>2</sub> is considered sustainable over the long term (BMW<sub>i</sub> 2020). Supporting the use of fossil-based H<sub>2</sub> with carbon capture should enhance its role as a transition fuel, while also unleashing positive effects for the ramp-up of H<sub>2</sub> supply and demand (see section 2) and the development of H<sub>2</sub> infrastructure (see section 6.1). At the same time, it should avoid delay in the development of more competitive renewable H<sub>2</sub> solutions.

34 A life cycle assessment of emissions covers the whole chain from the extraction of resources, through production, use, and recycling, up to the disposal of the remaining waste. In the cycle, the capture rate is the most relevant element.

35 The ability to create negative emissions is significant because almost all authoritative climate change scenarios show that the world needs substantial negative emissions to achieve carbon-neutrality by 2050 and keep the global temperature increase well below 2°C.

In contrast to renewable H<sub>2</sub>, **fossil-based H<sub>2</sub> with carbon capture does not require additional, dedicated policy support instruments**. The current policy framework already includes funding opportunities for fossil-based H<sub>2</sub> with carbon capture.

At the EU level, the EU Innovation Fund – financed through the EU ETS – and CEF provide CAPEX support, which is expected to augment production capacities for fossil-based H<sub>2</sub> with carbon capture in the coming years. CAPEX support is sufficient to close the price gap to fossil-based H<sub>2</sub>. However, at increasing capture rates, energy demand and thus operating costs also increase significantly. The Dutch support scheme SDE++ also supports CCS, thereby making fossil-based H<sub>2</sub> with carbon capture more competitive in relation to fossil-based H<sub>2</sub> (Netherlands Enterprise Agency 2021). For fossil-based H<sub>2</sub> with carbon capture, carbon pricing is an ideal instrument to foster its use as a substitute for natural gas.

The **switch from fossil-based H<sub>2</sub>** to renewable H<sub>2</sub> must be supported through the policy framework. In theory, the most potent instrument is the EU ETS (see section 1.2). Carbon pricing makes natural gas and fossil-based H<sub>2</sub> with carbon capture more expensive. However, in reality free allowances distort the intended effect, as renewable H<sub>2</sub> does not receive any free allowances. For example, if a conventional steel plant (basic oxygen furnace/blow furnace) switches to hydrogen based-steel making, no more free allowances are granted, thus further increasing the cost of production. The support instruments for the supply side, as detailed in section 2.2.1, can reduce or even fully close the cost gap (see factsheet A.2). Carbon pricing and supply side instruments for renewable H<sub>2</sub> such as H<sub>2</sub> supply contracts and Carbon Contracts for Different thus works hand in hand to bridge the cost gap.

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## Appendix: Detailed policy instrument factsheets

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# CARBON CONTRACTS FOR DIFFERENCE (CCFDs)

The aim of this instrument is to facilitate industry investment in breakthrough abatement technologies. By offsetting the additional

operating costs of such technologies, CCFDs de-risk long-term investment while also laying a foundation for green lead markets.

## INSTRUMENT DESCRIPTION

- Carbon Contracts for Difference (CCfDs) have a close relationship to the EU Emissions Trading System (ETS). CCFDs compensate for the incremental cost of production with a CO<sub>2</sub>-efficient breakthrough technology in comparison to a conventional GHG intensive technology. Therefore, CCFDs complement the effects of the EU-ETS carbon price and lead to additional emission reductions that have to be accounted for in the EU-ETS design.
- The CO<sub>2</sub> mitigation costs of breakthrough manufacturing technologies that rely on H<sub>2</sub> typically exceed €100/tonne. Therefore, the current CO<sub>2</sub>-market price of €40–50/tonne is insufficient to trigger investment in such technologies. Moreover, free carbon allowances for conventional technologies weaken the ability of the carbon price to encourage alternatives to CO<sub>2</sub>-intensive production.
- CCFDs provide compensation for the difference between the effective CO<sub>2</sub> price and the mitigation costs

- of a breakthrough technology, i.e. if the mitigation costs are €100/tCO<sub>2</sub> avoided (strike price) and the effective CO<sub>2</sub> price is €30/tonne, the government would pay the difference of €70 to the company for every tonne of CO<sub>2</sub> avoided. The avoided CO<sub>2</sub> would be calculated as the difference between the emissions of the breakthrough technology and those of a benchmark technology (as defined e.g. by EU ETS benchmarks).
- CCFDs can be awarded to individual projects or using competitive auctions. The party awarded support would be guaranteed a certain price (strike price). However, the awarded party should also have the option to sell its product as green for a premium that remunerates the implied emissions reductions. In this case, no funding would be required. The labelling of climate-friendly basic materials could incentivise off-takers to pay such a premium (Agora Industry et al. (2021))



### TIMELINE & SEQUENCING

Today–2030	2030–2040	2040 & beyond
Implementation of the first CCFD is anticipated in Germany in 2022. CCFDs should be awarded for around 10 years. With H <sub>2</sub> becoming cost competitive, higher CO <sub>2</sub> -prices, and the development of green lead markets, the instrument can likely be phased out in the late 2030s.		

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### FINANCING MECHANISM

The funding requirements for CCFDs could be very large. For one renewable H<sub>2</sub>-based steel plant producing 2 million tonnes of emissions per year, annual CCFD funding could exceed €400 million. Options for financing the mechanism include general tax revenues or EU ETS revenues over the short term. A climate surcharge on final products with high share of basic materials, a CBAM regime, or appropriate quotas and green purchase obligations are also possible over the medium term.



### RELIEF MEASURES / EXEMPTIONS

No measures or exemptions needed. Impacts on final consumer prices would be low (+1–3%).



