FLORENCE SCHOOL OF REGULATION

ROBERT SCHUMAN CENTRE

POLICY BRIEF

Five reflections on clean hydrogen's contribution to European industrial decarbonisation from 2024 to 2030

After years of record announcements, frantic policy development and the establishment of substantial public support mechanisms, the clean hydrogen[1][2] sector is nearing an inflexion point. Many clean hydrogen projects have reached the technical feasibility stage, with a global pipeline of clean hydrogen projects totalling nearly 25 million tonnes (Mt) of production by 2030, much of which is in Europe. However, only 4% of those projects reached financial investment decision (FID) in 2023. This rate is already twice as high as in 2022, but still very marginal given global hydrogen demand needs to grow from 95Mt to 150Mt by 2030 to stay on track for net-zero by 2050[3]. The key question for the coming months is: *how can a critical mass of the remaining clean hydrogen projects secure financing before momentum is lost?*

As it stands, production project financing in Europe is likely to come through either a bilateral deal with an off-taker willing to pay a premium for a decarbonised product or via selection in one of the European auctions or wider public support mechanisms. If financing can be secured, we might see the beginning of new technological cycles rooted in clean hydrogen path dependencies within key industries. This in turn could establish the basis for the birth of a wider clean hydrogen market,

1 For an introduction to the basics of hydrogen, please see Hydrogen in the Energy Transition - Florence School of Regulation (eui.eu)

2 Clean hydrogen can be either blue, produced by Steam Methane Reforming of fossil gas, with the addition of carbon capture (use) and storage (CCUS), or green, produced via electrolysis of water, driven by renewable electricity. For a full classification, see footnote 1.

3 International Energy Agency (IEA), (2023). Global Hydrogen Review, https://www.iea.org/reports/global-hydrogen-review-2023/executive-summary.

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driving economies of scale and ultimately facilitating deep decarbonisation of the European economy, stimulating some new manufacturing sectors in the process. However, if this first wave of projects fails to secure investment, confidence is likely to falter, and the momentum lost.

Clean hydrogen has been positioned as a potential technological vehicle for industrial transformation and as a future pillar of European energy security. Record low costs of solar and wind technology have added to an expectation that a similar learning curve could materialise for electrolysers and other clean hydrogen[4] technologies. Cheap clean hydrogen would take the energy transition where electrification finds it hard to go. However, high interest rates and a fall in gas prices after the 2022 summer peak have led to a cool-off in expectations for fast, large-scale deployment[5].

In this Policy Brief, we give a snapshot of the state of play for the sector, complemented by learnings from the High-Level Policy Dialogue (HLPD) hosted by the EUI's Florence School of Transnational Governance and the Florence School of Regulation on October 19, 2023.

1. Adjusting to realistic cost expectations

In recent years, the role of clean hydrogen as a breakthrough technology for industrial decarbonisation has been to a large extent based on an expectation that clean hydrogen could become at least as cheap as grey (fossil gas-based) hydrogen. The benchmark figure for the fossil incumbent is a Levelised Cost of Hydrogen (LCOH) of 1.5-2 €/kg, based on gas prices of around 30€ per megawatt-hour (MWh). Many of the quoted production costs of clean hydrogen for 2030 and 2050 achieve this figure. For example, in the recent IEA, Global Hydrogen Review 2023, green hydrogen is projected to be available at under 2€/kg in large parts of the world (South America, North Africa, South Asia, China, and Australia) by 2030. Blue hydrogen could be produced at 2 to 4€/kg, depending on the gas price. These production costs are even more attractive when you consider the inflationary impact of the EU Emissions Trading System (ETS) on the real cost of fossil hydrogen use in the EU.

However, project-specific data from the first wave of installations is beginning to show that the LCOH in Europe may be higher than expected. For example, the current cost of green hydrogen in Central European projects is in the range of 4.5-8€/kg and the cost of blue hydrogen is around 3€/kg[6]. Some factors contributing to these higher-than-expected prices include an increase in the cost of capital due to high interest rates, a slower decline of renewable electricity production costs, and electrolyser capital cost reductions and efficiency improvements which alone are not sufficient to deliver the expected cost breakthroughs. At the same time, the price of fossil incumbents has in many cases fallen recently, widening the green premium cost gap to be bridged. For example, global spot market prices for ammonia have dropped by 50% year-on-year to ~360€/t, less than half the price of green ammonia[7].

