The Market Ramp-Up of Renewable Hydrogen and its Derivatives - the Role of H2Global

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1. Introduction

Europe needs clean hydrogen[1] and its derivates to meet the climate goals. While the EU is the region with most research on renewable hydrogen and most hydrogen-related patents registered (EPO IEA, 2023), the implementation of clean hydrogen and its derivatives, mostly via Power-to-X[2], is advancing very slowly. The uncertainty regarding the regulatory framework for renewable hydrogen projects in Europe remains high, while the introduction of the Inflation Reduction Act (IRA) in the US has led to multiple announcements of renewable hydrogen projects and investments into electrolyzer production capacity. Europe is losing the position as a frontrunner in the emerging global renewable hydrogen market: In the last six months, the European share of global early stage electrolyzer projects has fallen from 63% to 56% based on the projected electrolysis capacity, and the US is expected to overtake Europe by 2024 (Aurora Energy Research, 2023).

The key questions of this paper are:

- How can the gap between European policy goals for renewable hydrogen and the status of the market be closed?
- Which framework conditions are necessary for the private sector to realize the investments required for a market ramp-up?
- How can public funding support the development of this framework?
- How do the necessary public subsidies decrease as fast as possible?
- How can the H2Global instrument contribute to the market ramp-up for clean hydrogen in Europe and worldwide?

[1] There are several methods for generating 'clean hydrogen'. The most important methods will likely be renewable (i.e. 'green') hydrogen (via electrolysis using renewable electricity) and 'blue' hydrogen (via the conventional Steam Methane Reforming or Autothermal Reforming route but including Carbon Capture and Storage or Carbon Capture and Usage (CCS/CCU)). 'Blue' hydrogen may imply low CO_2 emissions depending on configuration and operation of the plants (see Schippert et al. 2023), in which case it may be considered as 'clean'. This, for example, is the approach taken in the context of the US Inflation Reduction Act (IRA). For US regulation connecting the classification of 'blue' hydrogen to its CO_2-footprint, see Title 42 U.S. Code § 16152 and § 16166, as well as the U.S. National Clean Hydrogen Strategy and Roadmap (2023). In the European Union, 'blue' hydrogen will likely also play a role, but clear criteria are still to be specified. In this paper, the focus is on the role of H2Global for the ramp-up of renewable hydrogen.

[2] Hydrogen derivatives are gaseous or liquid molecules that can be synthesized from hydrogen and another reactant such as carbon dioxide or nitrogen. Examples of hydrogen derivatives include methane, ammonia, methanol, kerosene, naphtha, and diesel. The term Power-to-X (PtX) 'describes the conversion and storage of electrical energy into an energy carrier (gas, fuel or raw material) or a product (basic material, feedstock). It is a collective term for Power-to-Gas, Power-to-Liquid, Power-to-Fuel, Power-to-Chemicals and Power-to-Product' (Sterner, Specht, 2021).

Box 1: The H2Global instrument – briefly explained

H2Global is a competition-based instrument to promote a timely and effective ramp-up of the renewable hydrogen and hydrogen derivatives market towards an industrial scale. To achieve this, H2Global sets up a physical intermediary (the Hydrogen Intermediary Company, hereafter Hintco) between the supply side and the demand side. Hintco concludes long-term purchase contracts with producers of hydrogen (derivatives) and sells the products via short term contracts to offtakers. Doing so, the instrument provides immediate investment security to producers by furnishing price, volume, and legal certainty through long-term offtake agreements, allowing projects to move from planning stage to actual implementation. On the demand-side, H2Global reveals price data, enabling the emergence of a transparent and liquid hydrogen market. H2Global thus constitutes a 'double-auction scheme', which awards contracts on both the supply and the demand side, via competitive auctions. At the end of this competitive bidding process, producers offering the lowest bid and offtakers offering the highest bid are awarded. Given the still relatively high production costs for renewable hydrogen and the fact that the market price for fossil-based 'grey' hydrogen is significantly lower, there will be a price gap between supply and demand prices. This 'cost of difference' will be compensated by Hintco utilizing funds provided by a public (or philanthropic) funding body. The short duration of hydrogen sales contracts will lead to signals of any changes in market prices for renewable hydrogen (i.e. rising prices due to an increase in demand over time), which makes H2Global an efficient and dynamic instrument when it comes to the use of available (public) resources. In addition, due to contract design on the producer side, Hintco will only draw on public funding once the physical delivery of the hydrogen takes place, ruling out any risk of subsidizing a 'stranded asset'.