### LEGISLATIVE IMPLICATIONS

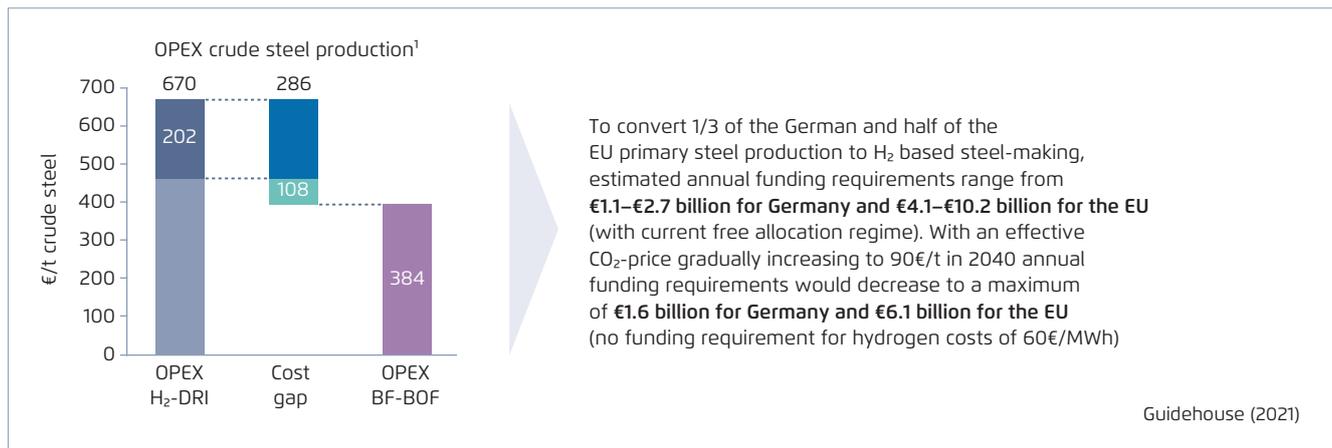
- ✕ draft new legislation
- adapt legislation



### STATE OF THE LARGER DEBATE

Implementation of first CCFD legislation is expected in early 2022. Germany's Environment Ministry (BMU) is the responsible government body. Initial funds of around €500 million have been made available and a budget increase is being discussed as part of an immediate program that is being developed under revised climate law. The focal sectors for initial support are steel and chemicals. The Netherlands has already implemented a CCFD scheme (SDE++) and an increasing number of Member States have shown interest in implementing such a mechanism.

## ECONOMIC ANALYSIS



<sup>1</sup> Under the current free allocation regime. Assuming an effective carbon price increasing from €50/tCO<sub>2</sub> (2021) to €90/tCO<sub>2</sub> in 2040 would decrease the cost gap due to higher OPEX for BF-BOF (Blast Furnace Basic Oxygen Furnace) (costs of CO<sub>2</sub> are included in OPEX).

## LEGAL ASSESSMENT

- Whether a CCfD mechanism is compatible with the requirements of European and national law depends on its specific design and can therefore not be answered conclusively here.
- In principle, there are no fundamental legal objections to the introduction of a CCfD. Depending on the specific financing mechanism, it can be classified as state aid within the meaning of Article 107 TFEU. A separate approval procedure under state aid law would have to be carried out by the European Commission. There is much to suggest that approval would be possible. The Commission has already classified a CCfD used by the UK to promote a nuclear power plant as aid compatible with the internal market.
- 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 auctions must be equipped with maximum bid limits. The encroachment on the freedom of movement of goods, which is also affected, can probably be justified by environmental protection efforts.
- A market premium in particular can be considered for the type and manner of financial support. If the support system were controlled via tenders, the reference point for the premium would result from the tender result. If the subsidy level were set administratively, technological progress and learning effects should be taken into account via a degression. However, it should be borne in mind that, due to the permissible aid intensities, 100% of the eligible costs can only be funded through auctions.



## ARGUMENTS IN FAVOR OF INSTRUMENT:

- Fast implementation by Member States would ease private sector planning while allowing preparation for reforms to EU ETS, including higher CO<sub>2</sub> prices.
- Targeted funding of specific H<sub>2</sub> applications, e.g. for industry sectors which truly need hydrogen to become climate-neutral
- CCfDs de-risk long-term investment in breakthrough technologies, thus creating consistent demand for H<sub>2</sub>.
- The awarded party has the choice of recovering the incremental cost of clean production by obtaining the CCfD payment or selling the product as green for an adequate premium, thus gradually reducing CCfD funding requirements.
- Rising CO<sub>2</sub> prices lead to reduced funding needs, creating an incentive for policy makers to strengthen the EU ETS.



## ARGUMENTS AGAINST INSTRUMENT:

- Substantial funding requirements. Funding of one H<sub>2</sub>-based steel production plant can exceed €400 million annually.
- CCfDs can cause technological lock-in effects.
- The more granular the support (e.g. subsector-specific, or possibly technology-specific), the greater the complexity in handling the instrument.
- If a CCfD is awarded on a project-by-project basis, the question arises whether and how the regulators should set the strike price and how information asymmetries regarding actual abatement costs can be overcome. This issue can be avoided if the CCfD is awarded using competitive auctions.

# H<sub>2</sub> SUPPLY CONTRACTS

H<sub>2</sub> supply contracts would cover the difference between the lowest possible renewable H<sub>2</sub> production price (on the supply

side) and the highest willingness to pay (on the demand side) in a two-phase auction.

## INSTRUMENT DESCRIPTION

- This instrument would close the price gap between renewable H<sub>2</sub> production costs and willingness to pay on the demand side for eligible usage applications in the German industrial sector. Over the long term, it could include some applications in the transport sector as well.
- **Long term:** The purpose of the instrument is to buy hydrogen from producers and sell it to end users through an auction mechanism. The price gap between the lowest bid on the supply side and the highest bid on the demand side would be covered for defined time spans.<sup>1</sup> An intermediary would administer the public funds to cover the difference. The price difference would decline over time as production costs decrease and willingness to pay increases (e.g. due to stricter climate regulations).
- **Short term:** The instrument would work in the context of liquid markets, which depends on widely available H<sub>2</sub> transport infrastructure. Until this becomes a reality (towards 2030), H<sub>2</sub> supply contracts would need to be tied to fixed delivery locations within Germany.

- Until infrastructure is available, support would be awarded in a location-specific manner. This means that integrated projects including production, transport and offtake would be granted support for the price difference. Alternatively, offtake can be determined in a demand side auction followed by a “matchmaking” supply side auction in which suppliers meet the specified demand volumes and locations.
- Design options for the instrument include: the specific organisational setup for the administration of public funds; financing caps; penalties for the abandonment of projects; the support volume and time span; auction frequency; H<sub>2</sub> sustainability criteria; and system integration criteria.
- At the EU level, the quota could be implemented as part of the RED revision.

