Pathways Towards a Global Market for Green and Sustainable Hydrogen

Need for Action and Policy Options

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Abbreviations

CCUS	Carbon Capture, Utilisation and Storage
DRI	Direct Reduced Iron
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy
IRENA	International Renewable Energy Association
IEA	International Energy Agency
H_2	Hydrogen
CO_2	Carbon dioxide
GHG	Greenhouse gas
Mt	Megaton (1,000,000 tons)
WTO	World Trade Organisation
CBAM	Carbon Border Adjustment Mechanism
DRI	Direct Reduced Iron (also sponge iron)

Executive summary

Green hydrogen is no miracle solution. But it can play an important role in a climate-neutral economy – first and foremost in "hard-to-abate" sectors and uses where direct electrification is not (yet) a viable option. No-regret candidates are long-distance transport (maritime shipping and long-haul aviation) and certain industrial applications. To be consistent with climate neutrality, hydrogen needs to be produced with fossil-free, i.e. renewable, electricity. Since production costs for green hydrogen will be driven largely by renewable potential, there is a huge opportunity for international trade in hydrogen – or derived products, such as ammonia, exported from countries with abundant renewable potential.

The global market for green hydrogen and its derivatives is only starting to emerge – and is expected to multiply in size in the coming years. While its shape and structure are still unclear, what is clear is that any such market will be a hybrid – with elements of a commodity market (akin to existing markets for hydrocarbons), but also strongly influenced by political design choices (in particular regarding the green nature of hydrogen and its role in the market). However, the current situation with a growing number of bilateral partnerships is not conducive to the end goal of a single, global, unified market for green and sustainable hydrogen. To establish such a market, and to ensure its proper function, several elements must be in place:

1. A tracking and accounting system for green hydrogen and its derivative, to document the green property of traded hydrogen and derivatives. This could take the form of a hydrogen registry of sorts, documenting the origin of the traded hydrogen (or derivatives) and its embedded emissions,
2. Standards for green and sustainable hydrogen (see chapter 4.1),
3. Oversight and grievance mechanisms to ensure compliance with said standards – and to specify a course of action / remedy in case of non-compliance,
4. Arrangements for the actual trading (which commodity is being traded on which platform under which conditions, which financial products apply, how are trades cleared),
5. Assurances / guarantees to investors regarding the conditions under which they can market the hydrogen produced in projected investment projects.

In principle, these elements can be arranged at different levels:

- At **bilateral** level – in cooperation between two countries (typically one prospective supplier and one prospective importer)
- At **plurilateral** level – agreed between a limited group of like-minded countries with shared interests. This could be the EU (possibly with partners), but also initiatives out of the G7/G20 orbit such as the "The International Partnership for Hydrogen and Fuel Cells in the Economy" (IPHE).
- As a genuine **multilateral** initiative, that is (in principle) open to any country, and applicable to any country that is a member of the initiative.

Clearly, action at these different levels has its pro's and con's: the more partners are involved (with diverging views and interests), the harder it will be to reach agreement. At the same time, the more parties involved, the more authoritative the outcome. Plurilateral initiatives promise to operate at the "sweet spot" where both come together: small enough to avoid protected negotiations between a large set of partners with diverging (or opposed) interests – but also large enough to have an impact, and potentially even establish a de-facto standard.

1 The international market for green hydrogen

1.1 Introduction

Green hydrogen can play an important role in a climate-neutral economy – first and foremost in “hard-to-abate” sectors and uses where direct electrification is not a viable option for the foreseeable future. No-regret candidates are long-distance transport (maritime shipping and long-haul aviation) and certain industrial applications. Hydrogen could also serve as a reaction agent e.g. in steelmaking in a Direct Reduced Iron (DRI) furnace, or as a feedstock e.g. for ammonia production. For these applications to be consistent with climate neutrality, the hydrogen needs to be produced with fossil-free, i.e. renewable, electricity. Where direct electrification is possible (e.g. in passenger transport or space heating), it will almost always be the superior choice – economically, but also in terms of resource use (Liebreich 2020).

Production costs for green hydrogen will be driven largely by the available renewable energy potential, and the costs of bringing hydrogen to the market. Therefore, there is huge potential for hydrogen – or derived products, such as ammonia – to be traded internationally, exported from countries with abundant renewable potential. The global market for green hydrogen and its derivatives is only starting to emerge – and is expected to multiply in size in the coming years.

As the market is emerging, its shape and structure are still unclear – for the time, it is largely structured around bilateral agreements between future suppliers and future importers. What is quite clear is that any international market for green hydrogen will be a hybrid – with elements of a commodity market (akin to existing markets for hydrocarbons), but also strongly influenced by political design choices (in particular regarding the green nature of hydrogen and its role in the market).

As in other areas of energy policy, the Russian invasion of Ukraine changes the terms of the debate. Above all, it increases the urgency of Europe’s transition away from (imported) fossil fuels, particularly gas. While imports of green hydrogen and derived products will only be a relevant part of the solution in the medium to long term, it may change the situation in important regards: it is a painful reminder of the importance of import diversification. By adding pressure, it weakens Europe’s negotiating position vis-à-vis would-be-suppliers, and may increase the willingness to accept compromise solutions (e.g. weaker standards for a transition period). Depending on how long natural gas prices remain at their current, high levels, it also changes the economics of the different shades of hydrogen and brings renewable-based (green) hydrogen considerably closer to competitiveness with fossil-based (grey or blue) hydrogen. But in any case, it greatly increases the uncertainties for any energy-related investments, particularly with a longer time horizon.

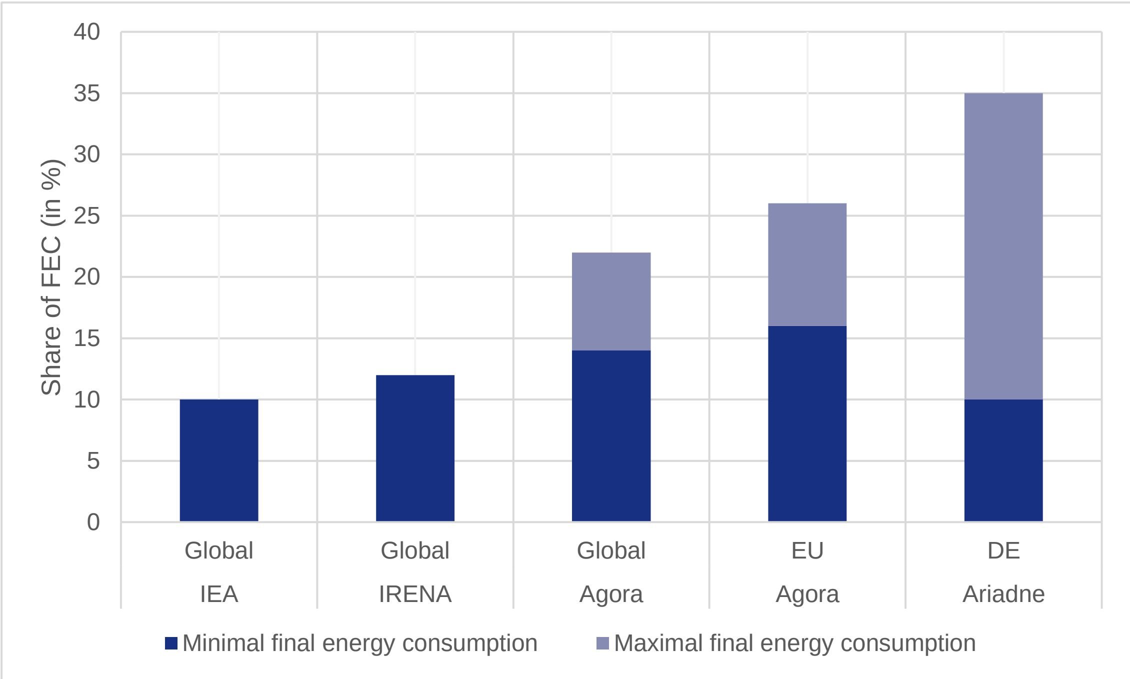
1.2 Trends and figures

The hydrogen market is expected to grow substantially in the coming decades. Currently, more than 30 hydrogen strategies and road maps exist that are paving the way for hydrogen development in places such as Europe, South Korea, Australia, Chile, Colombia and Oman

(Clarke et al. 2022). Global scenarios assume that the share of clean hydrogen (predominantly green) in final energy consumption will increase significantly by 2050. Globally, hydrogen is estimated to reach a share of between 10 and 22 % of final energy consumption, with an even higher share expected for Europe and Germany (see

Figure 1).

Figure 1: Scenario estimates for clean hydrogen in FEC of 2050



Sources: Flis and Deutsch 2021; IEA 2021; IRENA 2022;Ueckerdt et al. 2021; Note: The above scenario estimates represent the hydrogen share in final energy consumption of 2050 (in %), with the exception of Germany, where the estimates are given for 2045.