H2Global is being implemented through a scalable 'funding window' approach. The instrument itself is flexible and for each 'H2Global window' the respective funding body can define its own criteria in the grant decision ('Zuwendungsbescheid'), e.g., the products to be procured, the geographical regions to be targeted and the sustainability criteria to be applied. This allows to serve different goals the funding body aims to achieve, such as purchase price minimization/volume maximization, diversification of supply origin, technology promotion, fostering imports or regional/domestic production, etc. (H2Global Foundation, 2022). The first funding window with a volume of EUR 900 million is financed by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) and serves as a global auction (production outside of the EU and EFTA, offtake within the EU). Following a market analysis (Sterner et al, 2021), BMWK determined that the Power-to-X products renewable ammonia, renewable methanol, and electricity-based Sustainable Aviation Fuel (eSAF) shall be procured by H2Global in this funding window.

2. Gap analysis

Germany and the EU are facing a several-layered challenge where an anticipated increasing demand for hydrogen is met by limited hydrogen production capacities and renewable energy capacities both, domestically and abroad.

Demand

The demand for clean hydrogen and hydrogen derivatives is expected to experience a significant surge in the coming years. Numerous studies indicate that in Germany alone the additional demand for renewable hydrogen, including the demand for the production of derivatives, reaches 56 to 93 TWh in 2030 (NWR, 2023). Currently, around 55 TWh fossil-based, 'grey' hydrogen are produced and consumed in Germany (BMWi, 2020). The fossil hydrogen volume will decrease and partly be substituted by renewable hydrogen until 2030. This might further increase the German demand for renewable hydrogen. Beyond 2030, the total German hydrogen demand is projected to reach a range of 528 to 1 364 TWh by 2045 (dena, 2021; NWR, 2023; Prognos, Öko-Institut & Wuppertal-Institut, 2021; Agora, 2021; Kopernikus P2X, 2023).

Production capacities

As of Mid-2023, the installed electrolysis capacity in Germany is only about 0,1 GW (OTH Regensburg, 2023). The German Federal Government doubled the target for installed electrolysis capacity by 2030 from 5 to 10 GW (SPD, FDP, & Bündnis 90 / Die Grünen, 2021) which is expected to be confirmed in the upcoming update of the national hydrogen strategy. Even if this ambitious target is met, estimates suggest that domestic production in 2030 will still clearly fall short of meeting the forecasted demand[3] (see Figure 1).

Besides its domestic electrolytic production, Germany will therefore have to rely on imports of hydrogen and derivatives to meet the projected demand. Depending on the actual level of demand (see Figure 1), Germany alone will be required to import between 30 to 67 TWh of hydrogen by 2030 with a substantial further increase needed until 2045 to meet the domestic demand. This will require approximately 12 to 26 GW of electrolyzer capacity outside Germany to meet the German import gap in 2030 (calculating with 4000 full load hours per year for the electrolyzers and a power to hydrogen efficiency of 65%).

[3] 10 GW of electrolysis capacity are sufficient to produce approximately 26 TWh of hydrogen per year. This calculation assumes 4,000 full-load hours and an efficiency rate of 65%. However, it should be noted that the projected full-load hours and the renewable hydrogen production might be lower, considering the legal framework under development (the rules foreseen in the Delegated Act 27(3) of the Renewable Energy Directive II, defining the renewability of hydrogen, e.g. for temporal correlation).