<sup>1</sup> This basic mechanism was originally proposed by the H<sub>2</sub>Global Initiative of GIZ and DWV, in a project supported by the German Federal Ministry for Economic Affairs and Energy (BMWi). <https://H2-global.de/>



### TIMELINE & SEQUENCING

Today–2030	2030–2040	2040 & beyond
Phase 1	Phase 2	

The instrument would support H<sub>2</sub> market uptake over the short and medium term. It should be phased out as soon as policies are in place to trigger demand in the end-use applications that truly need hydrogen.



### FINANCING MECHANISM

No intrinsic financing mechanism is foreseen. The state may be able to finance some of the costs from early phases with long-term upsides (demand price higher than supply price).



### RELIEF MEASURES / EXEMPTIONS

Relief measures or exemptions are not relevant for this instrument because no burden for private actors is created.



### LEGISLATIVE IMPLICATIONS

- ✗ draft new legislation
- ☐ adapt legislation



### STATE OF THE LARGER DEBATE

The German development agency GIZ has developed a concept for the international version of this instrument, called H<sub>2</sub>Global, in a project undertaken on behalf of the German Federal Ministry for Economic Affairs and Energy (BMWi). During deliberations on the GIZ proposal, Germany’s parliamentary opposition voiced concern about lack of control over public funds. At the European level, a similar instrument is not yet being discussed.

## ECONOMIC ANALYSIS



## LEGAL ASSESSMENT

- The instrument is legally feasible in principle.
- The instrument would count as state aid since the funding originates from tax revenues. By contrast, it would not count as state aid if a financing mechanism similar to that of the EEG levy were adopted. State aid notification to the European Commission would be required given general tax funding. The Commission's approval would be likely, however, as the instrument is necessary, suitable and appropriate.
- It is crucial that support is awarded based on competitive bidding. The binding period for support should be less than six years. Auction design should differ depending on whether support is being auctioned on the supply or demand sides of the market.
- The instrument would qualify as unequal treatment under Article 3 of the Basic Law. However, this can be justified by appealing to the need for environmental protection.
- Due to civil law regulations, the contractual period should be limited to five years, or alternatively to a maximum of 10 years.



## ARGUMENTS IN FAVOR OF INSTRUMENT:

- The instrument would target both the supply and demand sides of the market, thus comprehensively addressing the price gap.
- Basing support on competitive auctions would allow for competitive price formation.
- Depending on the frequency of the auctions, the instrument would provide sufficient flexibility to reflect the decreasing difference between supply bids and demand-side willingness to pay.
- Demand side auctions could include criteria regarding end use, while supply side auctions could include multiple eligibility criteria, including such aspects as system integration.
- In the short term, only sites close to demand centres would be able to bid competitively for pure H<sub>2</sub>, as transport is included in the bid. In the long term, sites would compete globally.
- The instrument could allow for H<sub>2</sub> sale on secondary markets.



## ARGUMENTS AGAINST INSTRUMENT:

- High funding requirements could result. Cost risks could be effectively managed by limiting the allocation of funding with caps.
- In the long term, the intermediary would design and enter into complex contracts, which would require relevant expertise. This must be taken into account when setting up the intermediary.
- The intermediary would face significant risks if suppliers fell short of their commitments. The instrument design must therefore include de-risking provisions.
- The instrument does not have an intrinsic financing mechanism.
- The early technology development phase (especially for PtX fuels) might not allow for enough competition to effectively drive down prices.

# SUPPORT FOR H<sub>2</sub>-FUELLED CHP PLANTS

Under this instrument, support for combined heat and power (CHP) plants that use renewable H<sub>2</sub> would be auctioned under the existing CHP Act.

Plants would receive support per unit of electricity generated, covering both the incremental CAPEX as well as the OPEX cost difference between renewable H<sub>2</sub> and natural gas.

## INSTRUMENT DESCRIPTION

- Suppliers would bid competitively to receive a fixed feed-in premium for each unit of power generated by H<sub>2</sub>-based CHP plants.<sup>1</sup> This support would be necessary to achieve the scenario presented in the study “Towards a Climate-Neutral Germany”, which foresees 2.5 GW H<sub>2</sub>-fuelled capacity in 2030, generating 8 TWh electricity and 5 TWh heat (Prognos et al. 2021).
- Projects awarded support would receive a fixed payment per unit of electricity generated during their depreciation period (e.g. 10–15 years). This premium would aim to cover the cost difference between generation with renewable H<sub>2</sub> and generation with natural gas, including associated capital expenditures.
- CHP plants granted support would be required to actually consume pure hydrogen. This means they would need to be located close to electrolyzers or directly connected to an H<sub>2</sub> network. Adequate hydrogen supply could be assured by

developing integrated projects (CHP + electrolysis + H<sub>2</sub> storage), or through H<sub>2</sub> supply contracts.

- To ensure that the supported capacities are operated flexibly and not used to serve baseload demand, their operation should be limited to around 3,000 hours p.a.<sup>2</sup> System-friendly dispatch would be incentivised through the spot market prices for electricity.
- The auction mechanism could be implemented under the existing CHP Act, e.g. as part of the auction procedure for innovative CHP systems or by amending the coal/gas replacement bonus to include H<sub>2</sub>.

<sup>1</sup> Smaller installations could also receive an administratively determined feed-in tariff rather than support determined by auction. This is currently the method used by the CHP Act.

<sup>2</sup> The study “Towards a Climate-Neutral Germany” foresees 8 TWh of electricity generation from 2.5 GW of H<sub>2</sub>-fuelled capacities in 2030, resulting in 3,200 hrs p.a. on average.



### TIMELINE & SEQUENCING

Today–2030	2030–2040	2040 & beyond
	Support H <sub>2</sub> in CHP	Support H <sub>2</sub> in gas plants

This instrument could be introduced during the next legislative term and then replaced with an H<sub>2</sub> quota for gas plants once coal-based electricity generation has stopped – otherwise, it could shift the power mix away from gas and toward coal. In principle, the EU ETS could also trigger a switch from fossil to H<sub>2</sub> – however only at prices of ~650 €/t of CO<sub>2</sub>,<sup>3</sup> which are highly unlikely by 2040. Similarly, spot market prices would have to be at 33 ct/kWh to trigger H<sub>2</sub>-based dispatch (Prognos et al. 2021).



### FINANCING MECHANISM

Support granted under the CHP Act is currently financed through levies on end power consumers. However, financing through electricity prices may have regressive effects on low-income households. It may also worsen the economic incentives for direct electrification. Financing through carbon tax revenues (BEHG or EU ETS) might therefore be more appropriate (Agora Energiewende 2018).