Likely suppliers of green hydrogen will be countries where different factors come together: (i) abundant renewable energy resources (above all sun and wind – and thus implicitly also the land on which solar and wind energy can be captured); (jj) sufficient (clean) water for H_2 production (including sea water that could be desalinated) – and (iii) the capacity to export (see

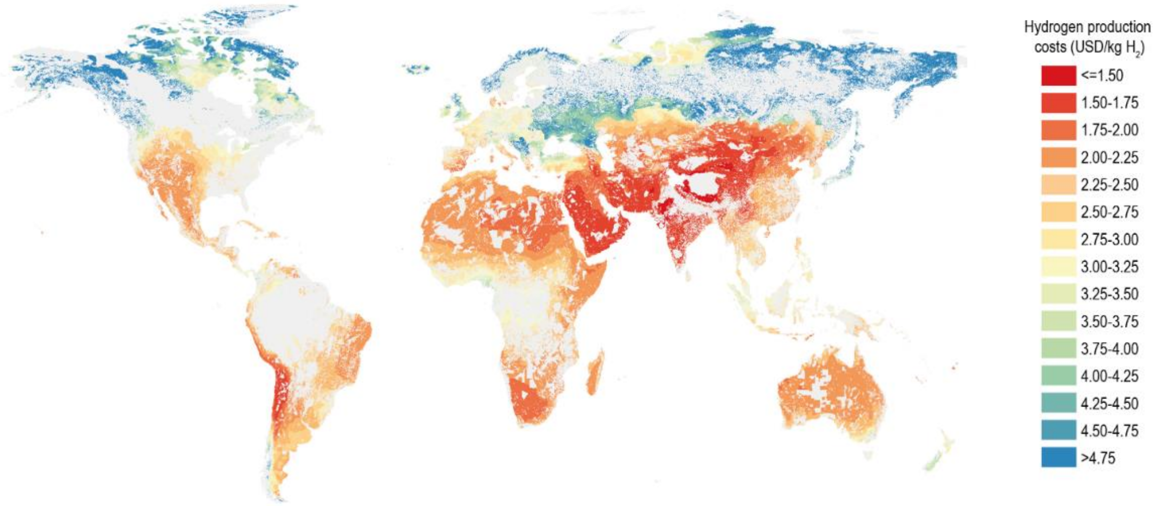
Figure 2). In the latter category, the production of hydrogen is not only a matter of (physical) infrastructure, but also of access to technologies and cost of capital, investment climate and political stability. These factors are not immutable, but can be shaped in particular by international collaboration.

Unlike fossil hydrocarbons, hydrogen could be produced in any world region with good renewable energy resources, such as Australia, Chile, Namibia and North Africa (IEA 2021; Clarke et al. 2022; IRENA 2022); Other studies also include Argentina and Iceland (Hebling et al. 2019) – but also Canada (with abundant hydropower), or Kenya (thanks to geothermal resources). In the European context, Spain and Portugal are considered to play a significant role as producers in the future (Clarke et al. 2022).

The availability of energy infrastructure, skills in the workforce and existing trade relations all create path dependencies that favour traditional hydrocarbon exporters expanding to hydrogen.

This could favour, for instance, the Middle East is seen as a potential producer (IEA 2021; Ueckerdt et al. 2021; Hebling et al. 2019), partly because of their existing gas infrastructure (Clarke et al. 2022) but also due to their established trade relations (IRENA 2022). For this reason, it seems plausible that current fossil hydrocarbon producers might offer blue hydrogen (using CCUS) on the global market once prices for natural gas in the form of LNG go down.

Figure 2: Hydrogen production costs from hybrid solar PV and wind systems for a minimum load of 40%, 2030



Source: IEA, Global Hydrogen Review 2022 (IEA 2022, 97).

At present, the international supply of hydrogen is still relatively low. In 2020, 90 Mt of hydrogen were produced globally. The majority of this hydrogen was produced by using fossil fuels (sometimes in combination with CCUS), in regions such as the Middle East, the USA and Canada (IEA 2021). The amount of green hydrogen currently produced through electrolysis, by contrast, is negligible: In 2020, the worldwide electrolysis capacity amounted to 0.3 GW (Clarke et al. 2022), producing around 0.03% of the global hydrogen. Most capacity is located in Europe (40%), followed by Canada (9%) and China (8%) (IEA 2021).

Many studies project, however, that the supply of green hydrogen will increase sharply in the coming decades. One main driver is the increased deployment of renewable electricity and resulting cost declines – as countries approach intensify the deployment of renewables, generation costs are expected to fall further. Also, higher shares of variable renewable electricity generation translate into more and longer periods with a surplus of low-cost renewable electricity, for which conversion to green hydrogen represents one attractive usage. The growth trend in the supply of green hydrogen is also reflected in the willingness to invest into hydrogen projects. Projections of the expected global capacity for electrolysis are impressive – growing to 54 - 80 GW by 2030, the largest part of which in Europe, followed by Latin America and the Middle East (IEA 2021; Clarke et al. 2022). As per its hydrogen strategy, the EU alone plans to build 40 GW of electrolysis capacity by 2030 (COM 2020). These numbers, however, do not always differentiate between green (renewable-based) and other types of purportedly “clean” hydrogen.

In most parts of the world, grey (fossil-based) hydrogen still represents the cheapest option to produce hydrogen, followed by blue and green hydrogen. Yet the costs of the different options depend on several factors, among them the cost of electrolysers (expected to decrease with installed capacity), the cost of electricity in general, the cost and availability of renewable electricity (expected to improve further), the cost of natural gas (expected to remain high) and the cost of CO_2 emissions, where applicable. This means that cost parity between green and grey hydrogen will first be reached in those regions of the world where cheap and abundant renewable potential is paired with relatively higher gas prices, and possibly a price on CO_2 emissions.[1] From there, as costs of renewable electricity generation continue to fall. green hydrogen is expected to reach cost parity with grey hydrogen successively in more world regions, including by 2030 also those with average cost of renewables and of natural gas (Clarke et al. 2022).

2 An emerging market for green hydrogen

Due to production and transport costs, hydrogen markets will mostly be regionalised. This is already visible today, as 85% of the produced hydrogen was consumed on-site and not traded over longer distances (IRENA 2022). On the one hand, proximity of hydrogen producers to their consumers is beneficial, which supports regionalisation. On the other hand, the cost of transporting hydrogen increases significantly with distance, meaning that regional distribution results in more competitive prices. For this reason, the IRENA projects that two thirds of hydrogen will continue to be distributed regionally in the future, mainly via repurposed gas pipelines, which are considered the most cost-effective transport option for short distances (IRENA 2022).

While the bulk of trading will happen within regions, these regional trading systems will also be embedded in a global market.[2] Some countries will need to import hydrogen also across longer distances if domestic resources are limited. As a result, projections suggest that 20-33% of globally produced hydrogen will be traded across borders in 2050 (Clarke et al. 2022; IEA 2021; IRENA 2022).

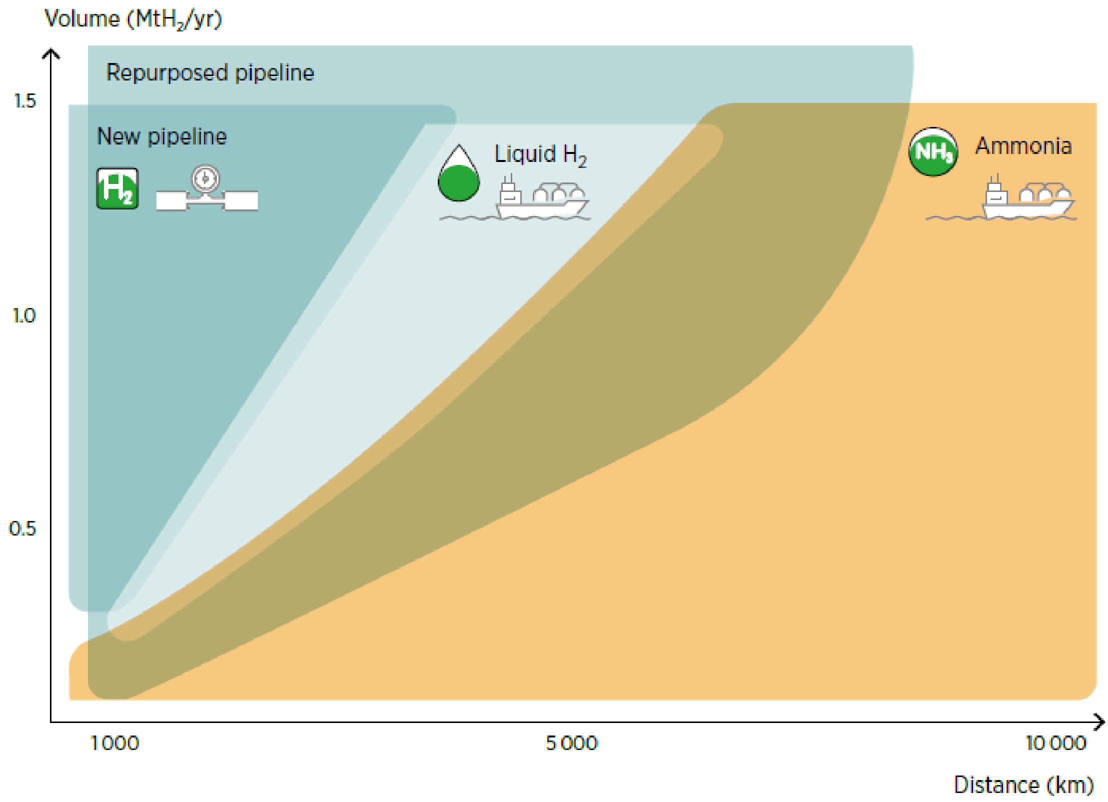
How and in what form this hydrogen will be traded depends on the distance it has to travel. For short distances (up to 4000 km), it may be most economical to transport hydrogen in the form of gas via pipelines (Clarke et al. 2022; IEA 2021; IRENA 2022). Many countries already have gas infrastructure that could be converted to hydrogen networks at comparably low cost. In cases where pipelines are not available and their construction not practicable, hydrogen may also be shipped – less likely in the form of liquefied hydrogen, more likely as ammonia, methanol or LOHC (Clarke et al. 2022; IEA 2021; IRENA 2022). Shipping would be particularly viable for longer distances (starting from 2500 - 4000km). Countries that have to rely on shipping will most likely import hydrogen from regions where renewable energy is widely available and production costs are comparatively low (e.g. Argentina, Australia, Chile, the Middle East, Morocco, Namibia and South Africa) (Fils and Deutsch 2021; SYSTEMIQ 2022). Experts predict that the transport costs of hydrogen or hydrogen-based energy carriers via

[1] Due to the current hausse of natural gas prices, these conditions were achieved in 2022 in many parts of Europe (Clarke et al. 2022, 50).