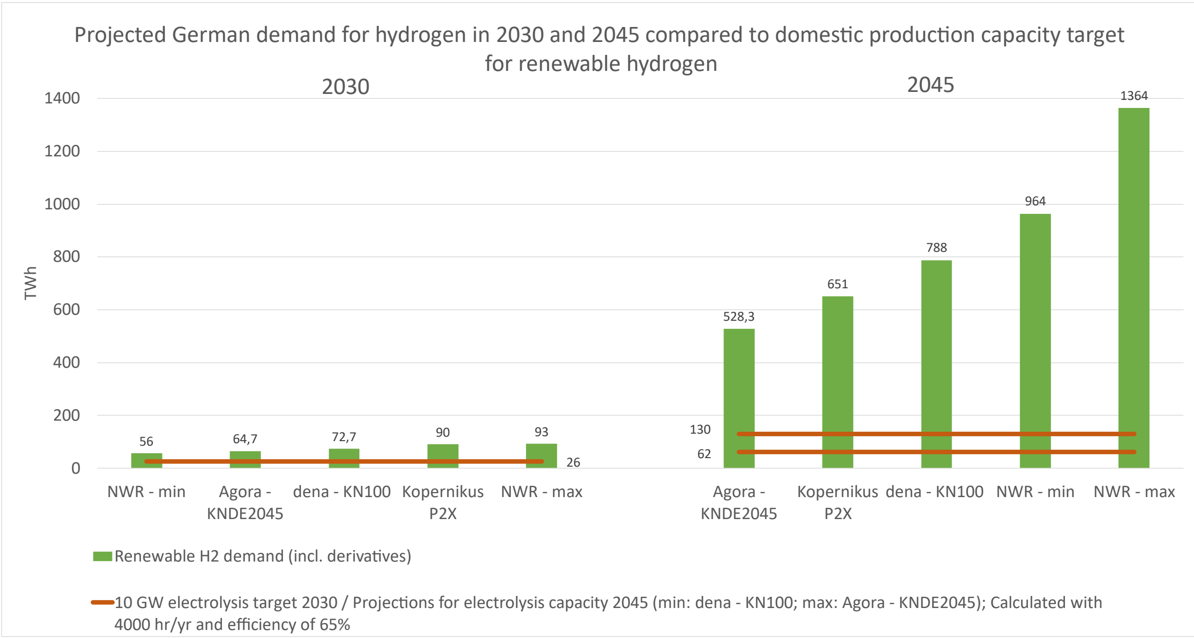


Figure 1: Projected German demand for hydrogen in 2030 and 2045 compared to domestic production capacity target for renewable hydrogen. Own illustration based on Bauer, Gawlick, Sterner, & Hamacher (2023); dena (2021); NWR (2023); Prognos et al. (2021).

As a result, providing the power supply for these electrolyzer plants abroad, substantial additional renewable energy capacities are needed. This applies in particular to plants that will be commissioned from 2028 onwards and for which more stringent additionality criteria (among others) apply in accordance with the respective Delegated Act (European Commission, 2023). Overall, to produce hydrogen at the required scale to meet the demand for imports, between 14 to 48 GW of renewable energy plants are needed.[4] Furthermore, additional process plants for the conversion of hydrogen into derivatives, the production of feedstock for derivatives such as nitrogen or carbon (dioxide) and the transport options and infrastructure, including ships, ports, and pipelines are required.

Investment needs

To meet the projected additional German demand for clean hydrogen in 2030 indicated above, substantial infrastructure expansions and hence massive investments in all segments of the value chain are necessary. To supply the German import gap in 2030 with renewable hydrogen alone, estimated investments in electrolyzer between EUR 11 and EUR 25 billion are required based on current CAPEX data from PIK (2023). Further investments in renewable energy plants to generate the required electricity for the electrolyzers abroad are projected to amount to approximately EUR 17 to EUR 44 billion based on CAPEX data from IRENA (2022). These investment costs neither include expenses related to the conversion of hydrogen into derivatives, nor the costs for the underlying transport infrastructure nor investments in the conversion of demand-side infrastructure. The latter will be required to unlock other fields of use for renewable hydrogen and hydrogen derivatives, beyond the

[4] The assumption about the necessary capacity for renewable energy plants is strongly dependent on the potential for renewable energy like wind and PV in the exporting country (compare also Runge et al. (2020) and Egerer et al. (2023)).

mere replacement of conventional hydrogen. The complete value chain will thus need further large investments beyond renewable energy plants and electrolyzers (Egerer et al. 2023b)

EU perspective

The above only depicts the German perspective. On EU level, the goal of producing and consuming 10 million tones (Mt) of renewable hydrogen domestically and importing the same quantity from third countries (European Commission, 2020) annually from 2030 onwards are no less ambitious. Hence, the associated challenges are just as substantial. Studies suggest that on EU level, the annual hydrogen demand rises from 264 TWh today to around 396 TWh by 2030 (Tarvydas D., 2022). Considering the EU target of 667 TWh (10 Mt local production, 10 Mt import) until 2030, van Wijk et al. (2022) calculate that around 350 GW of electrolyzer capacity will be needed in the EU and the importing countries to reach this target. For the infrastructure required to produce, transport, and consume 10 Mt of renewable hydrogen, investment needs are estimated to be in the range of EUR 335-471 billion (European Commission, 2022a). This includes EUR 200-300 billion for additional renewable energy capacities and EUR 50-75 billion for electrolyzers among others (European Commission, 2022a).

Time horizon

As the abovementioned costs for investments in electrolyzer capacities are based on current cost estimates, it is worth mentioning that significant cost degression can be expected in the context of the market scale-up (PIK, 2023). The idea of delaying investment decisions in anticipation of benefiting from cost reductions due to the market growth in other regions such as the US however comes at the considerable risk of further delaying the timely market ramp-up in Europe and thus missing the own climate targets on national and EU level.