In the context of considerable price uncertainty, the H2Global and European Innovation Fund Hydrogen Bank auctions come at a timely moment. With budgets of under €1bn for each of these first auctions, they will not bring the tens of millions of tonnes of clean hydrogen to market that the European Commission is targeting[8]. Nevertheless, the auctions are expected to lead to price discovery for green hydrogen projects for 2024-2030, both produced within the EU and, in later auction rounds, imported from third countries. Detailed results of the first Hydrogen Bank auction round will be available in Spring 2024 following evaluation, but early numbers suggest a high level of interest. A

4 In this paper we use the generic term clean energy, including green (renewable) and blue hydrogen (gas-based with CCUS).

5 'Reality check' | Hydrogen developers walk back large-scale ambitions this decade | Hydrogen news and intelligence (hydrogeninsight.com) and Hydrogen: A reality check – EURACTIV.com

6 BCG, Turning the European Green Hydrogen Dream into Reality: A Call to Action, White Paper, October 2023.

7 S&P Global, Analysis: Global ammonia prices fall 50% on year, sparking concerns over future low-carbon market, Retrieved from: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/081523-global-ammonia-prices-fall-50-on-year-sparking-concerns-over-future-low-carbon-ammonia-market.

8 The Hydrogen Bank has a subsidy ceiling price of 4.5 €/kg and a budget of €800m. At a subsidy price of 2 €/kg this budget would provide 0.4Mt of clean hydrogen. The EU is targeting 10 million tonnes of domestic production per year by 2030.

total of 132 bids were received, spread across 17 EEA countries, totalling 8.8 gigawatts (GW) of electrolyser capacity and 8.8mt of RFNBO capacity[9]. The results of the first H2Global auctions are also expected to be made public in the first half of 2024[10]. These results will guide the expectations of developers, policy-makers and off-takers for the years to come.

2. Stimulating demand for low-carbon fuels and goods through regulation

Clean hydrogen demand in Europe is being created in industry and transport with a mix of carbon pricing and offtake obligations. A natural gas price of 44€/MWh, a delivered clean hydrogen price of 2€/kg, and a carbon price of ~70€/t are enough to trigger a fuel switch to renewable hydrogen in certain industries[11]. However, in regions with cheap natural gas, the required CO_2 price could be more than €230. Given the abundance of cheap natural gas in the world, especially after 2025 with the start of new Qatari gas deliveries, it is expected that in Europe a price beyond 100€/t CO_2 would be needed for clean hydrogen to be competitive. Such a price is in line with long-term expectations during the second half of this decade. However, in the years leading up to 2030, the EU cannot rely on carbon pricing alone to drive the uptake.

Taking cue from renewable electricity and biofuels development, agreement has been reached on a series of targets and fuel mix obligations in the EU. In the revised Renewable Energy Directive, which recently entered into force, the EU has incentivised demand for Renewable Fuels of Non-Biological Origin (RFNBOs) in industry and transport:

1. RFNBOs must account for at least 42% of the hydrogen used in industry in 2030, rising to 60% in 2035. However, several exceptions apply and the policy toolbox is at the discretion of the Member States.
2. RFNBOs must account for at least 1% of the fuel supplied to the transport sector by 2030.

Moreover in the FuelEU Maritime regulation, a sub-target of 2% of the energy supplied to maritime transport has to come from RFNBOs from 2033, if the target of 1% is not met in 2031. The ReFuelEU Aviation agreement includes a target of 2% of energy supplied to aviation to come from sustainable aviation fuels (SAFs) by 2025, rising to 6% by 2030. Moreover, upon review of the international CORSIA[12] scheme in 2026, the EU will determine whether the derogation from the EU ETS for departing flights to third countries will be extended or not.