[2] This document analyses the potential for, and possible governance of, an emerging market for green and sustainable hydrogen and its derivatives, where the hydrogen, its derivatives, or possibly products produced with green hydrogen are traded and shipped internationally. As an alternative, a book & claim system would also be conceivable – whereby green hydrogen or derivatives are paid for by actors in one country (e.g. the EU), are produced and used in another country – but the environmental benefit in the form of avoided emissions is claimed by the funder (similar to trade in CO_2 offset credits). This would obliterate the need for transporting the resource, while delivering in principle the same climate benefit – but not the energy security benefit. While this alternative would be conceivable, it is not investigated further in this document.

shipping will decrease to 2-3 USD/kg by 2030 (Hydrogen Council and McKinsey & Company 2021),.

Figure 3: Costs and volumes of different options to transport H2 and ammonia



Source: IRENA 2022

The physical transport of hydrogen (pipelines) is likely to account for half of international trade at most, with a possibly larger share traded in the form of derivatives, such as ammonia, methanol or synthetic fuels (IRENA 2022). This also includes the possibility that subsequent stages in the value chain (e.g. direct reduction steelmaking using green hydrogen as reduction agent) move to locations with higher renewable potentials. Countries with a high availability of renewable energy could thus specialize in energy-intensive industries (IRENA 2022).

At the moment, the international hydrogen market is emerging mainly through bilateral agreements between main supplier countries and main recipients. Current bilateral agreements indicate that hydrogen supply chains will differ from conventional trade routes for hydrocarbons (IRENA 2022). However, unlike the well-established markets for fossil hydrocarbons (oil and gas), the market(s) for hydrogen has yet to develop. So far, there are no established routines with respect to marketplaces, price formation, standardised products (futures and derivatives trading), criteria for carbon footprint and other sustainability implications or procedures for monitoring and tracking hydrogen (and its derivatives). Nevertheless, the first contours of a global hydrogen market are already visible. For instance, the first bilateral hydrogen transactions have been carried out between countries, such as between Japan, Saudi Arabia, Australia and Brunei (IEA 2021; IRENA 2022).

3 A market design for green and sustainable hydrogen

The situation of the global market for green and sustainable hydrogen is unique. On the one hand, the emerging world market for green and sustainable hydrogen will see another energy commodity being traded, far exceeding the current global market for (conventional, fossil-based) hydrogen and its derivatives, and growing over time while the global market for conventional fossil energy resources is expected to decline to (near) zero.[3] On the other hand, the emerging global market differs in one important respect: part of what gives green and sustainable hydrogen its commercial value is its green property, the fact that it has been produced (near) carbon-free. This property needs to be monitored, verified, documented and tracked in a transparent and reliable way, in accordance with established and internationally agreed criteria. In this regard, the global market for green and sustainable hydrogen depends on regulation and oversight – as a politically created market, it shares some properties with other politically created markets, such as that for carbon offset credits.

At prices prior to the price shock unleashed by the Russian invasion of Ukraine, green hydrogen is still far more costly than conventional, fossil-based alternatives.[4] For green hydrogen to become cost-competitive requires not only increasing the cost of using fossil fuels through political instruments – but also bringing down the cost of green hydrogen. The good news is that there is scope for that to happen – as the costs of renewable power generation have been falling considerably over the last decades and the cost of green hydrogen infrastructure (e.g. electrolysers) is showing similar signs of cost degression. The not-so-good news is that this cost degression only comes with scale – the more capacity is built, the quicker costs decline. This scale can take the form of increased capacity per unit deployed – but more importantly through a rapid increase in the number of (standardised, modular and mass-produced) units. There are indications that China is about to repeat its success in driving down costs of clean technologies, this time with electrolysers that are reported to cost 75% less than Western equivalents (https://www.rechargenews.com/energy-transition/exclusive-chance-is-high-that-china-will-take-over-global-hydrogen-electrolyser-market-in-similar-way-to-solar-sector-bnef/2-1-1230106)

To achieve cost degression and rapid scaling, the hydrogen market will initially rely on long-term arrangements that reduce risks and drive down the cost of capital. Such arrangements have become all the more important due to the increased concern about security of supply in the wake of the current gas market situation. Long-term arrangements can take the form bilateral relationships / memoranda of understanding that mitigate supply and demand risk, and bringing down cost of capital via political risk guarantees. They can also take the form of long-term contracts in which buyers and suppliers commit for 10-20 years. At a later stage, elements of a competitive spot market may emerge – with suppliers competing on a single, global market on the basis of their marginal production costs, favouring those suppliers that can produce at least cost. In particular in the latter market structure it is vital that environmental and sustainability criteria are fulfilled, can be documented and traced.[5] One of the pitfalls is therefore

[3] According to the IEA (2021), in 2020 90 Mt H_2 were produced globally. Only a fraction of this was produced in a low-carbon way (less than 1% in total). According to the IEA, global production of renewable-based hydrogen will need to increase to at least 500 Mt globally to be consistent with climate neutrality scenarios.

[4] Based on 2020 prices, the IEA estimated the average cost of green hydrogen at 8 USD / kg, compared to an average cost of 2 USD / kg for blue and 1.7 USD / kg for grey hydrogen. With the increase in gas prices observed since then, this gap may have narrowed somewhat.

[5] Such a single, global market not only has the benefit of faster cost degression through competition, but also of ensuring greater security of supply than an alternative arrangement based on bilateral contracts and agreements (Piria et al. 2022).

to ensure that producers do *not* compete on sustainability standards (or how strictly they are adhered to), which could lead to a "race to the bottom" whereby laxer or less strictly enforced standards have a competitive advantage – but instead *only* on the basis of their production costs after having complied with agreed minimum standards.[6]

While this describes the global market for green and sustainable hydrogen in its end state, i.e. to be achieved possibly in the 2030s (Piria et al. 2022), the lead-up to this market could look quite different. The global hydrogen market at current faces a chicken-and-egg problem: demand will only scale if there is a reliable and affordable supply of green hydrogen – but this supply will only come about at the necessary scale if it is sure to meet sufficient demand (including demand that is prepared to pay the price differential for green and sustainable hydrogen (Grischgl, Pepe, and Westphal 2021). To overcome this situation, partnerships and agreements between buyer and supplier countries give the necessary certainty to investors and allow for economies of scale that come with investments into technology and infrastructure. Such partnerships and agreement do not need to cover the production capacity in its entirety – they could also serve to provide a stable foundation for investment planning, with additional production volumes traded flexibly, and the share of output covered by agreements declining over time. WTO rules permitting, this transition from a more regulated market based on bilateral partnerships to a more open, global market could also proceed at different speeds for different partner countries.

EU countries are likely to be net importers and account for a large share of expected global demand in the future market for green and sustainable hydrogen. This puts them in a position to shape the market by setting and defining a global standard for green hydrogen. As observed in other markets, the EU could use its economic leverage to set a commercial standard for EU imports that then becomes a de-facto global industry standard – either because other importers (out of their own accord or negotiated in a joint process) adopt similar standards, or simply because exporters find it too cumbersome and expensive to produce for multiple standards. To leverage the EU's market power as a main buyer of green hydrogen, cooperation between EU countries is needed. Yet as several major economies are also likely to end up as net importers for at least part of their demand (Japan, South Korea, possibly China for certain derivatives), the likelihood that the EU would dominate the market is limited (Hydrogen Council and McKinsey & Company 2021, 12). On the positive side, this means that a limited number of actors (EU, South Korea and Japan) account for the vast majority of demand, which would allow them – if they can agree to cooperate – to shape the terms of the market, including criteria and standards for the traded products (see following chapter).

Green hydrogen and derivatives are chemically and commercially perfect substitutes for their fossil counterparts. The green property of hydrogen and its derivatives therefore needs to be ascertained, documented, tracked in a robust and reliable way, that prevents fraud. Investors, buyers and sellers need the assurance that products accepted as green by one importer (according to agreed criteria) also need to be accepted as green by all others on the same market, and that the green property of the traded hydrogen cannot be cancelled retroactively. This points to a need not only for common criteria, but also agreed protocols and procedures to ascertain the green property and prevent fraud: where several countries join up to form a

[6] This does not preclude the option that the market could be segmented to include (niche) markets of producers offering hydrogen products that meet higher standards, and consumers prepared to pay extra – in a similar way as the "gold standard" carbon offset projects or certain fair-trade products.

common market for green and sustainable hydrogen, a ton of hydrogen accepted as green in one country would also need to qualify as green in another.[7]

4 Criteria for green and sustainable hydrogen

Domestic production of green hydrogen is unlikely to meet the projected future demand in Germany and the EU. Rather, large-scale imports of green hydrogen from countries with abundant potentials for low-cost renewable energy and land area can be expected. Such imports could help take advantage of these countries' favourable conditions and offer opportunities for sustainable development in exporting countries[8]. They might, however, also result in adverse ecological and social outcomes, as discussed below. Standards and procedures therefore need to be in place to guarantee that green hydrogen imports to Germany and the EU at least do no harm in producing countries and ideally contribute to their sustainable development. The following section discusses first what these criteria could consist of, and second the process through which criteria could be established.

4.1 Sustainability criteria for imported hydrogen and derivatives

4.1.1 Ecological

Ecological challenges resulting from the production and export of green hydrogen include the potential of delay of the energy transition, if renewable resources are prioritized for export instead of using them for the most effective domestic use. Green hydrogen production might also increase the risk of overusing or expropriating water and land, in particular when groups with weak formal land and water rights are affected (https://www.boell.de/sites/default/files/2022-05/Pastoralism-and-large-scale-REnewable-energy-and-green-hydrogen-projects.pdf). Further issues that need to be considered is the risk of hydrogen leakage and the effects of materials used for hydrolysers and the renewable energy sources that power them.