Against the background of long project development times and the need to build up additional renewable energy capacity (for hydrogen production starting in 2028 and later), the investment decisions need to be taken in the short term. Site selection for additional renewable energy or hydrogen production plants is time-consuming; the same applies to obtaining the necessary permits. The development and construction process of a renewable hydrogen or hydrogen derivatives production project takes several years, which implies that final investment decisions for projects, which are supposed to come into operation before 2030 need to be taken in the next 2-3 years. To decrease investment uncertainty and thus, project risk premiums as well as production costs, the establishment of stable framework conditions for renewable hydrogen (derivative) projects is of high importance.

Reaching the German and EU targets on both, domestic production and imports, and meeting the projected demand for clean hydrogen and derivatives is a challenge with highest urgency. Only with a substantial and timely increase in private investments, the EU/German objectives for the renewable hydrogen market can be achieved. Hence, the very limited public funds available to stimulate this market (as compared to the challenge) must be used as efficiently as possible to maximize the leverage of additional private investments.

3. Framework conditions necessary for market growth and developing a market for renewable hydrogen

The underlying investments needed for the rapid scale-up of the hydrogen economy are characterized by highly specific, costly technological assets and long-term commitments. These capital investments must be made based on a risk assessment in a market which is not yet developed. In addition, at least at the beginning of the ramp-up of the hydrogen economy, there are mutual dependencies between producers and offtakers of hydrogen and hydrogen derivatives, as a global and liquid market for those products does not yet exist. Furthermore, the uncertain political framework also impacts the risk assessment in the form of political risks connected to investment decisions in hydrogen (SVR, 2022; Wietschel et al., 2021).

To decrease risks and foster private investments, the following aspects are fundamental:

Markets and Trading

Building up a European hydrogen economy is a complex task. The various aspects of production, storage, transportation, and consumption of hydrogen are interdependent and must be developed in a coordinated way, yet none of them currently exists at sufficient scale. This creates a classic 'chicken and egg' problem. Waiting for a hydrogen infrastructure to exist before creating a market based on that infrastructure would be costly, inefficient, and would ignore the lessons learned from past energy market scale-ups.

Trading venues, such as exchanges, can play a crucial role in building up a market already at an early stage. In the case of hydrogen and its derivatives, trading venues can provide a platform for buyers and sellers to trade hydrogen in a standardized and transparent way, which offers several benefits even if the number of players is low and the volumes are small. A trading venue can provide a transparent price discovery mechanism, establish a fair market price, build up a liquid market, help standardize the specifications such as sustainability requirements and contractual specifications of renewable hydrogen being traded and attracts new investors to this market.

Emission Trading Scheme, Carbon Price and Carbon Border Adjustment Mechanism

Another key element for ramping up a renewable hydrogen economy in Europe is a robust and effective EU Emission Trading Scheme (EU ETS) with a strong CO2 price signal. It incentivizes emitters to reduce their emissions and encourages investments in renewable hydrogen production and infrastructure and stimulates innovation in renewable hydrogen production and technologies. At a sufficiently high price level, the ETS may finally provide sufficient stimulus for switching to renewable hydrogen.

Due to the absence of a globally harmonized system to account for emission savings and trading, the EU introduced the Carbon Border Adjustment Mechanism (CBAM) which takes effect in Q4 2023.[5] The CBAM aims at reducing the risk of carbon leakage and leveling the playing field for EU companies in the global market. Covering the import of certain goods and selected precursors (incl. steel, fertilizers and hydrogen) that are characterized by a carbon intensive production and associated with a significant

[5] The statements made in this section are subject to potential changes in the design of the CBAM prior to its implementation.

risk of carbon leakage, CBAM will eventually – when fully phased in – capture more than 50% of the emissions in ETS covered sectors (European Commission, 2022b).

Due to the low carbon intensity of renewable hydrogen, CBAM will not have a strong impact on costs of imports. This increases the relative attractiveness of imported renewable hydrogen as compared to imported fossil-based hydrogen. It is worth noting however, that the CBAM may create some challenges for the import of renewable hydrogen through additional administrative burdens and costs for exporters and might create incentives to shift imports along the value chains towards products that are not subject to CBAM (Garnadt et al. 2020).

Standardization and certification

Besides effective carbon pricing, the definition of clear and concise sustainability criteria for clean hydrogen in general and especially for renewable hydrogen and derivatives, which is embedded in the regulatory framework, is crucial. Such binding criteria together with a defined verification framework are vital for a sustainable market development.

In defining the renewable character and emission intensity of products, the EU regulatory framework not only sets boundaries for the market's environmental integrity; it also provides the foundation for investments on both, producers', and offtakers' side by removing investment risks and allowing for a 'green premium' to be monetized. To mitigate risks for market actors and provide legal security, the definitions set out in the regulatory framework should be transparent and unambiguous. Moreover, to be widely compatible and to prevent barriers to trading, the regulatory framework should also be harmonized internationally (EWK 2021). There should be applicable and verifiable international standards and certification processes which are also implementable in the context of non-EU countries.