### RELIEF MEASURES / EXEMPTIONS

Energy intensive companies are already exempt from the CHP levy (and from the EEG levy).



### LEGISLATIVE IMPLICATIONS

- draft new legislation
- ✗ adapt CHP Act (KWKG)



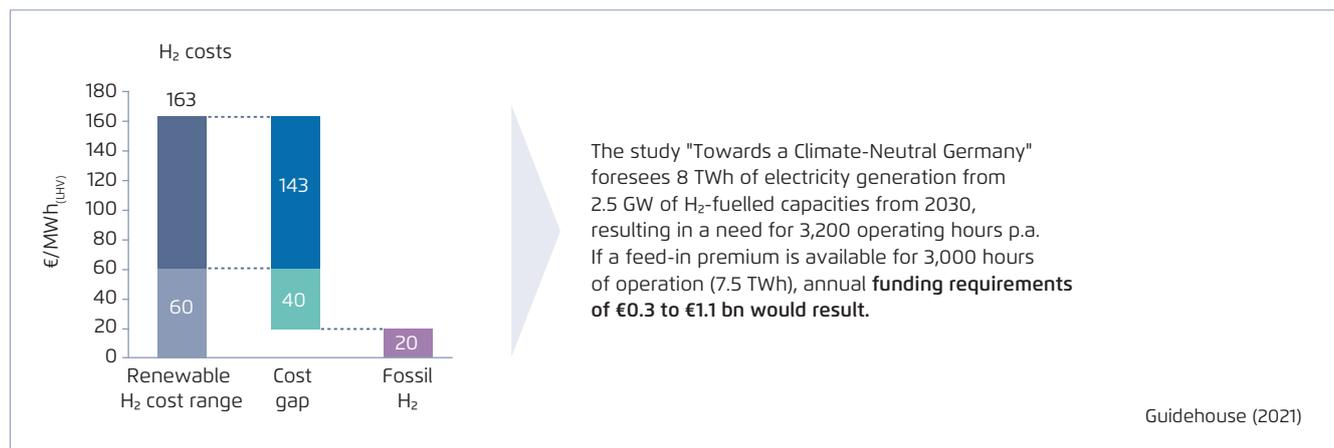
### STATE OF THE LARGER DEBATE

The use of H<sub>2</sub> in power generation has not been a prominent topic of discussion. The German H<sub>2</sub> strategy contains only one related aim: to support ‘hydrogen-ready’ facilities under the CHP Act. However, such a measure would be insufficient, as it would postpone the installation of plants that run on pure hydrogen and fail to incentivise the actual use of H<sub>2</sub>. CHP plants are also relevant for covering the residual heat load<sup>4</sup> in district heating. The next revision of the CHP Act is expected in 2023.

<sup>3</sup> Assumptions, from “Towards a Climate-Neutral Germany”: €150/MWh for H<sub>2</sub>, €20/MWh for natural gas, 0.2 tCO<sub>2</sub>/MWh of natural gas (not taking into account additional investment costs for H<sub>2</sub>-fuelled plants).

<sup>4</sup> The residual heat load in district heating is the load that remains after all other sources of renewable heat and recycled waste heat have been tapped. In the long run, the most important contribution will come from large-scale heat pumps (Prognos et al. 2021).

## ECONOMIC ANALYSIS



Note: Assuming similar CAPEX for hydrogen and conventional CHPs, both for new investments and retrofits.

## LEGAL ASSESSMENT

- The fixed feed-in premium for H<sub>2</sub>-fuelled CHP plants that is proposed here resembles the auction-based support for new CHP plants that is provided under Article 8a KWKG.<sup>5</sup> As natural gas and hydrogen have divergent economic parameters, auctions for H<sub>2</sub>-fuelled CHP should be managed and conducted separately from the auction mechanism described under Article 8a KWKG. The existing mechanism for innovative CHP systems shows that a separate auction procedure is already an option under the KWKG.
- For the purposes of easier comparison and to simplify the integration of the auction mechanism in the KWKG, it might be helpful to extend the permissible annual operating hours from 3,000 hours to 3,500 hours, as is the case for existing support schemes. However, if the goal of the instrument is to maximize capacity growth, it might be useful to lower the number of operating hours that can qualify for support even further – for instance, to 2,500 hours each year.
- We recommend linking the duration of support to the depreciation period for the plant, rather than a fixed number of years. Another option would be to limit support to 45,000 full load hours, in line with the current support mechanism for innovative CHP systems, as a longer support period could also bolster capacity expansion.
- The scheme should clarify a minimum capacity threshold for CHP plants, such as 500 kW or 1 MW. Allowing CHP retrofits to qualify for support could aid the achievement of capacity targets. This could include, for example, projects for retrofitting a block CHP plant, with simultaneous replacement of the steam generator.

<sup>5</sup> KWKG refers to the German support scheme for CHPs



## ARGUMENTS IN FAVOR OF INSTRUMENT:

- Reliable and predictable expansion of H<sub>2</sub>-fuelled flexible power generation, which is absolutely necessary over the long-term.
- Guaranteed emission savings in power sector by covering cost gap between H<sub>2</sub> and natural gas.
- Expansion of flexibly dispatchable capacities to cover times of low renewable electricity feed-in.
- Efficient use of expensive renewable H<sub>2</sub> for combined power and heat production.



## ARGUMENTS AGAINST INSTRUMENT:

- Very expensive instrument because large cost gap between H<sub>2</sub> and natural gas needs to be covered. Fair cost allocation would be important, as well as phase-out as soon as possible. Also, consensus that H<sub>2</sub> is needed in the power sector by 2030 is crucial to justify the costs.
- Costs will be incurred for a long time, even after discontinuation of new auctions.
- Only projects in sites with access to H<sub>2</sub> supply can participate, limiting the number of potential projects. Especially in early years, the auctions would need to be carefully designed based on prior market surveys.

# PTL QUOTA FOR AVIATION

A power-to-liquid (PtL) quota in aviation would increase demand for e-kerosene, thus stimulating renewable H<sub>2</sub> and PtL production while furthering technological learning.

