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The EU in the Global Hydrogen Race

Bringing together Climate Action, Energy Security, and Industrial Policy

Yana Zabanova

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Summary

The European Union has identified clean hydrogen as essential to its climate targets, technology leadership and energy security in the decarbonizing world. The EU has emerged as a global pioneer in developing a comprehensive regulatory framework for a hydrogen economy, complete with supply-side policies and binding demand-side targets. The EU's approach has an impact beyond the bloc's borders, shaping debates in other jurisdictions. At the same time, navigating the often diverging interests of Member States and various hydrogen stakeholders has been a challenge. There have been disagreements on the stringency of sustainability requirements for renewable hydrogen, the role of nuclear power, sources of funding for hydrogen-related measures, the shape of the future hydrogen infrastructure, and the ambition level of the European industrial policy. As the global hydrogen race accelerates and powerful actors like the US offer massive and easily accessible subsidies for the hydrogen industry, the EU has struggled to keep up. The EU does have several sources of funding for hydrogen-related measures, including revenues from the auctioning of emission allowances, as well as the Recovery and Resilience Facility, a central part of the EU's pandemic recovery package funded by external borrowing. Still, much of the public funding for hydrogen will have to come from Member States, which often have very different priorities and ideas about the future role of this energy carrier. While the EU has relaxed its strict rules on granting state-level subsidies in order to promote the green transition, this carries the risk of entrenching structural imbalances between wealthier Member States eager to support their industry, and poorer ones without the means to do so. However, agreeing on an ambitious European-wide industrial policy instrument or fund accessible to all Member States has proven difficult so far.

The EU's hydrogen vision has a prominent international component, not least because of the bloc's announced plans to import large volumes of clean hydrogen. The EU is interested in promoting a functioning international hydrogen market with strong sustainability standards. This would allow it to diversify suppliers, lower costs, create demand for EU-produced hydrogen technologies, and ensure hydrogen's positive climate impact. To this end, the EU and the European Commission are actively participating in shaping multilateral governance on hydrogen, especially with regard to defining common standards and promoting hydrogen valleys. The EU has begun developing bilateral hydrogen diplomacy as well. Its declared ambition is to go beyond securing hydrogen supplies by also supporting local green industrial development in partner countries. However, to move from declarations to reality, the EU will need to prove its ability to mobilize large volumes of public and private financing to support these efforts in the partner economies. This process is still at a very early stage. In parallel, much will depend on the EU's relationship with the United States, which has had its fair share of tensions. It remains to be seen whether the EU succeeds in drawing on its early mover advantage and domestic synergies to remain an attractive investment destination and build resilient and mutually beneficial hydrogen partnerships with countries around the globe.

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Federal Foreign Office

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1. Introduction

With its pioneering hydrogen strategy adopted in July 2020, the European Union has sent a clear message that it views hydrogen as essential to reaching its climate goals and maintaining technology leadership. Following Russia's 2022 invasion of Ukraine, hydrogen development has acquired an additional energy security dimension: the hope is that hydrogen can, in the future, make the EU less dependent on natural gas imports, in particular from Russia. This is expected to happen through both massively ramping up domestic production and sourcing large amounts of clean hydrogen from abroad. This, in turn, requires a solid regulatory framework, including internationally harmonized standards and certification schemes, a cross-border infrastructure within Europe and beyond, large amounts of public and private investment, and strong relations with prospective hydrogen exporters.

The EU has many advantages to draw on in the emerging international hydrogen economy. With a combined population of 447 million, it boasts a large and attractive single market and highly qualified human resources. Europe is home to the world's most innovative electrolyzer manufacturers and has a long history of funding public-private partnerships to promote R&D on hydrogen. It has the world's most developed natural gas pipeline infrastructure that could be repurposed to carry hydrogen, and its key ports such as Rotterdam and Hamburg are actively seeking to position themselves as hubs for handling clean fuels. The EU was the first global player to set ambitious – and legally binding - climate targets. As a result, Europe has emerged as an attractive location for hydrogen projects: as of May 2023, it was the world's leader in announced hydrogen projects, with total investment equaling 117 billion USD, or 35 per cent of the world's total (Hydrogen Council & McKinsey, 2023).