Considering the ambitious (short-term) goals, however, equally as important as the regulatory framework and its design is the speed of its adoption. To eliminate regulatory uncertainty and create a conducive environment for rapid market development in Europe, both the rules for defining renewable products and an operative verification and certification system through voluntary schemes need to be established quickly.

As of today, regulatory definitions by the European Commission for renewable hydrogen have not yet come into force. Consequently, producers that intend to supply their products within or export their products to the EU and offtakers in the EU face a lack of clarity, e.g., on electricity sourcing requirements, and hence investment uncertainty (European Clean Hydrogen Alliance, 2021). In the meantime, the H2Global instrument offers a temporal solution to the problem for producers. One of the main objectives of the H2Global instrument is to provide investment security to producers of renewable hydrogen: Through its physical intermediary Hintco, a contractual offtake guarantee is issued to producers and transparent criteria for the hydrogen purchase agreement (HPA) are defined based on the current regulatory guidelines of the EU (Renewable Energy Directive II and respective Delegated Acts which have not yet come into force). In the absence of clear standardization and certification procedures and, as a result, under regulatory uncertainty, the H2Global instrument minimizes the risks of producers by providing stable contractual conditions. Once the contract between the producer and Hintco has been signed, it provides a clear framework regarding the requirements defined for the product to be delivered throughout the duration of the HPA.

However, this temporary solution via Hintco for long-term contracts that are concluded in the next few years by no means implies that the clarification of regulatory definitions and certification processes is not urgent. On the contrary, while there are past and ongoing initiatives aimed at developing hydrogen standards and certification schemes (German Energy Agency, World Energy Council, 2022), the EU should quickly provide clarity on this matter and strive to ensure that its own criteria, e.g. for the renewable attribute of hydrogen and its derivatives are defined and internationally compatible.

Lessons learned from the gas markets

Long-term, point-to-point contracts between producers and offtakers of renewable hydrogen and derivatives will play an important role in private trade relations for the scaling up of the global market. Such agreements minimize investment risks by sharing the volume and price risks between the producers and offtakers, provide price security and volume security and hence ensure clear and stable revenue streams (SVR, 2022; Wietschel et al., 2021). In this context, lessons learned from the development of the European natural gas markets should be considered. Before the liberalization of gas markets in Europe, such bilateral long-term gas contracts, typically ranging from 10-20 years, were common between producers and suppliers. These contracts were often rigid and inflexible, with fixed prices and volumes, which made it difficult for new entrants to enter the market and for existing players to adjust to changing market conditions. Those patterns led to high price levels and welfare losses (Bundeskartellamt, 2006; Zweifel, Praktiknjo, & Erdmann, 2017). Furthermore, long-term contracts often contained destination or take-or-pay clauses[6] and therefore did not allow for flexible trading, inhibiting the transparent price discovery and the market to operate efficiently.

To overcome these obstacles and to create liquidity in markets, it was necessary to complement long-term bilateral contracts by trading via platforms provided by energy exchanges and brokers. Rulings on long-term contracts have in that respect played a critical role in the development of liquid gas markets, see for example Bundeskartellamt (2006). Such rulings have challenged the traditional take-or-pay provisions of long-term gas contracts, which required buyers to pay for gas they had no use for and were not allowed to resell. As a result, buyers were allowed to renegotiate their contracts enabling more flexible supply arrangements including the resale of non-used gas on the free market, which has increased liquidity in the gas market.

When shaping the clean hydrogen market, lessons from the past should be considered to avoid lock-in effects through a vast number of state-supported, long-term contracts. Instead, focus should be on stimulating liquid markets that help to foster price transparency, facilitate the mitigation of risks, provide flexibility to offtakers and attract new customers and investors.

[6] In the LNG markets in particular, supply contracts contained fixed destination clauses specifying the destination of an LNG vessel without the possibility of changing the destination at short notice in the event of arbitrage opportunities. It was not until regasification unit capacities increased that these clauses were dissolved by mutual agreement in order to exploit price differentials (Hallack, 2013). Due to take-or-pay clauses, importers had to pay for the contracted gas volume even if they did not import it in total due to lower demand. As a result, the volume risk of the import contract was assigned to the importing company, while the price risk was accepted by the exporter through index-based price formulas (Zweifel, Praktiknjo, & Erdmann, 2017).