It is expected that these industrial and transport sectors will now generate market demand for clean hydrogen. However, there is still considerable uncertainty about which green molecules will eventually be procured in which other remaining sectors. The highest ‘value-added’ sectors for renewable hydrogen deployment are arguably fertiliser plants, the pulp and paper industry, and oil refineries. In September 2022 TotalEnergies launched a tender for 0.5Mt of green hydrogen per year for use in its refineries, 5% of the EU’s entire renewable hydrogen consumption target for 2030. However, demand in refineries will drop with the electrification of road transport, and the broader phasing out of petroleum products. A more long-term demand option often cited is the fertiliser sector, but the outlook here is also uncertain, with Europe targeting a 20% reduction in fertiliser use by 2030, and domestic production trending down since the energy crisis. The steel sector is often quoted as another hard-to-abate sector needing clean hydrogen to decarbonise. However, electrification could already reduce 65% of steel emissions and the hydrogen needed to reduce the remaining 35% of emissions would in any case need to be

9 European Commission, (2024). European Hydrogen Bank pilot auction: 132 bids received from 17 European countries, Retrieved from: https://climate.ec.europa.eu/news-your-voice/news/european-hydrogen-bank-pilot-auction-132-bids-received-17-european-countries-2024-02-19_en

10 H2Global floats timeframe to announce winners of massive €900m hydrogen auctions — and confirms extra funding | Hydrogen news and intelligence (hydrogeninsight.com).

11 Hasan, (2023). Creating Demand for Low-Carbon Hydrogen for Industry Decarbonization: Lessons from the Electricity Sector, KAPSARC, Retrieved from: https://www.kapsarc.org/file-download.php?i=199813 .

12 Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

extremely cheap[13] to be competitive. This makes it an unlikely candidate for large-scale early market adoption – at least without supply-side support or demand-side obligations/premiums.

The above considerations raise the question of whether an extension of sectoral obligations within auctions and regulations is needed to create market conditions for low-carbon industrial goods. Linking policies closer to preferred use cases could arguably be more effective at this stage than sector and technology-neutral policies. The EU Hydrogen Bank does not currently follow such an approach, in contrast to the sectoral auctions of H2Global. The results of the first Hydrogen Bank auction will help inform us on which sectors will emerge as first movers, from here we might begin to consider more targeted auctions.

3. Which transport infrastructure to build first?

A global or regional market for clean hydrogen requires transport infrastructure to move the molecules from production to consumption centres. Moreover, as acknowledged in REPowerEU, mass demand for the cheapest clean hydrogen will require import from outside of Europe. The Middle East and North Africa (MENA) region, in particular, is likely to host centres of green hydrogen production for export to Europe.

Several transport options emerge in the literature. Hydrogen could be piped, either blended with natural gas or through dedicated hydrogen pipelines, or it could be shipped, either in a condensed or liquefied state or via another molecule such as ammonia, methanol or a liquid organic hydrogen carrier (LOHC). With current technologies, transport often doubles the price of hydrogen for the end user, costs are highest when new infrastructure and new vessels are required, as well as when economies of scale are not achieved[14].

These transport costs will have a meaningful impact on the economic geography. For example, Europe's largely east-west oriented continental gas pipeline system would need reorientation south-north, for better connection to the low-cost renewables in northern and southern Europe, as well as beyond to the MENA region. This outlook poses several challenges for building appropriate hydrogen transport infrastructure, one key difference being that future clean hydrogen production is likely to be more diversified and the consumption centres more concentrated than for natural gas.

With future trade patterns unclear, it is difficult to plan and finance transport infrastructure, particularly for fixed assets like pipelines. Moreover, in the prevailing climate of energy geopolitics, pipelines are politically unfashionable in Europe. Against this backdrop, the port areas are more advantageously positioned to act as both receivers and consumers of hydrogen, although likely in the form of hydrogen derivatives. In this configuration, they can rely both on shipped deliveries and local production, without having to factor in costly 'last mile' connections. Ports are also well positioned to store clean molecules for both industry and transport, who are likely to be the first consumers. From a planning perspective, ports are much more attractive than most locations given that they are brownfield sites, and in some cases even benefit from special economic and planning exemptions.