Energy systems

Green hydrogen production can boost the energy transition in exporting countries. Expanding renewables creates market opportunities that can counterbalance the political resistance of fossil-based industries that stand to lose from the transition, and hydrogen could be used in producing countries to e.g. stabilize the power grid or decarbonise some forms of transport. However, there is the danger that even hydrogen produced from 100% renewables could delay the transformation of the power grid in the producing country, as renewable resources are prioritised for export. This can be resolved if the renewable electricity used for hydrogen production is unambiguously "additional", i.e. would not have been installed in the absence of green hydrogen production. Yet documenting and ensuring this additionality is challenging. At the extreme, additionality would be guaranteed if hydrogen could only be traded if it was produced with renewable electricity from sources that are not connected to the power grid. Yet,

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[7] This represents a situation that can also be found e.g. with carbon offset credits in linked carbon markets – where credits accepted into one system are also valid in any other system, and where therefore both the criteria for credits and the procedures for enforcing them need to be equivalent in the linked systems.

[8] From a sustainable development perspective, climbing up the value chain of products produced on the basis of green hydrogen will be of paramount importance. This may conflict with the desire of EU industries to maintain production and jobs inside the EU.

such island solutions would be economically costly, and would run against the objective that hydrogen production ought to be aligned with national energy system transformation. A weaker option would allow renewable electricity from grid-connected sources provided that the carbon intensity of electricity (i.e. emissions per kWh) does not exceed a certain threshold. This could provide an incentive for countries to decarbonize their grid to become eligible to export hydrogen. Furthermore, the required carbon intensity could be adjusted dynamically over time to ensure that this incentive is maintained.

Water

Water use to supply the required hydrogen molecules (which are split from oxygen by electrolysis or thermochemical processes) is relatively limited and would probably only be a concern for very water scarce countries. In water-scarce regions, sea water would need to be desalinated. This offers the opportunity to establish additional desalination capacities, which could then be used to expand water access to the local population. If sea water desalination is used, the resulting sludge needs to be treated to prevent contamination.

Hence, sustainable, truly green, hydrogen will need to demonstrate that it does not exacerbate water stress. This requires tracking water use from the source through the entire production chain to the final product, i.e. the hydrogen. This is of particular importance if renewable power is generated by means of concentrated solar power, which is an order of magnitude more intense in terms of water use than electrolysis.

Land use

Renewable energies, such as solar power and wind, use extensive land areas. For some countries, land requirements are less problematic – such as Australia or Saudi-Arabia, which possess huge land areas that cannot be put to a different use. For land use a viable approach could be to exclude hydrogen produced in certain vulnerable areas, such as biodiversity hotspots or arable land. A second, related issue concerns land rights and ownership, especially where indigenous communities or marginalised groups are affected (discussed under social criteria below).

Hydrogen leakage

If hydrogen leaks into the atmosphere, it forms tropospheric ozone and increases the lifetime of methane, hence increasing climate forcing. Even though the extent of this effect is still unclear, it is important to address hydrogen leakage early on to prevent lock-in into a system that turns out to be harmful for the climate.

Due to lack of detailed knowledge, it seems advisable to include monitoring requirements for hydrogen leaks and a clear commitment to exclude any hydrogen imports that involve major leaks.

Resource use

Solar panels, wind turbines and electrolysers use materials, such as rare earths, that involve mining. Extractive industries have repeatedly been associated with environmental degradation and human rights violations.

Hence, hydrogen production should rely on materials that have been sourced under well-defined environmental and human rights standards for extractive activities. For instance, one could require that renewable energy sources and hydrolyser include a certain (high) minimum share of materials from countries that are signatories to the Extractive Industries Transparency Initiative.

4.1.2 Social

Social challenges related to hydrogen production most importantly relate to safeguarding human rights. But it is also important that hydrogen advances socio-economic development by creating domestic value and employment opportunities.

Human rights

Hydrogen production could affect human rights if people are forced to leave their place of residence or if it infringes on land areas that are of economic, cultural or religious significance, e.g. for sustaining the livelihoods of traditional communities. Areas with optimal wind and solar resources are often occupied with marginalised social groups with weak political clout and limited legal recourse (see https://www.boell.de/sites/default/files/2022-05/Pastoralism-and-large-scale-REnewable-energy-and-green-hydrogen-projects.pdf). Prior and informed consent by the affected communities can be regarded as indicating a project's integrity with human rights standards..

Socio-economic development

Extractive industries, such as mining and fossil fuels, create substantial profits but often fail to advance socio-economic development. In some cases, extractive industries have even been found to increase poverty and inequality. It is conceivable that production of green hydrogen, if badly managed, could face similar problems.

To assess the impact of hydrogen production on socio-economic development, it is insufficient to look at the job created in this industry. Rather, indicators such as the distribution of income and aggregate employment need to be considered. Furthermore, to ensure high-quality and well-paid employment is generated in the producing country, the necessary skills need to be developed among the domestic labour force.

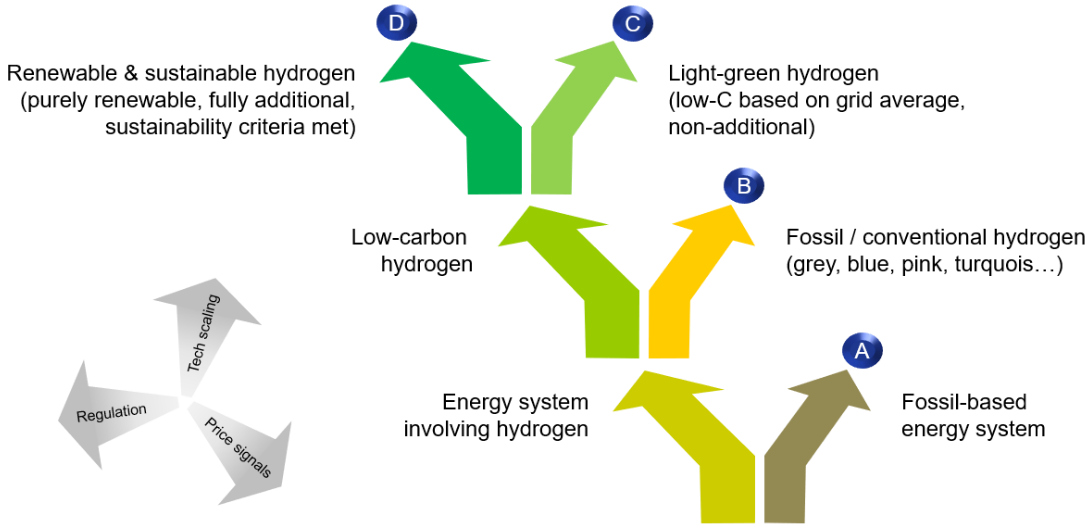
4.2 Defining criteria for green and sustainable hydrogen

As listed above, there are several conceivable criteria and standards to ascertain the green and sustainable nature of traded hydrogen (and derivatives), and these criteria and standards can be applied in a more or less rigorous way. To scale up production of green and sustainable hydrogen, the product needs to compete with alternatives – and this competition happens on different levels.

- At the outset, there is the competition between the current, fossil-based energy system and an alternative energy system involving hydrogen (be it green, blue, grey or whichever colour) – as the new elements in the energy system, they need to outcompete the incumbent fossil technologies.
- Second, at the level of hydrogen-based technologies, the renewable-based (green) hydrogen competes with hydrogen produced in other ways, involving fossil fuels (blue, grey, turquois) or nuclear (pink).
- Third, within the segment of renewable-based (green) hydrogen, standards that can be applied with greater or lower ambition – resulting in different shades of green, from deep green (purely renewable, fully additional, meeting all sustainability criteria) to lighter green (using lower-carbon electricity based e.g. on grid average, not necessarily additional, or compromising on sustainability criteria).

Competition occurs based on the costs of the different options – which are in turn influenced by different factors. Uncorrected price signals tend to favour the status quo. Regulation can change this equation and favour greener solutions – e.g. by pricing CO_2 emissions, but also by adjusting other cost components, such as taxes and levies applied to electricity. A further determinant of the cost of different options is the availability and the cost of infrastructure. Finally, and importantly, the costs of different alternatives are not fixed over time: particularly for a rapidly emerging field such as (green) hydrogen, they depend on the level of deployment – as scale increases, costs will (continue to) go down.

Figure 4: Competition and path dependencies in the hydrogen market



At the same time, there will not be an abrupt and immediate transition from the current energy system (A) to a fully green hydrogen system (D). Hydrogen solutions are more likely to first emerge as islands in the current energy system, anchored around industry clusters with high demand, and from there extend to more widespread applications (Grischgl, Pepe, and Westphal 2021). And in these island solutions, to ensure a reliable and uninterrupted supply, it may be necessary to also rely on non-green (or lighter-green) hydrogen varieties.

The transition from the current energy system to a future energy system with a substantial share of hydrogen will not proceed at equal pace, and with equal direction, in different world regions. Numerous countries have begun to invest into this future energy system – or declared their intention to do so – but have arrived at very different choices regarding the trade-offs involved at the various stages (hydrogen vs. fossil, renewable-based vs. conventional, light green vs. fully sustainable). Therefore, Germany and Europe also face global competition from other world regions in rolling out and shaping the emerging global hydrogen economy – and with significantly different preferences for how green the hydrogen should be.

A central problem in the transition is that current economic structures are not conducive to change, but rather to preserve the status quo, i.e. the fossil-based system. Regulation, infrastructure, and scale effects can help to break away from the current path dependency that favours the status quo (point A in the figure above) – but then avoid running into new path dependencies at a different level, which could favour light green or otherwise unsustainable varieties of hydrogen (points B or C). At the same time, more ambitious standards (more rigorously enforced) mean higher costs. This entails the risk that the intended scaling of technologies and cost degressions do not materialise and that instead of the green hydrogen revolution (point D), the status quo prevails, with green hydrogen remaining limited to a niche application.