## INSTRUMENT DESCRIPTION

- A PtL quota in the aviation sector would create demand for e-kerosene, a drop-in fuel that can be blended with conventional kerosene up to a 50% share, according to current regulations.
- We propose requiring kerosene distributors in Europe to fulfill a 5% e-kerosene quota for kerosene bunkered in the EU (as a share of energy content). This quota should be adopted as part of sustainable aviation fuel (SAF) quotas.
- The PtL quota should be reviewed in 2025 and, if feasible, increased to 10% (or higher).
- Kerosene distributors would need to prove compliance to a regulatory authority through certificates.
- The target should be tradable, i.e. certificate trading ('book & claim') should also be possible. However, certificate trading should only be allowed under bilateral contracts between parties subject to the scheme.
- E-kerosene cannot yet be produced at an industrial scale, as the production technology is still under development. Hence, a few years must pass prior to actual implementation.
- At the EU level, the quota could be implemented as part of the RED revision.



### TIMELINE & SEQUENCING

Today–2030	2030–2040	2040 & beyond
2025–2030	2030–2050	

Due to current technical limitations, implementation earlier than 2025 is unrealistic. PtL and other SAFs must cover 100% of kerosene by 2050. The PtL quota must therefore increase in coordination with a quota for SAFs.



### FINANCING MECHANISM

Costs would be passed from fuel providers to airlines and from airlines to end customers.



### RELIEF MEASURES / EXEMPTIONS

Relief measures or exemptions are not under discussion.



### LEGISLATIVE IMPLICATIONS

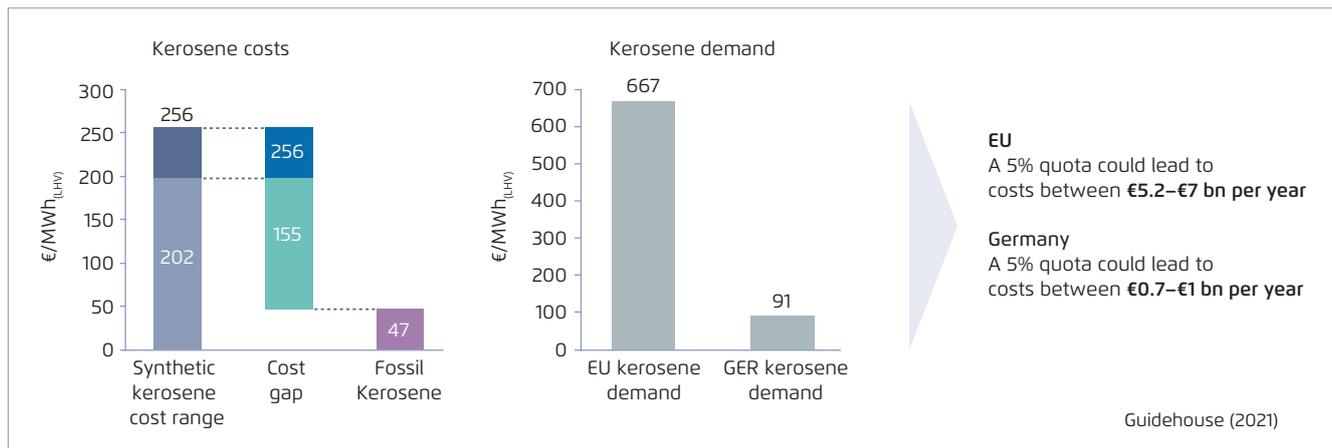
- draft new legislation at the EU level
- × adapt legislation at the EU Level (e.g. Renewable Energy Directive)



### STATE OF THE LARGER DEBATE

Germany is planning to oblige distributors to fulfill a volume-based PtL quota in aviation of 0.5% in 2026, 1% in 2028, 2% in 2030, applying to all fuels bunkered in Germany. The relevant federal ministries have agreed on the draft law (BImSchG) and industry is not opposed to it. Some are skeptical whether sufficient fuel quantities can be supplied. The EU is considering a SAF quota, including a sub-quota for e-kerosene, in the context of the RED revision (European Commission 2020b).

## ECONOMIC ANALYSIS



## LEGAL ASSESSMENT

- Adoption of the instrument is legally feasible both in Germany and at the EU level.
- The quota could be implemented as a regulation or directive.
- A notification to the European Commission is not necessary as the quota is not linked to state aid.
- Non-European producers must have market access, meaning that imported e-kerosene must be eligible.
- E-kerosene must be produced according to RED II criteria on sustainability.
- The quota must be technically achievable and place no undue burden on obligated parties to fulfill the principle of proportionality.
- Legal challenge could result if the quota covers only e-kerosene while excluding bio-based kerosene. If the quota

is not implemented as part of SAF quotas, non-interference with the principle of equality would have to be substantiated. Possible justifications include limited land availability and land use competition with biofuels, as well as the medium- to long-term need for biofuels in industry. In addition, e-kerosene has a technical advantage, as it is chemically identical to conventional kerosene, unlike bio-based kerosene.

- The quota could also be implemented such that it applies directly to fuel combusted in the EU (i.e. all flights that depart from or arrive in the EU). Such a rule would be highly likely to withstand possible legal challenge through appeal to the principle of territorial sovereignty.



## ARGUMENTS IN FAVOR OF INSTRUMENT:

- The instrument would create targeted demand in a sector where PtL fuels are needed, according to most experts.
- There would be no burden on public budgets.
- Higher costs would be borne by market actors.
- A European quota makes more sense than national quotas to prevent carbon leakage and distorted competition between market actors in EU aviation.
- Allowing for international trading ("book & claim") could facilitate production at ideal sites (e.g. regions with high renewable energy potential) but would make monitoring more difficult. Hence, only obligated parties should be allowed to engage in certificate trading.
- Over the long term, high quota levels would require regulatory adjustments, as currently the maximum allowed drop-in quota is 50%.



## ARGUMENTS AGAINST INSTRUMENT:

- The quota could induce adverse ecological effects such as tankering, re-routing and carbon leakage. It could also create competitive disadvantages for EU airlines. Covering all kerosene combusted by planes departing from or arriving in the EU (as opposed to only covering airlines that bunker fuel within the EU) could counteract these risks (Bullerdiek et al. 2021). This alternative design would also be legally feasible.
- A PtL quota can only reduce CO<sub>2</sub> emissions. To address the other, non-negligible climate change impacts of aviation (Atmosfair 2021), instruments inducing a modal shift are needed.
- If end consumer prices become too high due to a PtL quota, there would be regressive social effects, i.e. flying would only be possible for the wealthy. In the early phases, the effect on ticket prices would be relatively minor.
- Setting the target as an energetic share would create insecurity about actual volumes needed in target years. However, this is preferable to setting fixed volume targets.