Yet Europe's lead on hydrogen is not uncontested. Other major players - notably the United States - are raising the stakes by offering massive public subsidies to hydrogen producers. However, this is precisely the area where the EU finds itself at a strategic disadvantage. With its origins steeped in economic liberalism and free trade, the EU has traditionally been uneasy with the idea of allowing state subsidies due to their potential to distort the single market. Given that the EU lacks the powers to directly collect taxes and has been, until recently, reluctant to borrow externally, it does not have significant resources of its own to undertake large strategic investments. This role falls mainly to the Member States, whose economic and geopolitical interests, as well as fiscal resources, vary significantly. In this regard, the EU functions rather as a forum for Member States to hash out their positions and disagreements on just how important hydrogen should be, how much and what kind of support is required and whether subsidies should come from national budgets or from a European-level facility – all of which slows down the legislative process. In addition, if hydrogen is to play a major role in the EU's economy, large-scale imports are unavoidable, continuing Europe's energy dependence on third countries, whereas China and the US can be largely self-sufficient.

The challenges the EU is facing in navigating its place in the emerging international hydrogen economy are formidable, and time is running short. This paper will examine the domestic and external dimensions of the EU's hydrogen vision, situating it within the bloc's wider climate and energy policy and recent geopolitical developments. It will discuss key domestic policies, regulations, and funding schemes for hydrogen in Europe, highlighting existing points of contention and the interplay between the EU and Member States. Then, the paper will turn to the EU's international engagement on hydrogen, including participation in multilateral hydrogen governance institutions, bilateral cooperation initiatives, EU efforts to promote cross-border trade in clean hydrogen and derivatives, and European investment into a hydrogen economy in third countries. The external repercussions of EU hydrogen policy will be addressed as a separate point. Finally, the conclusion will summarize the main themes emerging from the paper, as well as the issues the EU will need to tackle moving forward, both domestically and internationally.

2. The EU's strategic vision for a hydrogen economy

The EU has garnered a reputation as a global regulatory power (Bradford, 2019) and has been a pioneer in creating a regulatory framework for the transition to carbon neutrality. Its vision of using hydrogen to decarbonize hard-to-abate sectors is rooted in the steadily expanding scope and ambition of its climate policy. Among EU institutions, the European Commission in particular has emerged as the strongest advocate of the transition to net-zero, including a clean hydrogen economy. In December 2019, the Commission proposed the European Green Deal, a strategy aimed at making the EU climate-neutral by 2050 while promoting sustainable economic growth. This was followed by the "Fit for 55" package in 2021, which contains legislative proposals and amendments to achieve a 55 per cent reduction in greenhouse gas emissions in the EU by 2030 (from the 1990 baseline) and touches on a wide range of fields, including renewable energy deployment, energy efficiency, emissions trading, use of alternative fuels in the maritime industry and aviation, a Social Climate Fund, and many others. The European Climate Law adopted in 2021 includes a legally binding 2050 net zero target and requires all Union policies and legislation to be consistent with this goal. The EU's approach to climate policy features a strong emphasis on timelines and numerical targets, and the bloc has also consciously positioned itself as a "policy laboratory" of sorts, developing and testing innovative policies and instruments that are often adopted by other jurisdictions as well (Rayner et al., 2023, pp. 1–3). The EU has also worked towards tackling emissions beyond its borders, such as from international aviation and shipping, where the key sectoral organizations – the International Civil Aviation Association and the International Maritime Organization – have been criticized for dragging their feet (Vogler, 2023). Geopolitics, too, is beginning to play a more prominent role in shaping the EU's green transition. Faced with geopolitical tensions, supply chain risks, and the intensifying global competition for clean technology leadership, the EU is now seeking to reduce its asymmetric dependencies on other actors, including in the area of key clean technologies, hydrogen and critical raw materials.