One possible way out of this dilemma is to adopt a two-tier approach to hydrogen imports, consisting of a minimum ‘do-no-harm standard’ that ensures that hydrogen production has no adverse effects in producing countries, and a more ambitious 'gold standard' that accounts for additional sustainable development benefits. This gold standard could, for instance, be awarded to hydrogen if its production facilitates access to clean electricity or water for the local population or leads to additional job creation and local economic development. Hydrogen that conforms to such higher standards could also serve market segments with a higher ability to pay, such as public procurement or the voluntary market (similar to internal differentiation in the market for carbon offset credits).

A second possibility is to understand standards as dynamic, with ambition increasing over time and standards becoming more rigorous as technology and infrastructure evolve, and as costs decline with scale. The risk of such an approach is obvious, in that the medium- to long-term signal of increasing stringency might be insufficient to avoid a lock-in into unsustainable varieties of hydrogen production, and that pressure may result to relax or delay the announced tightening of standards.

5 Instruments to support green and sustainable hydrogen

Green, sustainable hydrogen – and the applications in which it is used –compete with conventional, typically fossil-based alternatives, but are currently still more expensive. As production volumes of green hydrogen increase, the associated economies of scale are expected to gradually close the price gap (and all the quicker if the price of fossil alternatives is increased). Economies of scale only materialise if the needed investments take place. Yet investments into installations that use green hydrogen – as well as associated infrastructure – is still considered too risky, unless a steady supply at cost-competitive rates can be ensured. To move beyond this chicken-and-egg situation – where demand will not grow if the supply is not there, and supply will not emerge if there is no demand – political guidance and assurances will be needed (Grischgl, Pepe, and Westphal 2021).

Fortunately, several instruments can help to overcome this conundrum. These include both unilateral instruments, bilateral instruments (applied in cooperation between producing and importing countries), and multilateral approaches. In addition, support instruments can be differentiated based on their intervention logic:

- **Close the price gap:** A number of instruments are available to elicit a higher price for green hydrogen, or to cover the price difference between green and conventional hydrogen. For instance, support via (publicly supported / controlled) lead markets for green and sustainable hydrogen (and derivatives) can elicit a price premium. Other options are public procurement (e.g. green steel in public construction projects) and labels for imported hydrogen and derivatives that comply with (higher) standards. Indirectly, green hydrogen could also benefit from support measures for renewable energy: For instance, only hydrogen that meets the requirements stated in the EU's Renewable Energy Directive could be counted for the achievement of the targets specified there. For this reason, financial support, i.e. in the form of revenue from tradable quota schemes, is restricted to hydrogen that meets these demanding criteria - regardless of whether it is imported or produced within the EU.
- **Ban fossil alternatives:** this includes market access restrictions for hydrogen and derivative products that fail to comply with (minimum) standards – banning imports of hydrogen that does not comply with meet the standards on the basis of EU supply

chain legislation or (soft) guidelines. Such access restrictions could also be implemented in the form of dynamic standards with increasing ambition. Concerns are commonly raised about lacking compatibility with WTO law, which sets demanding requirements to imposing barriers based on a products' production process. How well-founded these concerns are, however, remains to be investigated.[9] Alternatively, the import ban could also be implemented as a (domestic) phase-out obligation for non-green hydrogen and derivatives (be it imported or domestically produced), banning their sale and/or use after an announced phase-out date.

- **Create / guarantee demand:** Quotas and obligations for the use of green and sustainable hydrogen guarantee a fixed demand, and thus greater certainty for suppliers. Public procurement with the intention of creating lead markets for green hydrogen and derivatives could also be included in this category.

The following table provides an overview of the instrument types, their primary mode of application (unilateral, bilateral or multilateral) and examples of instruments. The instruments are presented and discussed in greater detail in the Annex.

Table 1: Instruments to support green and sustainable hydrogen

Mechanism	Instrument type	Application	Example of instruments
Close the price gap	Direct support for green H_2	Unilateral	Contracts-for-Difference (H2Global model)
	Premium for green H_2	Unilateral	Lead markets, public procurement Labels (Offset / Art 6 transfers?)
	Other advantages for green H_2	Unilateral	CBAM for H_2 & exemption for green H_2
Create demand	Mandatory use for green H_2	Unilateral	Green H_2 quotas / obligations / blending requirements…
Penalise alternatives	Market access restrictions for non-green H_2	Unilateral	Minimum standards for imported H_2 Announced phase-out / import ban for non-green H_2
Boost supply	Stimulate / de-risk green H_2 investment	Bilateral	Long-term contract, price and/or offtake guarantee Investment support (tax incentives, access to finance, export credit guarantees, private-public partnerships)

[9] A variation of this approach would be to include hydrogen imports in a border carbon adjustment measure, such as the CBAM proposed by the European Commission as part of its "Fit for 55" package. This would pose a considerable penalty on carbon emissions generated during the production of hydrogen. It could make grey hydrogen uncompetitive in the market and be less problematic from the perspective of trade law, as it ensures equal treatment of foreign and domestic producers and non-discrimination between different export countries. Yet, as this instrument only addresses carbon emissions, it would not be able to distinguish between renewable-based and other, less sustainable but low-carbon varieties of hydrogen (e.g. blue hydrogen using CCUS or pink hydrogen using nuclear power).

Secure supply	Secure long-term arrangements between supplier and buyer	Bilateral	Long-term contracts (incl. public guarantees) Bilateral partnerships, joint ventures Investments in transport infrastructure

The (non-exhaustive) list of instruments above focuses on instruments of public policy – possibly implemented jointly with private partners. In principle, several elements could also be promoted through private initiatives, such as voluntary guidelines for green H_2 as part of an industry-led initiative (supported and/or monitored by public authorities), or the adoption of voluntary commitments, standards and reporting procedures. This would be akin to existing voluntary initiatives (such as global compact, equator principles, voluntary carbon market principles, green bond principles.) and would suffer from the same restrictions and caveats.

The instruments above all aim to favour green or to penalise non-green hydrogen, to secure the supply or to de-risk and to promote investments. These instruments are not exclusive (i.e. they could also be applied in combination).While there is no silver bullet, there is one fundamental instrument which – in and of itself – does not encourage green and sustainable hydrogen, but nonetheless is crucial to any effort. Tracking and reporting systems for green and sustainable hydrogen (documented along the value chain if necessary) will be needed regardless of the instrument chosen. For any shipment of hydrogen (or derivatives) that enters the EU market, it will be necessary to ascertain its origin and its compliance with the applicable standards – including embedded emissions that originate during the production process.[10] Establishing such reporting processes and registries in a robust way will be key – starting with the identification of existing institutions to support them or setting up new ones. The establishment of such tracking and accounting systems is obviously closely related to the definition of criteria for green and sustainable hydrogen – and as such is central to defining the shape of the future market: Technical norms and standards define lead markets and technology pathways, and thereby also the chances of different suppliers to succeed in the market (Grischgl, Pepe, and Westphal 2021).

Detailed descriptions of selected instruments can be found in the Annex, grouped into instruments that are (primarily) applied unilaterally, bilaterally, or multilaterally. It also provides a qualitative assessment of these instruments in three different dimensions:[11]

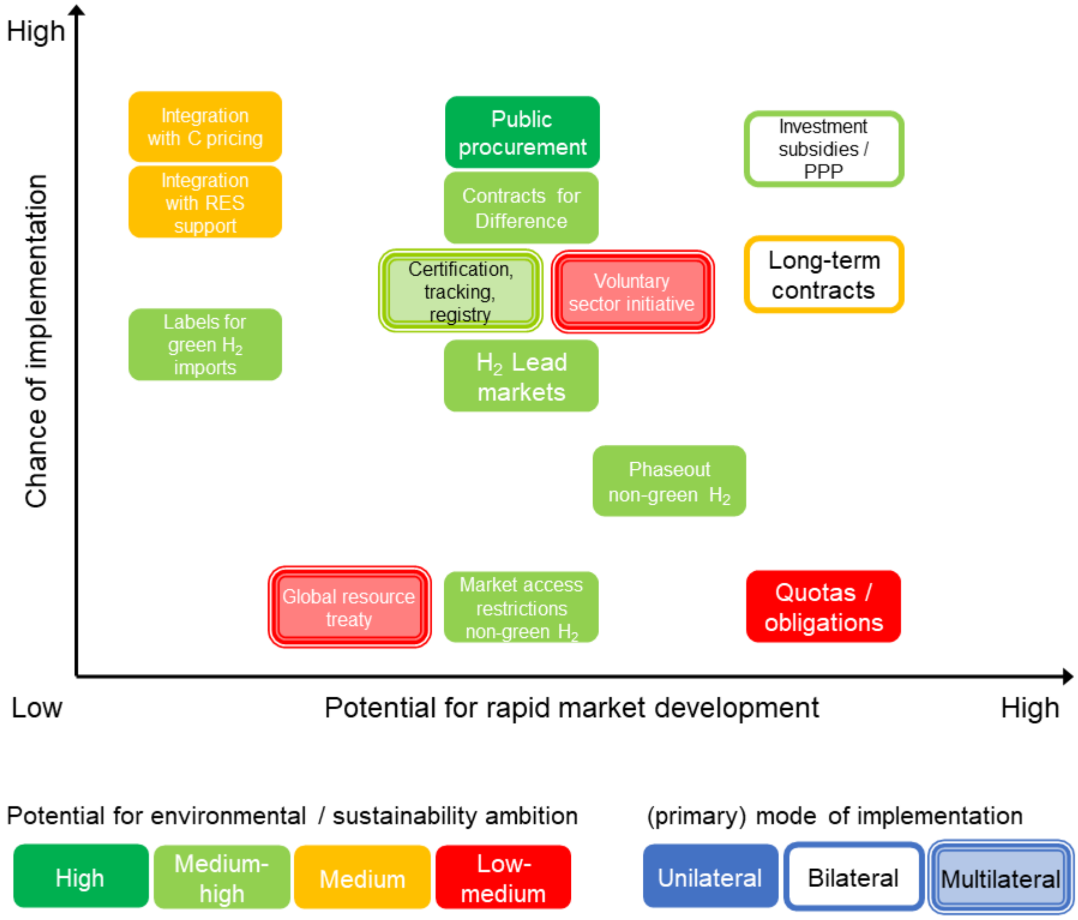
- **Chance of implementation:** What is the overall likelihood that this instrument could be agreed and implemented in a relevant timeframe (typically around 5-10 years)?
- **Potential impact for rapid market development:** What potential does this instrument hold to accelerate the development of a market for green and sustainable hydrogen and derivates, and to scale up the necessary investments?
- **Potential for anchoring ambitious environmental and sustainability criteria:** What potential does this instrument hold to establish stringent and ambitious environmental and sustainability criteria?