# GENERAL HYDROGEN QUOTA

Setting a general quota for renewable H<sub>2</sub> would create reliable demand in industry, transport and the buildings sector. This

would stimulate growth in renewable H<sub>2</sub> production while also encouraging technological learning.

## INSTRUMENT DESCRIPTION

- This instrument foresees a renewable H<sub>2</sub> quota of 3–5% on general gas demand.<sup>1</sup> The quota would target the demand side of the market, but the obligation to comply would be placed on fuel suppliers.
- The renewable H<sub>2</sub> would be directly blended into the gas network or accounted for virtually. In the case of blending, technical compatibility issues would arise, in part related to gas purity (e.g. for use in industry and pipeline transport).<sup>2</sup>
- RED II introduced a 2030 renewable energy target of 14% for road and rail transport. RED II defines sustainability and GHG emission criteria for bioliquids in these areas. Compliance checks for the general H<sub>2</sub> quota should be modelled after RED II provisions.

- The quota would induce significant renewable H<sub>2</sub> demand in transport and the buildings sector, due to a higher willingness to pay. However, other low and zero carbon alternatives are available to these sectors. A general H<sub>2</sub> quota is therefore unlikely to target the applications that will depend on renewable H<sub>2</sub> to become climate-neutral.

<sup>1</sup> We use "gas" as an umbrella term for gas in power generation, industrial production and for final demand by consumers. Today, this demand is primarily served with natural gas.

<sup>2</sup> The "Gas 2030" industry dialogue, spearheaded by the Federal Ministry of for Economic Affairs and Energy, stressed the importance of gas quality and identified risks to industrial demand arising from blending (BMWi 2019).



### TIMELINE & SEQUENCING

Today–2030	2030–2040	2040 & beyond
2021–2030		

The quota would commence immediately and continue until renewable H<sub>2</sub> achieves cost-parity (in 2030 at the earliest). In 2026, the quota could be reviewed and potentially revised.



### FINANCING MECHANISM

The increased cost of production would lead to higher consumer gas bills. This would have regressive effects on low-income households. Industry and transport would pass costs on to consumers, making goods and services more expensive.



### RELIEF MEASURES / EXEMPTIONS

Industry would be likely to seek exemption by pointing to competitive disadvantages in international markets and carbon leakage risks. Low income households may need a compensatory measure to avoid regressive effects.



### LEGISLATIVE IMPLICATIONS

- ✕ draft new legislation
- adapt RED II legislation)



### STATE OF THE LARGER DEBATE

A quota for renewable H<sub>2</sub> has been proposed by industry as an efficient instrument for significantly increasing demand as well as indirectly increasing supply (FNB Gas 2019, E.ON 2020). However, the instrument has been criticized by the BMU, Agora Energiewende and others for not targeting the applications that truly require renewable H<sub>2</sub> to become climate-neutral. Accordingly, more targeted instruments are recommended (Agora Energiewende, Agora Verkehrswende 2019, BMU 2020).

## LEGAL ASSESSMENT

- Adoption of the instrument is legally feasible.
- Regarding the free movement of goods, the quota would constitute a measure of equivalent effect with an import restriction. However, this would probably be justifiable if it is ensured that all EU hydrogen producers are allowed to supply the obligated parties.
- The implementation would have to take into account Article 27 of the RED II for application in the transport sector, as RED II places requirements on the electricity used to produce renewable hydrogen as an intermediate product for e-kerosene. (These requirements include additionality, temporal and geographic correlation, and carbon source requirements).
- The quota would not constitute state aid and would comply with relevant German and EU primary and secondary legislation. The encroachment on freedom of occupation pursuant to Article 12 of the German Basic Law and the principle of equal treatment under Article 3 of the German Basic Law would probably be justifiable through appeal to the importance of renewable hydrogen for decarbonisation and for climate protection (which is enshrined as a goal of the state under Article 20s of the German Basic Law).
- Finally, the quota is not a levy and does not have to fulfill requirements set forth under Article 104a of the German Basic Law (which governs taxes).



### ARGUMENTS IN FAVOR OF INSTRUMENT:

- The instrument would not place a burden on government budgets.
- Higher gas costs would be directly or indirectly passed on to end consumers.
- As the scope of demand covered by the quota would be significant, it would trigger a significant ramp-up in production capacity.
- The effects would be immediate, thus enabling a rapid increase in production and the fulfilment of climate policy ambitions.
- The quota is legally feasible in principle both in Germany and at the EU level. However, legal feasibility will depend on the precise design of the quota.



### ARGUMENTS AGAINST INSTRUMENT:

- Low-income households would be disproportionately burdened by higher gas prices and could require a compensatory mechanism.
- Companies that compete in global markets may demand or require a compensatory mechanism or exemptions.
- The quota is not targeted to specific sectors, and thus unable to directly trigger demand in applications that truly require renewable H<sub>2</sub> to become climate-neutral (e.g. specific industrial processes).
- Due to a higher willingness to pay, renewable H<sub>2</sub> demand would be particularly strong in the transport and buildings sectors. Other low-carbon or zero carbon alternatives are available to those sectors, however. As a consequence, unnecessary H<sub>2</sub> demand and associated lock-in effects could result.
- Given the more favourable assessment of sector-specific demand instruments, the general H<sub>2</sub> quota is dismissed from the regulatory architecture for renewable H<sub>2</sub>.

# LABELLING SYSTEM FOR CLIMATE-FRIENDLY BASIC MATERIALS

A labelling system would be most effective in combination with other instruments, such as carbon limits on final products (CISL and Agora Energiewende 2021).<sup>1</sup> Climate labels can be used to demonstrate the embedded emissions of basic materials, thus allowing CO<sub>2</sub> passporting.<sup>2</sup> Labels can also be used to communicate the necessity of charging a price premium (e.g. to finance new production processes based on renewable H<sub>2</sub>).

Labelling can thus support the expansion of renewable H<sub>2</sub> production and the development of green lead markets.

<sup>1</sup> Carbon limits are understood as policies that place embedded life cycle CO<sub>2</sub> limits on final products that are material intensive, ensuring these are reduced over time.