4. Role of the H2Global instrument

Market development and catalytic effect

The H2Global instrument provides investment security to producers and offtakers of renewable hydrogen and its derivatives. In the current market situation, supply and demand do not meet due to a significant gap between production costs and offtakers' willingness or ability to pay for the additional costs of the renewable product. H2Global addresses this issue by creating a transparent and competitive market environment for producers and offtakers. Even though initially the volumes traded through H2Global will be relatively small, by making the products available to offtakers through auctions, the H2Global instrument triggers the development of a liquid market. The H2Global auctions are a first step of the transition towards exchange-based market for renewable hydrogen and derivatives. As a lesson learned from the European gas market ramp-up, to create liquidity and to accelerate the establishment of a market for renewable hydrogen and derivatives, an exchanged-based market should develop in parallel to other trading instruments, such as OTC ('Over-the-Counter') transactions. The latter already exists for fossil-based hydrogen and derivatives. In the context of the H2Global auctions, market-based price signals derived from the purchase and sale of renewable hydrogen and derivatives through the H2Global instrument will provide valuable information to companies considering entering the market as producers, offtakers or as developers of the required infrastructure. Both market liquidity and price signals will provide a basis for investment decisions and will facilitate the entry of new players into the renewable hydrogen economy.

The public money invested through the H2Global instrument into the renewable hydrogen economy will thereby have a catalytic effect by mobilizing substantial private capital. This catalytic effect will contribute to building up a market which will not only grow based on public subsidies, but which develop its own dynamic. In doing so, the public funds are expected to be complemented and in the next stage of market development completely substituted by private investments. Considering the tremendous investment needs and limited public resources, a market dynamic with strongly increasing private investments could be considered the only way Germany and the EU can come close to achieving the targets set out for renewable hydrogen. The H2Global instrument and its underlying principles could therefore play a crucial role in the development of the renewable hydrogen economy.

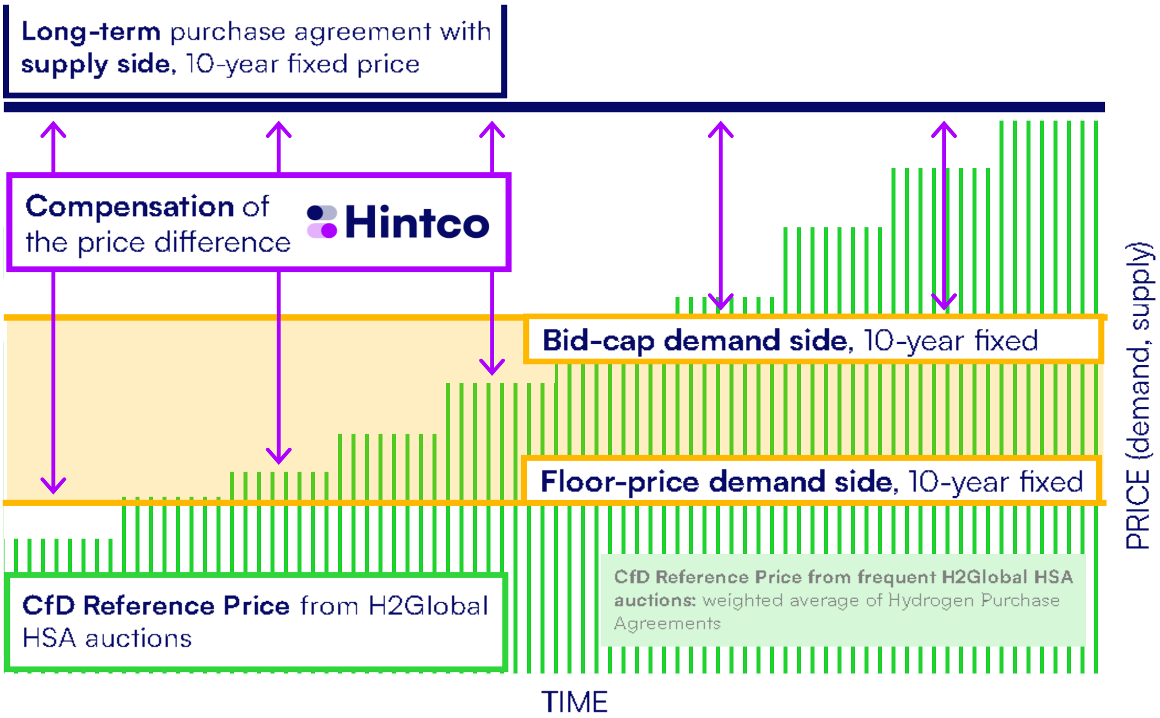
Price signals and the development of a hydrogen index

Price signals derived from the H2Global instrument can be the basis for or feed into an index for renewable hydrogen. Reflecting real market values, an index serves as a reliable benchmark which ensures transparency, credibility, and facilitates fair pricing in the overall renewable hydrogen market. In the absence of market-based hydrogen trading, most existing hydrogen indices are currently derived from costs and reflections of hydrogen substitutes such as power, gas and European Union Allowances (EUA). Since May 2023, the European Energy Exchange (EEX) publishes a virtual hydrogen index, 'HYDRIX', on a weekly basis, reflecting the price for renewable hydrogen offered in Germany, determined from supply and demand prices of hydrogen provided by companies from the industrial and energy sector (EEX, 2023). As of today, no price index based on an auction for renewable hydrogen exists.