[10] This requirement has a parallel in another current policy discussion: for the establishment of a Carbon Border Adjustment Mechanism, comparable tracking and accounting structures will be necessary, if importers want to demonstrate the production emissions for shipments of covered products. Also in this instances, comprehensive structures and processes will be needed to document process emissions in a transparent and verifiable way.

[11] The assessment is qualitative, on a scale from low-medium-high, and obviously depends on how existing risks can be mitigated in the design and implementation of the instrument. It benefited from inputs by various German stakeholders, received at an online workshop held on 18 March 2022.

Figure 5 below gives an overview of selected instruments, based on these criteria.

Figure 5: Overview of instruments to promote green and sustainable hydrogen



6 Options for an international hydrogen governance

As the international market for green and sustainable hydrogen is beginning to emerge, an opportunity arises to shape this market in a positive way – and to avoid some of the manifold well-known problems of markets for fossil energy resources, with typically have benefited only few, and resulted in unhealthy concentrations of economic and political power. For the emerging market for green and sustainable hydrogen, this will look differently: Since renewable resources are spread out much more evenly across world regions (IRENA 2022), concentration of economic and political power might be less of an issue than it is for fossil resources. While many world regions are assessing their potential to become significant producers, and are taking steps into this direction, it is not clear who will be winning in this market: success depends not only on abundant, cheap and readily available renewable resources from wind, solar, hydro or geothermal, but also on the capacity to exploit these resources, to attract investment, to roll out the necessary infrastructure, and to bring green hydrogen (or derivatives) to the market at competitive rates.

In this politically created market, lowering cost of green and sustainable hydrogen is important to enable scaling-up of hydrogen-based solutions. Success in the market cannot be only a matter of sourcing at lowest cost. Instead, international hydrogen governance needs to ensure from the outset that the emerging market is geared to also deliver social and environmental benefits, and ends up more open, transparent, participatory, inclusive and democratic than current energy markets.

As there is no international market for green hydrogen yet, there are also no governance mechanisms for this market. Instead, there is a proliferation of bilateral agreements that bring together (future) suppliers of green hydrogen with (future) importers. With fewer parties involved, bilateral agreements give countries more flexibility to agree on minimum standards that should apply to the production of traded hydrogen. Bilateral partnerships are also more likely to lead to arrangements built around the interests of both sides commensurate with countries' national strategies.

Yet a flurry of bilateral partnerships does not necessarily pave the way to a well-functioning international market. Three aspects in particular are problematic:

- A proliferation of bilateral agreements should not lead to a **proliferation of standards**. Besides reducing overall transparency, this would also create the risk of cherry-picking or a "race to the bottom" – if one country considers that the standards proposed by its trading partner are too strict, the hydrogen is sold elsewhere.
- Besides, a proliferation of diverging standards is bound to create problems where **internationally integrated value chains** are concerned, e.g. if green hydrogen sourced from different countries is used to produce low-carbon steel, which is then sold on (and marketed as low-carbon). If the hydrogen used in steel-making comes in different shades of green, this would mean different batches of steel produced would have diverging carbon footprints, making it yet more difficult to track, label and market them.
- Finally, bilateral agreements could lead to a **fragmentation of the market** – different standards would suggest diverging prices for green hydrogen and its derivatives if they come in different shades of green. Smaller markets would incur a greater price volatility, and prevent diversification, so that importers remain dependent on producers that meet the agreed standards, and vice versa).

Thus, the current situation with a growing number of bilateral partnerships is not necessarily conducive to the end goal of a single, global, unified market for green and sustainable hydrogen. To establish such a market, and to ensure its proper function, several elements must be in place:

1. A **tracking and accounting system** for green hydrogen and its derivatives to document their green property. This could take the form of a hydrogen registry of sorts, documenting the origin of the traded hydrogen (or derivatives) and its embedded emissions.
2. **Standards** for green and sustainable hydrogen (see chapter 4.1).
3. **Oversight and grievance mechanisms** to ensure compliance with said standards and to specify a course of action / remedy in case of non-compliance.
4. Arrangements for the **actual trading** (which commodity is being traded on which platform under which conditions, which financial products apply, how are trades cleared).
5. **Assurances / guarantees to investors** regarding the conditions under which they can market the hydrogen produced in projected investments.

In principle, these elements can be arranged at different levels:

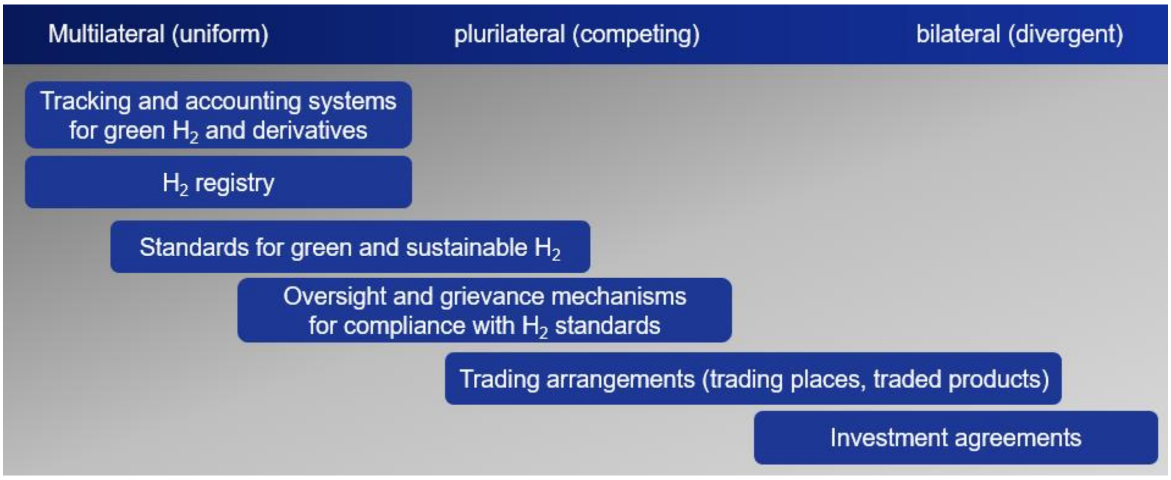
- At the **bilateral** level – in cooperation between two countries (typically one prospective supplier and one prospective importer).
- At the **plurilateral** level – agreed between a limited group of like-minded countries with shared interests. This could be the EU (possibly with partners), but also initiatives out of the G7/G20 orbit such as the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE).
- As a genuine **multilateral** initiative, that is (in principle) open to any country, and applicable to any country that is a member of the initiative.

Clearly, action at these different levels has its pros and cons: the more partners are involved (with diverging views and interests), the harder it will be to reach agreement. At the same time, the more parties involved, the more authoritative the outcome. Plurilateral initiatives promise to operate at the "sweet spot" where both come together: small enough to avoid protected negotiations between a large set of partners with diverging (or opposed) interests – but also large enough to have an impact, and potentially even establish a de-facto standard (that could eventually be taken up by a multilateral initiative).

For the elements of a common market described above, these pros and cons play out quite differently (See Figure 6).

- For some elements, it is strongly preferable to have a **multilateral uniform approach** –, since it would be highly inefficient to have multiple parallel solutions. This applies above all to a common tracking and accounting system – but to some extent also to standards for green and sustainable hydrogen (and derivatives).
- For other elements, **plurilateral initiatives** and partnership of selected, like-minded countries are conceivable, even if this entails that there may be parallel, competing solutions. This could be an approach for standards if uniform standards for green and sustainable hydrogen turn out to be not attainable, or only at the cost of diluting the standards. It would also be an option for oversight and verification mechanisms to ascertain compliance of individual producers with the standards. Finally, plurilateral arrangements would be an option for the actual trading infrastructure: having numerous competing trading places is common in other commodity markets and would be conceivable also for trading of green hydrogen (and derivatives).
- Finally, some elements can be addressed efficiently through **bilateral partnerships** (but can also be extend to plurilateral initiatives). This applies for instance to investment agreements through which countries cooperate on specific investment projects for green hydrogen production and transport infrastructure.

Figure 6: Elements of a governance for green and sustainable hydrogen



At the same time, a gradual progression is possible from the current, mostly bilateral, towards plurilateral and ultimately multilateral solutions. For instance, the EU accounts for a sizeable share of the projected hydrogen demand. Possibly in collaboration with G7 and/or G20 partners, the EU would be in a favourable position to establish a lead market for green and sustainable hydrogen. By moving quickly and getting further partners on board, such a plurilateral approach may establish a de-facto standard that is then adopted elsewhere and paves the way to a multilateral outcome (the "Brussels effect"). This is evident for standards for green and sustainable hydrogen. Harmonised standards are important for a "thick" global hydrogen market in which producers have the choice to export to different destinations, and importers can choose between different suppliers. Defining common standards for main importers, e.g. in the G7, can help establish such a market.[12]

7 Political options for Germany

There are different options for Germany to accelerate the development of a global market for green and sustainable hydrogen, and to influence this process towards greater integrity and higher ambition.