<sup>2</sup> Digital passports include product-related information by manufacturers on embedded emissions.

## INSTRUMENT DESCRIPTION

- A climate labeling system for basic materials would document the CO<sub>2</sub> content of basic materials (such as steel) that are used as inputs to manufacture final products (such as cars).
- Standards would be needed to determine how embedded emissions are calculated (e.g. for the hydrogen used during the production of basic materials). The climate-friendly basic material would be certified and labelled. Monitoring by an independent entity would ensure consistency.
- The labeling would be mandatory for the basic materials that fall under the system, which could include steel, basic chemicals, and cement. Additional costs would be passed along to consumers through the final product price.
- As the initial demand-side pull will not be sufficient to justify investment in H<sub>2</sub> technologies, additional instruments such as Carbon Contracts for Difference (CCfDs) may be required. Labelling could reduce the funding costs of CCfDs, as the purchasers of climate-friendly materials could only claim the CO<sub>2</sub> savings if they paid the cost premium for the climate friendly basic material. Consequently, when a climate-friendly basic material is supported through a CCfD, the offtaker should not be allowed to claim the CO<sub>2</sub> savings.
- The instruments for labeling and for the promotion of demand for green products should define a level playing field for all CO<sub>2</sub>-abatement strategies (including material avoidance and substitution, recycling and secondary production, and low CO<sub>2</sub> primary production).



### TIMELINE & SEQUENCING



The label could be introduced as soon as possible and retained over the long term. It should be complemented by additional policies that incentivise the renewable H<sub>2</sub> ramp-up.



### FINANCING MECHANISM

The EC is considering a broader system of embedded carbon reporting under the Sustainable Products Initiative. Already, the Ecodesign Directive sets out minimum mandatory requirements for the energy efficiency of products. methanol-to-olefin/-aromatics route (chemicals) and carbon capture with the oxyfuel process (cement).



### RELIEF MEASURES / EXEMPTIONS

No measures or exemptions would be necessary.



### LEGISLATIVE IMPLICATIONS

See legal assessment.



### STATE OF THE LARGER DEBATE

The EC is considering a broader system of embedded carbon reporting under the Sustainable Products Initiative. Already, the Ecodesign Directive sets out minimum mandatory requirements for the energy efficiency of products. methanol-to-olefin/-aromatics route (chemicals) and carbon capture with the oxyfuel process (cement).

## LEGAL ASSESSMENT

- In the context of CO<sub>2</sub> passporting, it would be essential to observe the requirements of WTO law (including in particular the TBT Agreement), and the free movement of goods.
- A legal basis for the introduction of the label would be required. For implementation at the EU level, incorporation into the Ecodesign Directive should be considered. The idea of a label may also be addressed in the context of RED III. An EU Directive could – depending on its design – leave more room for individual regulations in Member States (exemptions, strengthening of protection, etc.). This could potentially ease ratification. Alternatively, a new EU Regulation could be considered. A Regulation could be adopted faster, and would be more uniform. This would ensure more rapid adoption as well as intra-European competition. The benefits of competition across Europe argue against granting excessive leeway for exemptions.
- For reasons of proportionality and appropriateness, it would be necessary to gradually introduce the necessary measures, in order to ensure transparency and establish quality standards. However, there are no concrete legal requirements foreseen in this respect.



### ARGUMENTS IN FAVOR OF INSTRUMENT:

- The instrument would allow the embedded CO<sub>2</sub> content of basic materials to be more easily compared while also lowering barriers to use for SME manufacturers of final products.
- Studies show strong public support for labels (Carbon Trust 2020).
- A label creates transparency for consumers and prepares the market for future market-based instruments.
- As an increasing number of companies have been making commitments to carbon neutrality, the instrument could add further momentum to this trend.
- The instrument appears politically feasible.
- The instrument can be implemented as soon as standards and a certification system are determined.
- A credible label would ensure transparency and consumer choice, which are needed to generate demand for renewable H<sub>2</sub>-based production. The instrument could thereby complement the CCfD, minimise associated costs, and promote demand for green products.



### ARGUMENTS AGAINST INSTRUMENT:

- A label enables consumers to finance renewable H<sub>2</sub> technologies by buying green products. However, there is uncertainty concerning consumers' willingness to pay for such products (even though renewable H<sub>2</sub> steel would increase the price of a car by 1–2%).
- Impacts on renewable H<sub>2</sub> demand would depend in part on policy ambition to adopt stricter carbon limits on final products.
- The short-term introduction of a label could lead to resistance from industry, as industry actors may need more time to switch to climate-friendly production processes.

# GREEN PUBLIC PROCUREMENT

This instrument would oblige the government to establish strict sustainability criteria for public procurement. This would create reliable demand for sustainably manufac-

tured products (including steel, cement and vehicles) while also encouraging the growth of a lead market for green products.

## INSTRUMENT DESCRIPTION

- In the area of public procurement, sustainability criteria have only been applied to particular product groups and are not obligatory. As a result, they are not widely used in practice. However, the public sector could exert a strong influence on the development of green products and processes, thanks to the volume of spending by government (Agora Energiewende and Wuppertal Institut 2021).
  - The instrument could be made mandatory for all procurement when the public share of funding exceeds 50%. The criteria could also become stricter over time. For instance, one could stipulate that 2% of steel used in public building projects must be green from 2022, that 50% must be green from 2030 and that 100% must be green from 2050.
- Exceptions to this rule should only be allowed in certain, justifiable cases.
  - In the area of transport services, the sustainability criteria should consider not only vehicle emissions but also the incentives that shape transport demand.
  - The instrument could also be extended to areas in which the government sets the terms for competitive bidding. In auctions for renewable energy support, for example, EU Member States could make sustainable materials mandatory.
  - The instrument would reduce the risks for businesses to invest in low-carbon production. Moreover, public procurement criteria would set standards for private sector transactions, and could complement and support CCfDs.



### TIMELINE & SEQUENCING

Today–2030	2030–2040	2040 & beyond
2021–2050		

No time restrictions would be necessary. The instrument would be a sensible and effective option over the long term. The government should commit itself to using sustainability criteria for at least 20 years to ensure businesses have a reliable basis for planning investment. Nevertheless, the sustainability criteria should be continuously adapted to technological developments.