The results of the H2Global auctions for offtakers will – for the first time – provide actual price data which can feed into a market-based price index for renewable hydrogen. Such an index could facilitate complementary long-term offtake agreements with offtakers, also under H2Global (see Box 2). In addition, the price signals revealed under H2Global could serve as a reference for bilateral contracts as well as for other public funding schemes. Utilizing this market-based price data of H2Global would have the effect of limiting windfall gains in the context of renewable hydrogen subsidies by setting a transparent reference price. Additional H2Global auctions for the production and offtake of renewable hydrogen and derivatives can further improve the data basis for indices and other funding instruments.

Box 2: Potential contract design options of the H2Global instrument - Example

The H2Global instrument in its current design follows clear principles aiming for a rapid market development and creating liquidity, as elaborated in this paper. However, additional elements could be added to the instrument, based on the priorities set by the respective funding body. One potential aspect is the option of extending the duration of the hydrogen sales agreements (HSA), to serve also offtakers' need for volume (and price) security. In such model, Hintco could either act as the physical intermediary or as a pure broker at a later stage.



To increase the efficiency in utilizing public funding compared to long-term agreements with fixed prices, such model could be based on the reference price/index derived from the results of the parallel and recurring auctions under the current H2Global design. This could also be applied for other, complementary current or future public funding instruments. If required, this model is also suitable to provide additional price security for offtakers, if combined with a price cap and floor price, thus creating guardrails for the fluctuating reference price. As discussed above, it is worth emphasizing, that a sufficiently large trading volume and number of price data revealed under the H2Global design is necessary to provide the basis for a broad-based index, before the extension of HSA contracts is being considered. Thus, they should only complement public funding for market-based efforts to stimulate the hydrogen economy.

Fostering private investments and phase-out of public support

When addressing the development of a renewable hydrogen economy, support schemes should prioritize the creation of markets and incentivize trading. Support schemes should ideally not interfere negatively with the emission trading scheme and the resulting CO_2 price formation. The H2Global instrument can address these challenges. By buying long-term from producers and selling short-term to offtakers via auctions, it fosters competition and transparency. The functionality of EU ETS is not negatively affected by the H2Global instrument, but on the contrary can unfold its full effect. In particular, the short-term contracts under H2Global ensure that the market participants' need for hedging on the (secondary) carbon market remains largely unaffected. This contrasts with other funding schemes such as Carbon Contracts for Difference (CCfD), that support bilateral long-term agreements. Consequently, the impact of H2Global on the carbon market's liquidity and price formation is likely minimal compared to other financial support instruments.

Through its competition-based approach, where producers and offtakers compete for the supply and offtake contracts, the H2Global instrument minimizes the financial gap that needs to be bridged. In addition, it caters for changes in offtakers' willingness-to-pay induced by, e.g. amendments to the regulatory framework. Whenever new regulations introduce additional incentives to decarbonize, the offtakers' willingness to pay a premium for a renewable hydrogen product is anticipated to change and potentially increase (see Box 1). Consequently, due to the short duration of sales contracts, the cost of difference to be compensated for might decrease accordingly. Hence, the H2Global instrument utilizes public funds only to the minimum extent required to bridge the price gap between producer and offtaker.

Over time, the H2Global instrument will incentivize and ultimately be replaced by platform-traded markets for renewable hydrogen, thanks to its provision of liquidity. In a further step of the evolution towards a renewable hydrogen commodity market, trading venues can offer physical markets where companies that have purchased hydrogen in auctions can easily resell their contracted volumes. This increased flexibility and simplification of trading in physical hydrogen markets also paves the way for the establishment of financial derivatives, including financial settlement, to mitigate risks and hedge positions within the hydrogen markets. As 'liquidity attracts liquidity', the presence of these trading venues and financial derivatives can attract additional volumes, further enhancing market liquidity and efficiency.

Box 3: Exchange-based energy trading

Trading venues, like European Energy Exchange (EEX), have played a crucial role in liberalizing the energy markets in Europe during the late 1990s.

Transparency and integrity are essential in exchange trading, forming the foundation for market players and the public to have confidence in the market's proper functioning. The publication of prices and trading turnover allows for an assessment of market activities. Additionally, pricing on the exchange relies on transparent, binding rules and processes, ensuring comprehensibility.