This uncertainty calls for a prudent approach to hydrogen transport planning and regulation. Firstly, it is logical to start with hydrogen clusters around Europe's key port areas and experiment with different transport modes and carriers between them and production centres in third countries. If fixed, cross-border infrastructure transport links are to be made in the near future, they need to be highly strategic, i.e. only where there is a high degree of confidence that the requisite economies of scale can be achieved. Secondly, the cost of transport infrastructure should be more thoroughly assessed from a business-to-business (B2B) perspective, together with the new CO_2 transport infrastructures. Although synergies exist between a hydrogen and a CO_2 transport infrastructure, they also imply potential technological path dependencies and investment in one path may cannibalise the other, if not well planned. To better reflect their value, network planning for CO_2 and hydrogen may benefit from regional socialization of costs,

13 Less than ~2€/kg at current commodity prices.

14 Kneebone, Piebalgs, (2023). Are pipelines and ships an 'either or' decision for Europe's hydrogen economy?: planning import lines for hydrogen and derivatives, Retrieved form: https://cadmus.eui.eu/handle/1814/75533

rather than more conventional cross-border cost allocation[15].

4. Revisiting blue vs green hydrogen

The question of blue vs green hydrogen is receiving new attention, on the back of gas prices sliding down to pre-war levels. The EU, incentivising demand for low-carbon goods through the EU ETS, could become a destination for blue hydrogen from oil and gas exporting states such as the US and Saudi Arabia. There are three key concerns related to this prospect.

Firstly, the rules on blue hydrogen have not been finalized in the EU, although progress is being made. The trilogue agreement on the EU gas and hydrogen package refers to a Commission delegated act (DA) on the methodology for assessing greenhouse gas emissions savings from low-carbon fuels. In the agreed version of the text, the DA would include minimum carbon capture rates and upstream methane emissions performance standards. However, implementation remains an issue. There are persistent doubts on whether carbon capture technology can consistently deliver capture rates of more than 70%, as foreseen in the definition of low-carbon gas in the EU's hydrogen and gas package. Moreover, if methane emissions are to be included, how accurately can they be measured and reported, particularly in exporting countries outside of the EU? Attempts to repair methane emission leaks and to stop deliberate venting and flaring practices in the oil and gas sector have so far been broadly unsuccessful, and emissions estimates have often been wildly under-estimated. The EU's latest methane regulation may go some way to help resolve these problems.

Secondly, the EU policy set-up is focused on RFNBOs which need to be produced from renewable electricity, both for the industry and transport targets and for the EU Hydrogen Bank auctions. As elaborated above, these first targets and auctions could help to create a market but are not sufficient to scale. Leaving the blue hydrogen door wide open could undercut the aims to scale the EU RFNBO market.

Lastly, since REPowerEU and the Net-Zero Industry Act (NZIA), the EU has signalled a higher priority for energy security. Blue hydrogen does not decrease nor diversify the EU's gas dependency. On the contrary, if new infrastructure is built for blue hydrogen flows, the dependence on natural gas might be further locked in. Green hydrogen has arguably been favoured within the European hydrogen policy framework designed over recent years, for example as regards certification and support schemes. However, the cost advantage of blue hydrogen remains promising, if sufficiently high capture rates and upstream methane emission performance can be achieved and verified. Wider considerations, such as energy security, need to be part of the debate moving forward, but with hydrogen forecasted to occupy less than 2% of final energy consumption in 2030, it could be too premature to compromise the buildout of the sector based on security of supply concerns.

5. Planning for the long term: future-proofing Europe's industrial base

Fuel substitution has been the dominant paradigm in the discourse on EU industrial decarbonisation. If natural gas could be replaced by green hydrogen at the EU's industrial sites, the EU would simultaneously decarbonise, reduce its energy dependency on Russia and protect its industry from fossil-based competition via the Carbon Border Adjustment Mechanism (CBAM). From that perspective, green hydrogen is the natural successor of coal, oil and natural gas, at least for the few remaining applications where direct electrification is not practical.