7.1.1 Bilateral: Strengthening alliances for green and sustainable hydrogen

Alliances between supplier and buyer countries, involving the private sector and civil society, can play important roles to de-risk the transition to green hydrogen for both sides: they can pave the way for longer-term contracts including price guarantees, investment support (and investment protection), technology transfer or direct financial assistance. Such alliances offer the potential for closer coordination between (potential) importers and exporters. This is crucial to ensure that criteria for the traded hydrogen are formulated in ways that conform with development priorities and capacities in producing countries and align with their national strategies for energy transition.

[12] It is not a foregone conclusion, however, that the EU or the G7 will have the economic and geopolitical leverage to establish what will eventually become a de-facto global standard: while there are benefits from cooperation, there are also obvious national and regional interests. Not least, hydrogen also features in existing geopolitical initiatives such as China's Belt and Road initiative, and may thus also become part of the competition between different economic systems (Grischgl, Pepe, and Westphal 2021)

Germany maintains bilateral climate and energy partnerships with key countries, ranging from Chile to India and from Namibia to Australia. Most of these partnerships also include cooperation on green and sustainable hydrogen. These existing energy partnerships could form a basis to cooperate with potential exporters in developing standards for hydrogen, combined with support for local hydrogen projects and long-term trade arrangements.

A crucial part of these bilateral partnerships is to define how green hydrogen investments can be part of a broader transformation strategy of the energy and industrial sectors in the partner countries. This could include investments into subsequent stages of hydrogen-based value chains, such as the production of ammonia or sponge iron, as well as building up local ancillary industries to realise a greater economic and employment benefit from deeper economic integration.

Strengthening partnerships may also involve the combination of existing bilateral partnerships to form "minilateral" initiatives combining different partners, e.g. as a cooperation of Germany with its Benelux neighbours, who are already closely connected through their gas infrastructure – or (eventually) under the coordination of the EU. Bringing in more partners allows pooling resources, and by putting the cooperation on a broader footing can help to increase (transformative) ambition: the Just Energy Transition Partnerships between several G7 countries and South Africa (concluded 2021) as well as Indonesia (2022) may serve as an examples in this regard, which could also be applied to other countries. Likewise, existing support instruments such as the German H2Global initiative could be extended to also include other countries, thereby coordinating and consolidating demand, and using the resulting economic leverage.

Finally, as another form of an extended bilateral approach, trade and investment agreements could be used to anchor standards for green and sustainable hydrogen. As an exclusive competence of the EU, these are negotiated between the EU and the respective trade partner(s). Since such agreements include chapters addressing sustainable development, including references to existing standards for green and sustainable hydrogen would provide a simple yet effective way of anchoring such standards in bilateral trade.

7.1.2 Plurilateral: Climate Club for cooperation on green and sustainable hydrogen

A plurilateral initiative on green hydrogen could see the EU taking action together with other countries from the ranks of the G20 (such as Australia, Canada, Japan, Mexico, South Korea and the US), but also with other partners beyond the G20 such as Chile, New Zealand, Norway or Switzerland. Elements of this initiative could include a joint agreement on ambitious standards for green and sustainable hydrogen, and a joint tracking and reporting system for green and sustainable hydrogen.[13]

With its initiative for a "Climate Club" to be formally launched before the end of 2022, the German G7 presidency has put forward a (mostly empty) shell that now needs to be filled with content. As some of the original intentions (e.g. a Climate Club based around a shared, uniform carbon price) have proven unattainable, a more focused approach seems promising.

[13] It needs to be stressed, however, that these countries and their hydrogen strategies are not necessarily aligned, with considerable differences e.g. regarding the use of nuclear power for hydrogen production (pink hydrogen) or the production of hydrogen from natural gas in combination with CCUS (blue hydrogen). Forging an alliance in support of ambitious standards for green and sustainable hydrogen will therefore require quite some diplomatic effort. Existing networks in this policy area -such as the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) focus above all on dialogue and knowledge sharing, and are not active in the field of setting standards or other forms of regulatory cooperation (Cames and Böttcher 2021).

Structuring a Climate Club around cooperation on green and sustainable hydrogen would deliver this and could incorporate elements such as the G7 Hydrogen Action Plan.

In this interpretation of the climate club, cooperation on green hydrogen would be a central element of the club. Beyond agreeing on joint standards, this could also include the option of forming a common market with shared access – where hydrogen (and derivatives) recognised as green in one market would also be regarded as such by the other club members. That would mean that the Club would indeed be constructed around a common club good: access to the common market for green H_2, mutual recognition of standards and the procedures to ascertain them (certification of green hydrogen), as well as related protocols (e.g. grievance mechanism, review). In the future, the club could also extend its activities to joint procurement, or mechanisms to coordinate procurement of green and sustainable hydrogen as a way of increasing security of supply.

A fundamental choice for any plurilateral initiative regards its membership. Two distinctions in this regard play a role here:

- First, whether an initiative should include only importers, or also future exporters of green and sustainable hydrogen? Here, the promise is that already with relatively small membership, an initiative that involves for instance the EU, Japan and South Korea would already account for a significant share of expected import demand and would thus be in a good position to establish standards for green and sustainable hydrogen. At the same time, by engaging with potential future exporters that are open to green and sustainable production processes, a small engagement could go a long way to establishing sufficient supply, and to provide an example of the co-benefits of establishing a green and sustainable domestic hydrogen economy.
- A second, how narrowly the initiative should be constrained to like-minded countries with shared and similar interests (and higher ambitions) – or whether it should also seek to include more difficult, but crucial partners, such as resource-rich countries whose economy is currently built around fossil exports? A smaller group of like-minded, ambitious countries with shared interest is more likely to arrive at results relatively quickly – this group could engage more reluctant countries through dedicated bilateral or minilateral partnerships.

7.1.3 Multilateral: New initiatives and institutions for global trade in green hydrogen

The “Climate Club” option described above should be inclusive to pave the way for multilateral agreement. At the same time, there are also other routes towards multilateral agreement on core parameters (such as a tracking and accounting system for green and sustainable hydrogen and derived products, or possibly agreement on global standards for green and sustainable hydrogen. These include:

- Extending the mandate of an existing initiative and equipping it with the necessary resources, such as the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)). This initiative stemming from the G20 includes 21 countries and the EU, but lacks members from some important world regions, e.g. the Middle East or Africa (other than South Africa).
- Tasking an existing intergovernmental organisation to establish the standards and infrastructure for a future green hydrogen market. Obvious candidates would be the IEA, or IRENA.
- As a long-run objective, the framework for a future global market for green and sustainable hydrogen could be laid out in a dedicated international agreement, analogous to the resource treaties that exist for numerous agricultural products (e.g.

cocoa, olive oil, sugar, tropical timber) or the study groups for natural resources (e.g. tin, copper), which are tasked with promoting markets transparency and proposing standards and procedures where needed.

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Annex: Descriptions of Instruments

Unilateral: Instruments to close the price gap

The following sections describe unilateral instruments from the perspective of an importing country (Germany or, where applicable, the EU). Such instruments can (and should) be extended to become part of bilateral agreements or partnerships and accommodated by communication and cooperation – but they are primarily designed and implemented from the perspective of the importing / buyer country, shaping the market by stimulating domestic demand and trying to incentivising (domestic and foreign) investments into the desired direction.

Instrument	Lead markets for green and sustainable hydrogen (and derivatives)
Functional mechanism	Public support for and control of lead markets, in which green and sustainable H_2 (and derivatives) elicit a price premium above conventional alternatives. Requires robust and transparent certification to avoid fraud, which would undermine trust and confidence in the lead market.
Mode of implementation	Primarily **unilateral** (certification of green H2 and derivatives requires bi- or multilateral agreement); implementation at EU level preferably to pure national implementation
Chance of implementation	**Medium** – private-initiative lead markets for steel based on green H_2 already emerging; other market segments more questionable
Potential impact for rapid market development	**Medium** – conceivably lead market will remain constrained to a niche, unless supported by other demand creation (public procurement, quota)
Potential for anchoring ambitious environmental and sustainability criteria	**Medium–high** – but with a trade-off between rapid scaling of the lead market and ambitious standards

Instrument	Public procurement for green H_2 and derivatives / products produced using green H_2
Functional mechanism	Commitment to only procure products that were produced using green H_2 (e.g. green steel in public construction projects).
Mode of implementation	Primarily **unilateral** (certification of green H2 and derivatives requires bi- or multilateral agreement); possibly also at EU level or with selected partners (e.g. G7)
Chance of implementation	**Medium/high** – can build on existing commitments for green public procurement e.g. in the context of G7
Potential impact for rapid market development	**Medium** – can guarantee stable demand relatively quickly in certain technology lines and applications (Hydrogen DRI

	steelmaking, freight transport), but more limited in other fields of application where the public is not a large source of demand (e.g. fertilisers).
Potential for anchoring ambitious environmental and sustainability criteria	**High** – standards defined by the government(s) that fund the procurement, flexibility to set high(er) standards and create a market for them.

Instrument	**Contracts for Difference (H_2Global model)**
Functional mechanism	Targeted payment in the form of a contract-for-difference that covers the price gap between green and conventional H2, matching sources of demand and of supply of green H2. Guarantees a price that allows investors to invest, while also remaining competitive with conventional H_2.
Mode of implementation	**Unilateral**, but with the possibility to expand to other partners.
Chance of implementation	**High** – model is being implemented as a pilot in Germany, could be extended to include other (private and public) partners
Potential impact for rapid market development	**Medium** – can be effective in closing the price gap, but limited to bilaterally agreed transactions
Potential for anchoring ambitious environmental and sustainability criteria	**Medium/high** – standards defined by the actor who funds and implements the mechanism.