Exchange trading products and processes exhibit a high degree of standardization, encompassing contract size, maturity, delivery terms, and settlement procedures. This standardization leads to a wide availability of supply and demand, facilitating good liquidity. Robust and representative market prices, along with reduced search and transaction costs, benefit market players. A sufficient level of liquidity ensures that every participant can find a trading partner at any time and execute transactions or adjust existing positions.

By ensuring trading anonymity, the exchange treats all market participants equally and without discrimination. Whether a small trader engages with a large trader or a domestic trader interacts with a foreign trader becomes irrelevant. Exchange rules guarantee that identical trading and settlement processes apply to all participants, and price and market information are accessible simultaneously. The exchange's rigorous admission procedure upholds professionalism and integrity in all trading and settlement activities (Gersdorf et al, 2022).

5. Outlook

A second funding window for the H2 Global instrument of EUR 3.5 billion by BMWK is foreseen for 2023. The detailed outline of the window is yet to be determined by BMWK (status June 2023). Furthermore, the Dutch government plans to utilize the H2Global instrument to set up a EUR 300 million funding window. End of May 2023, the European Commission expressed that H2Global has developed as a best practice to promote sustainable hydrogen markets and has announced that it is foreseen that the H2Global instrument will serve as a central pillar for the international leg of the European Hydrogen Bank which is currently established (BMWK, 2023a).

H2Global is a flexible instrument to support renewable hydrogen trading on a global scale. While other funding approaches focus exclusively on bilateral, long-term agreements or may even support unilateral contracts of companies that produce for their own on-site consumption, in its current design, the H2Global instrument takes an alternative approach. The focus of the H2Global instrument is on stimulating private sector engagement and market development by creating a catalytic effect. The direct contribution of the instrument to achieving the German and EU goal to ramp up the market through the renewable hydrogen or derivatives contracted depends on the volume of available public funding and hence is, under the current EUR 900 million funding window, limited as compared to the EU and German policy goals. Thus, the additional funding of EUR 3.5 billion for the H2Global instrument over a period of ten years is essential to contribute to market liquidity, as it increases the volume of the renewable hydrogen contracts, enables the creation of a broad portfolio of pricing data and thus enhances its catalytic effect on market development.

At the same time, the H2Global instrument leaves room for including additional elements in line with the strategic objectives and priorities of the funding body. In principle, the instrument also allows embedding long-term agreements with offtakers in selected cases such as where investments in production processes require volume and price security for the renewable hydrogen supply. It is worth emphasizing, that a multiple of the current H2Global funding window has already been allocated to support long-term bilateral contracts through other funding instruments in Germany and the EU. For example, the announced 'climate protection contracts' ('Klimaschutzverträge') in Germany are anticipated to receive public funding in the mid double-digit billion range over a period of 15 years (BMWK, 2023). Hence, additional funding for supporting long-term, demand-side contracts under the H2Global instrument should be reasonably scoped. Even more important is the need to reveal a broad portfolio of price data with H2Global, resulting from auctions under the H2Global instrument. The larger the volumes that are being traded under H2Global, the more accurate the pricing signals will be and the better H2Global can fulfill its guiding function for other funding instruments and the overall market creation.

The instrument could also be extended to particularly support certain technologies, such as direct air capture, other emission reduction technologies or specific elements of the renewable hydrogen (derivative) value chain, such as storage infrastructure. The H2Global instrument could focus on stimulating the development of regional renewable hydrogen hubs, where either supply or demand or both are supported.

Imports are considered vital to meet the German and EU demand for renewable hydrogen. In the context of ramping up imports, however, particular care should be taken to diversify the energy supply. To avoid dependencies on single suppliers or import regions, diversification should be a key criterion in the selection of suppliers, besides price. The H2Global instrument provides an inherent flexibility to enable diversification through a dedicated geographic delineation of import regions. While currently focused exclusively on supporting the import of hydrogen derivatives into the EU, the H2Global instrument could also be used to stimulate the production of renewable hydrogen derivatives within the EU.

Ultimately, a global hub for renewable hydrogen denominated in Euro could emerge. In pursuit of this objective, the EU Commission is committed to supporting the development of euro-denominated commodity derivatives for energy and raw materials. Furthermore, the Commission aims to facilitate the establishment of euro-denominated benchmark indices and trading venues, encompassing critical sectors, including emerging energy markets like hydrogen. By fostering the use of the Euro in these domains, the Commission seeks to reinforce the Euro's worldwide prominence and advance its strategic goal of strengthening the global role of the currency (European Commission, 2021).

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