### FINANCING MECHANISM

Funds should be allocated from the general budget.



### RELIEF MEASURES / EXEMPTIONS

No relief measures or exemptions would be required.



### LEGISLATIVE IMPLICATIONS

- raft new legislation
- × adapt RED II legislation).



### STATE OF THE LARGER DEBATE

The idea of adopting sustainability criteria in public procurement is not new. In 2003, the EU called on Member States to develop national action plans for a green public sector. Some countries are already using sustainability criteria in their public procurement. In the Netherlands, for example, government agencies are required to apply environmental criteria when awarding public contracts.

## LEGAL ASSESSMENT

- The introduction of mandatory environmental criteria for awarding public contracts faces manageable legal risks.
- In addition to the equal treatment of domestic and foreign bidders, the instrument would need to fulfil the publication and notification requirements for technological regulations. See Art. 2, para. 9-11 ÜtH (Agreement on Technical Barriers to Trade).
- The instrument conforms to the fundamental freedoms and the procurement directive of EU law. However, the award criteria must be connected to the purpose of the contract.



### ARGUMENTS IN FAVOR OF INSTRUMENT:

- Green public procurement would send an important signal to citizens and business that government is leading the way.
- The instrument would support the creation of reliable markets for green products.
- The instrument is highly cost-efficient if successfully implemented.
- The instrument is easy to implement nationally and regionally.
- The instrument is legally feasible both in Germany and at the EU level.



### ARGUMENTS AGAINST INSTRUMENT:

- The instrument creates additional costs and increased complexity when awarding public contracts and determining sustainability.
- Over the short term, supply shortages and limitations to competition could occur.
- In certain applications, it may not be possible to fulfill all product quality requirements.

# CLIMATE SURCHARGE ON END PRODUCTS (“CLIMATE LEVY”)

This instrument would apply a weight-based surcharge to selected materials (e.g. steel, plastics, aluminium and cement). The revenues would be used to fund other climate policy instruments, such as CCfDs. While only causing small cost

increases for end consumers, the instrument would create incentives for material efficiency (Agora Energiewende and Wuppertal Institut 2021).

## INSTRUMENT DESCRIPTION

- The surcharge would not be due immediately upon production; rather, it would be passed down the supply chain as part of a delayed charge procedure. The surcharge would only be due when the material is sold to an end consumer or non-exempt business.
- The climate surcharge would apply regardless of where the end products are produced.
- At first, the charge could be applied to steel, aluminium, cement and plastics. The instrument would not consider CO<sub>2</sub> quantities released during production. Zero-carbon steel would thus incur the same charge as conventional steel.
- The instrument would be similar to a carbon price on end products. The crucial difference would be no consideration of emissions released during production. Therefore, it would not require carbon footprint tracking.
- Because imported materials would be subject to the charge, while exported products would be exempt, domestic products would not be at a disadvantage (regardless of whether consumed domestically or exported). This eliminates the risk of carbon leakage.



### TIMELINE & SEQUENCING

Today–2030	2030–2040	2040 & beyond
2021–?		

The instrument would remain in force until an international system is in place for tracking the carbon footprint of materials or until carbon prices are harmonised internationally. .



### FINANCING MECHANISM

End consumers would bear the costs, but these would be low relative to the product price itself. A moderate steering effect on material efficiency and substitution can be expected.



### RELIEF MEASURES / EXEMPTIONS

No measures or exemptions would be necessary.



### LEGISLATIVE IMPLICATIONS

- × draft new legislation
- × adapt legislation



### STATE OF THE LARGER DEBATE

The levy is recommended by the Climate Friendly Materials Platform. A similar approach is being discussed by policymakers in Germany and the EU under the rubric of a plastics tax, intended primarily to eliminate waste. The levy would help to create a level playing field internationally for transformative investment in heavy industry (e.g. if revenues are used to finance low-carbon technologies via CCfDs).

## LEGAL ASSESSMENT

- The introduction of a climate surcharge on end products would be legally permissible in principle.
- As a charge on consumption, the instrument would be compliant with WTO rules as long as the equal treatment of imported and domestically produced materials is assured. Governments may not impose higher surcharges on imported products than on domestic ones. Moreover, flat rates must also be based on verifiable and robust assumptions.
- Depending on the design, a border carbon adjustment system for products with foreign inputs may be necessary – however, this is not generally permissible under WTO rules.
- If producers included in the EU ETS are covered by the surcharge, the product's carbon footprint may be charged twice – at the point of production and the point of consumption. To avoid double charging, the climate surcharge must be offset with free allocations or an equivalent EU ETS exemption.
- An adjustment mechanism in the form of free emissions allowances would require a change to the EU ETS directive – namely, the rescinding of the regulation under Article 10, para. 1 RL (EU) 2018/410. Potentially, technology benchmarks would have to be frozen at current levels.
- If necessary, an adjustment mechanism could be used to justify any equal or unequal treatment of products that is deemed unconstitutional.



### ARGUMENTS IN FAVOR OF INSTRUMENT:

- The levy would create income to fund other instruments (e.g. CCfDs).
- The market would determine material efficiency and the most favourable alternative technologies.
- No risk of carbon leakage, because the surcharge also applies to imports.
- Both imported materials and those produced domestically would be treated equally.
- No global carbon tracking would be necessary.
- A flat rate surcharge is not discriminatory, and thus complies with WTO rules and EU law.



### ARGUMENTS AGAINST INSTRUMENT:

- The instrument would require comprehensive implementation at the EU level. An opening clause for Member States may be possible, but this would require changes to the EU ETS Directive.
- The instrument could lead to the undesired use of materials not subject to the charge.
- The levy is at cross-purposes with the envisioned gradual reduction in free EU ETS allowances.
- It is uncertain whether such a levy would be permitted as an additional national measure for emitters that fall under the EU ETS.





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Agora Energiewende develops scientifically sound, politically feasible ways to ensure the success of the energy transition – in Germany, Europe and the rest of the world. The organization works independently of economic and partisan interests. Its only commitment is to climate action.

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### **Agora Energiewende**

Anna-Louisa-Karsch-Straße 2 | 10178 Berlin, Germany

P +49 (0)30 700 14 35-000

F +49 (0)30 700 14 35-129

[www.agora-energiewende.org](http://www.agora-energiewende.org)

[info@agora-energiewende.org](mailto:info@agora-energiewende.org)