Instrument	**Labels for imported hydrogen and derivatives that comply with (higher) standards.**
Functional mechanism	Certification and labelling for imported H2 and derivatives that comply with (higher) standards for climate, sustainability and environmental impacts, eliciting a higher price for such products, or granting them access to restricted markets (lead markets, public procurement).
Mode of implementation	**Unilateral**, but preferably pluri- or multilateral for enhanced impact
Chance of implementation	**Medium/high** – if agreement can be reached on the applicable standards and their (reliable) measurement and documentation
Potential impact for rapid market development	**Low** – only effective if there is demand and willingness to pay. Unless supported by other demand creation (public procurement, quotas), such demand will likely remain constrained to a niche
Potential for anchoring ambitious environmental and sustainability criteria	**Medium/high,** if targeted at higher end of the spectrum in terms of ambition of standards – also possibly in response to other less ambitious standards.

Instrument	Integration of green H_2 with renewable support measures
Functional mechanism	Green hydrogen could indirectly benefit from support measures for renewable energy: For instance, only hydrogen that meets the requirements stated in the EU's Renewable Energy Directive can be counted for the achievement of the targets specified there.
Mode of implementation	**Unilateral** (at EU level, hardly feasible at national level)
Chance of implementation	**Medium/high** (analogous to comparable regulations for biofuels)
Potential impact for rapid market development	**Low** – level of support that can realistically be expected likely to be insufficient to close the price gap between conventional and green H_2
Potential for anchoring ambitious environmental and sustainability criteria	**Medium** – high standards are feasible in principle, yet given the limited expectations regarding the level of support, are unlikely to emerge.

Instrument	Integration of green H_2 with carbon pricing measures
Functional mechanism	Green hydrogen and derivatives, as well as low-carbon products produced with green H_2, could benefit from exemptions under carbon pricing measures. Beyond the treatment in the EU ETS itself, this also applies to related instruments such as the Carbon Border Adjustment Mechanism.
Mode of implementation	**Unilateral** (at EU level, hardly feasible at national level)
Chance of implementation	**Medium/high** (analogous to comparable regulations for biofuels)
Potential impact for rapid market development	**Low** – level of support that can realistically be expected likely to be insufficient to close the price gap between conventional and green H_2
Potential for anchoring ambitious environmental and sustainability criteria	**Medium** – high standards are feasible in principle, yet given the limited expectations regarding the level of support, are unlikely to emerge.

Unilateral: Instruments to create (domestic) demand

Instrument	Quotas / obligations / blending requirements for green H_2
Functional mechanism	Green H_2 quotas / obligations / blending requirements for the use of green and sustainable hydrogen and derivatives guarantee a fixed demand, and thus provide greater certainty for suppliers to invest into production and transport infrastructure.
Mode of implementation	**Unilateral** (more effective if implemented at EU level, also less complex to administer in a single market, but also possible nationally)
Chance of implementation	**Low** – economic viability questionable if green hydrogen and derivatives are not used in a targeted way, but merely blended with conventional alternatives
Potential impact for rapid market development	**Medium/high** (dependent on the level of the quota that can be agreed)
Potential for anchoring ambitious environmental and sustainability criteria	**Low/medium** – for use of quotas, needs to be ensured that sufficient supply is available that conforms with given standard; high risk to compromise on the side of lower standards

Unilateral: Instruments to ban fossil alternatives

Instrument	Market access restrictions for non-green H_2
Functional mechanism	Ban on imports of hydrogen and derivative products that fail to comply with (minimum) standards – on the basis of EU supply chain legislation or (soft) guidelines. Such access restrictions could also be implemented as dynamic standards with increasing ambition / tightening standards.
Mode of implementation	**Unilateral** (at EU level, not feasible at national level)
Chance of implementation	**Low** – inter alia concerns about WTO conformity, administrative effort, risk of alienating trading partners. More likely to happen as part of a CBAM than outright ban (see above)
Potential impact for rapid market development	**Medium** – would not directly support capacity expansion for green and sustainable hydrogen, but only indirectly and gradually reduce viability of non-green alternatives.
Potential for anchoring ambitious environmental and sustainability criteria	**Medium/high** – to argue for WTO compatibility, environmental benefit of the measure would have to be clearly demonstrable, which suggests more ambitious standards

Instrument	Phase-out date for non-green H_2 imports
Functional mechanism	Announced end date for imports of non-green varieties of hydrogen and derivative products. This could also take effect as the end state of a dynamic standards with increasing ambition / tightening standards.
Mode of implementation	**Unilateral** (at EU level, not feasible at national level)
Chance of implementation	**Low/medium** – less problematic in terms of WTO law, if applied also to domestically produced hydrogen, likewise for the risk of alienating trading partners. Administrative and legal viability unclear, no direct precedent.
Potential impact for rapid market development	**Medium/high** – would not directly support capacity expansion for green and sustainable hydrogen, but (ideally) send a clear signal about that non-green alternatives are not viable.
Potential for anchoring ambitious environmental and sustainability criteria	**Medium/high** – to argue for WTO compatibility, environmental benefit of the measure would have to be clearly demonstrable, which suggests more ambitious standards

Bilateral: Instruments to secure supply and de-risk H_2 investments

Instrument	Long-term contracts (incl. public guarantees)
Functional mechanism	Bilateral energy partnerships including long-term contractual arrangement between supplier and buyer countries as a way to de-risk investments for both sides, possibly supported by public guarantee for investors, export credits or similar instruments.
Mode of implementation	**Bilateral** between supplier and purchasing country
Chance of implementation	**Medium/high** – common and established mode of cooperation in energy markets, strong mutual interest to enter such agreements.
Potential impact for rapid market development	**Medium/high** – instrument directly targets investments into infrastructure and capacities for green and sustainable hydrogen.
Potential for anchoring ambitious environmental and sustainability criteria	**Medium** – criteria need to be agreed by both sides, trade-off between rapid development of the market (and associated investments) and environmental ambition is evident.

Instrument	Investment subsidies / public-private-partnerships
Functional mechanism	Public support for investments in infrastructure and logistics, possibly in the form of public-private partnerships or joint-ventures including funding agencies from the buyer and supplier countries, including risk-sharing arrangements between public and private investors / funders.
Mode of implementation	**Bilateral** between supplier and purchasing country
Chance of implementation	**High** – established format for energy sector investments, strong mutual interest in rolling out the investment.
Potential impact for rapid market development	**Medium/high** – instrument directly targets investments into infrastructure and capacities for green and sustainable hydrogen.
Potential for anchoring ambitious environmental and sustainability criteria	**Medium/high** – trade-off between rapid roll-out and environmental ambition exists, criteria need to be agreed by both sides, but more potential for the buyer country (as an important funder) with more leverage to anchor ambitious criteria.

Multilateral: Instruments and initiatives to govern the market for green and sustainable H_2

Contrary to the instruments previously listed (unilateral and bilateral), multilateral instruments are less about directly driving or incentivising the deployment of green hydrogen technologies and associated infrastructure, but more about the process, laying the foundations, defining the political and legal framework in which other instruments can operate.

Instrument	Certification, tracking, registry
Functional mechanism	Tracking and reporting systems for green and sustainable hydrogen and derivatives (documented along the value chain if necessary), e.g. in the form of an international registry. Function is to ascertain the origin of hydrogen shipped to the EU and its compliance with the applicable standards – including embedded emissions during the production process.
Mode of implementation	At least plurilateral (starting with a sufficient group of like-minded countries that should be broader than EU / G7), at best multilateral / universal
Chance of implementation	**Medium/high** – common and shared interest to have such a registry, administrative implementation unclear (including which existing / new institutions best placed to support).
Potential impact for rapid market development	**Medium** – not an instrument to directly promote green hydrogen production but rather the basis without which many other conceivable policy instruments could not work.
Potential for anchoring ambitious environmental and sustainability criteria	**Medium/high** – if starting with a plurilateral group of like-minded (buyer and supplier) countries, more risk of diluted criteria for a genuine multilateral initiative.

Instrument	Global resource treaty
Functional mechanism	Similar to existing resource treaties / agreements for many internationally traded commodities and resources (copper, tin etc.), a global resource treaty / agreement on green and sustainable hydrogen could define properties and anchor standards of traded green H2, establish procedural elements (such as certification and tracking, compliance and sanctions) and designate supporting institutions and their roles.
Mode of implementation	**Multilateral** (ideally universal, including all major producers, current and future)
Chance of implementation	**Low** - As a genuine multilateral initiative, a resource treaty would need to cover all major producers (not only like-minded ones), setting the bar very high to reach agreement

Potential impact for rapid market development	**Low/medium** – need to include many actors suggests long and drawn-out negotiations, include concrete support elements would not be the function of such a treaty
Potential for anchoring ambitious environmental and sustainability criteria	**Low/medium** – need to include many actors lowers the prospect of agreeing on ambitious criteria

Instrument	Voluntary sector initiative
Functional mechanism	As a non-binding and narrower alternative to a global resource treaty, a voluntary initiative comprised of public regulators, private companies and civil society could agree on standards for green and sustainable hydrogen. Similar to existing initiatives (Equator principles, World Commission on Dams), such an initiative could establish a de-facto standard.
Mode of implementation	Multilateral, including public as well as private actors and civil society; should achieve broad coverage but does not need to include all major actors.
Chance of implementation	**Medium/high** – when starting with like-minded group
Potential impact for rapid market development	**Medium** – depending on the composition of actors involved; initiative would likely not include concrete elements to support expansion of green hydrogen capacities and infrastructure, but rather provide the basis for doing so.
Potential for anchoring ambitious environmental and sustainability criteria	**Low/medium** – trade-off between higher ambition and likelihood of securing a broad agreement, conflict of interest particularly for private parties between high standards and reliable and cost-competitive hydrogen.

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