However, this view overlooks the transport issue, as discussed above. The form in which the imported hydrogen will eventually be used strongly influences the choice of hydrogen carrier and the supply costs and logistics, particularly in the case of shipping. Simply put, liquid hydrogen is amongst the most expensive and challenging energy products to transport, it is virtually always preferable to transport in its final form (i.e. embedded in finished or semi-finished products) or via a carrier. For example, if imported hydrogen is destined to be consumed in the form of ammonia, synthetic fuel, or methanol, these products should be imported

15 Meeus, et al., (2023). Energy policy ideas for the next European Commission: from targets to investments, Retrieved from: https://cadmus.eui.eu/handle/1814/75989

and consumed directly in those forms - avoiding the costs and infrastructural burden of reconversion. Importing clean ammonia from third countries with very cheap renewable electricity could be cheaper than domestically produced fossil ammonia in northwest Europe when accounting for the ETS price.

Moreover, if green hydrogen is produced where renewable energy is cheap and abundant but transport is expensive, the industry might follow suit and relocate closer to the hydrogen production centres. For example, this could manifest in importing sponge iron – where clean hydrogen has already been used as the reducing agent – instead of importing iron ore and clean hydrogen separately, only to process the iron in Europe. Such green industrialisation would increase value for the local, exporting economies and could be a solution for the cost and technological challenges of transportation. Already, Egypt and Morocco are launching green fertiliser projects. Over time, this might expand to more renewable chemicals, low-carbon steel and other energy-intensive products.

CBAM might accelerate that trend. The carbon price under the EU ETS creates demand for low-carbon goods in the EU and the CBAM creates a penalty for carbon-intensive imports, but equally an opportunity for the import of green industrial goods. Given the resource abundance and the cost of transport, non-EU countries might beat the EU in low-carbon production when faced with the same carbon price via CBAM. Therefore, it is essential that CBAM also covers indirect emissions of steel, aluminium, hydrogen production etc. and that CBAM regulations enforce capture rates higher than 70% and upstream methane performance standards for any imported good based on blue hydrogen. It will be important to evaluate CBAM in 2025, especially if carbon prices exceed 100 €/tCO2.

Policy Implications

All the above considerations lead to two geopolitical and geoeconomic evolutions that need careful analysis and require a rethink of EU climate governance.

Firstly, the EU's rules on industrial decarbonisation might drive renewable industrialisation of its neighbourhood and the corresponding deindustrialisation of energy-intensive sectors within the EU. Various stakeholders will evaluate that differently. It is in any case not the way that green hydrogen is presented to the general public. Green hydrogen is typically framed as the EU's segway to industrial decarbonisation, with the CBAM to protect Europe's clean industry from dirty imports.

Secondly, the EU must carefully consider the geopolitics of hydrogen. With the growth of international renewable hydrogen value chains, we could be witnessing the emergence of the first global renewable energy commodity. Until now, solar and wind power have been used locally, at best regionally through interconnected electricity systems. Clean hydrogen will compete at a global price, either directly or through hydrogen-based molecules or industrial goods. This could bring clean hydrogen into the realm of the oil and gas business, with inframarginal rents from green hydrogen-producing countries. Many of these exporting countries might follow a twin-molecule approach: exporting both natural gas and hydrogen, whichever is more in demand. Meanwhile, renewable electrolytic fuels also have the potential to 'democratise'[16] trade in energy commodities, with the market theoretically open to any actor with renewable energy potential and a means of export[17]. This means importing regions, such as the EU, may be free to trade with a much larger number of partners, rather than only those that happen to have the good fortune of fossil fuel deposits[18].

16 International Renewable Energy Agency (IRENA), (2022). Geopolitics of the Energy Transformation, Retrieved from: https://irena.org/-/media/Files/IRENA/Agency/Publication/2022/Jan/IRENA_Geopolitics_Hydrogen_2022.pdf

17 This 'democratisation' is not without limits, and there will always be differences in the cost of renewable hydrogen based on local environmental and financial conditions. However, consumers will have the possibility to choose to trade with a larger number of partners, particularly if they are willing to pay a premium. For example, you may be willing to compromise on LCOH for a higher degree of security of supply or for the sake of onshoring/near-shoring production. For more in-depth analysis see here.

18 Kneebone, Piebalgs, (2022). Redrawing the EU's energy relations: Getting it right with African renewable hydrogen, Retrieved from: https://cadmus.eui.eu/bitstream/handle/1814/74890/PB_2022_50.pdf?sequence=1&isAllowed=y

These considerations call for a renewed assessment of the geopolitics of clean hydrogen, including all policy criteria such as greenhouse gas emission reduction, affordability, competitiveness of the EU industry, energy security, neighbourhood policy, etc. These criteria call for a coherent approach to:

a. the diversification of sources (energy security),

b. stability of investments (neighbourhood policy and international development policy via 'Global Gateway') and;

c. industrial policy (strategic autonomy).

Concretely: if the EU wants green steel, how much of it should be produced in its neighbourhood and how much must stay in the EU? Or to approach it a different way, which parts of the value chain should remain in the EU, and which can be offshored? These questions will guide the structuring of tariffs, for example, and are therefore better addressed upfront. Adding protectionist measures after promoting developments in the neighbourhood region would be a severe setback for the EU's international climate diplomacy and credibility at large.

Finally, the EU must focus and align its policy toolbox of state intervention with its sectoral green hydrogen ambitions. The EU is home to many (fossil) energy-intensive sectors, making up the industrial base of Europe's economy. These sectors were built on cheap energy imports and raw materials that are processed in Europe before being re-exported and domestically consumed in the form of much higher-value 'finished products'. Under current policies, the EU is pushing to retain the competitiveness of these sectors via derogations to state aid rules that allow for huge government subsidisation of electricity and gas costs at a national level (where the fiscal capacity exists). These state aid payments have reached record levels since 2021 and are arguably already beginning to distort the single market. Looking forward, Europe can expect to have structurally more expensive fossil energy[19] and guaranteed higher costs for fossil energy-derived products[20]. These conditions make incumbent fossil energy-intensive sectors fundamentally uncompetitive versus third countries, swell the financing obligation for state intervention[21], and to what end?

At the same time, the European net-zero-aligned industrial policy has two contradictory faces. On one side, the aforementioned fossil incumbent energy-intensive industries must be replaced by clean substitutes where a future exists for the products they produce. On the other side, industry must diversify towards new clean-tech products and services (manufacturing of electrolysers, batteries, fuel cells, refining of critical raw materials, etc). At a glance, the combination of massive state-specific support policies to artificially sustain fossil incumbents and the simultaneous funding and regulatory support for industrial modernisation may be the equivalent of putting one foot on the accelerator and one on the brake.

Conclusion

The strength and relevance of Europe in the global economy is its single market, the largest single market in the world. EU hydrogen policy needs to be compatible with that market and be based on clear priorities.

At the domestic level, this begins with the structural elimination of fossil hydrogen through carbon pricing, strict certification and scrutiny of abated fossil (blue) hydrogen, driving long-term and clear demand for green hydrogen in high-value-added sectors via a combination of mandatory targets and sector-specific financial support mechanisms. At the international level, the EU can ensure a coherent approach to trade in RFNBO and low-carbon industrial goods with the neighbouring regions by aligning its industrial, international development and extra-EU trade policy with its energy sector decarbonisation ambitions. Together, these measures can help achieve the critical mass of clean hydrogen projects necessary to get the sector off the ground.

19 Driven predominantly through a shift from cheap Russian pipeline gas to structurally more expensive LNG.

20 Via carbon pricing.

21 As Europe's fossil energy prices have risen, so too has the burden on public budgets to support the competitiveness of energy-intensive industries. This was particularly evident during the energy crisis of 2021 - 2023, but in the majority of cases this has not stopped, even now that prices have restabilised.

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