In July 2020, the European Union adopted a "Hydrogen Strategy for a Climate-Neutral Europe" as part of the European Green Deal package. The Strategy contains a vision of clean hydrogen as an energy carrier that would play a key role in decarbonizing Europe's economy and helping maintain European technology leadership. The document also lists ambitious targets, such as installing 40 GW of electrolyzer capacity in Europe to produce 5.6 million tons of green hydrogen by 2030. The Covid-19 pandemic played a central role in further galvanizing policy support for hydrogen development in Europe, as the European Commission successfully pushed for hydrogen to be integrated into "green recovery" efforts. In July 2021, the EU introduced NextGenerationEU, an 800 billion EUR economic stimulus package funded by external borrowing. The largest part of the package is the Recovery and Resilience Facility (RRF), a funding resource granted to member states, with 312.5 billion EUR in grants and 360 billion EUR in loans (in 2018 prices) (European Commission 2021b). Green transition is the most important of the RRF's three pillars, and the Facility has emerged as the dominant source of funding for related measures in the EU. In total, the 27 national plans approved under the RRF so far allot 250 billion EUR in funding under this pillar, including 10 billion EUR for hydrogen (European Commission, 2023b).

Russia's invasion of Ukraine in February 2022 has served as yet another accelerator for Europe's hydrogen ambitions. In May 2022, the European Commission presented its REPowerEU proposal, aimed at fully phasing out Europe's dependence on Russian fossil fuels by 2027. This is to be achieved through a combination of demand reduction, diversification of supplies, and accelerated energy transition, including green hydrogen development. The REPowerEU plan has substantially increased

hydrogen targets (albeit non-binding): 10 million tons annually in domestic production and the same amount in imports by 2030. All of a sudden, hydrogen came to be viewed as not only essential for reaching net zero, but as an important element of bolstering Europe's energy security.

With its Hydrogen Strategy and REPowerEU, the EU has articulated an ambitious vision of a future place of hydrogen in its economy. Yet the EU's status as a hydrogen frontrunner is being challenged as global competition accelerates. In August 2022, the United States adopted the landmark Inflation Reduction Act (IRA), complete with an estimated 369 billion USD in financial incentives for energy and climate-related measures. The IRA offers a generous tax credit for clean hydrogen production (up to 3 USD per kg), with the level of remuneration contingent on the amount of lifecycle GHG emissions avoided; a second tax credit targets blue hydrogen production (from natural gas with CCUS). The sheer scale and simplicity of the US scheme have sparked the interest of hydrogen investors worldwide. Faced with a tangible danger of seeing hydrogen investment and technology manufacturing relocate to the US, the EU has swayed towards a more assertive industrial policy.

On 1 February 2023, the Commission unveiled its proposed "Green Deal Industrial Plan for the Net-Zero Age" (GDIP), followed by the legislative proposal on the "Net Zero Industry Act" (NZIA) in March 2023. With the GDIP, the EU aims to promote investment in strategically important projects, facilitate skill development, speed up permitting for new clean energy production sites, and use trade measures to promote diversified and resilient supply chains (Stolton, 2023). In contrast to previous EU initiatives, NZIA directly focuses on the EU's "net-zero manufacturing capacity" (European Commission, 2023b), setting domestic manufacturing targets for selected "strategic" clean technologies. (However, which technologies should be included in this list remains a matter of contention between the Commission and the European Parliament). According to the Commission's proposal, at least 40 per cent of clean energy technologies must be produced domestically by 2030, including an electrolyzer capacity to produce 100 GW of green hydrogen. In an effort to motivate the European cleantech industry to keep its production facilities in the EU, NZIA also envisions anti-relocation incentives (to be granted by Member States from their budgets) such as grants, loans or tax breaks or even, in "exceptional cases," subsidies fully matching those offered by third countries. The downside is that the proposed GDIP and NZIA would not be equipped with new money from the EU but would rely mainly on repurposing existing EU-level funds (such as the Recovery and Resilience Facility and the Innovation Fund), as well as making it easier for Member States to grant state aids as described above.

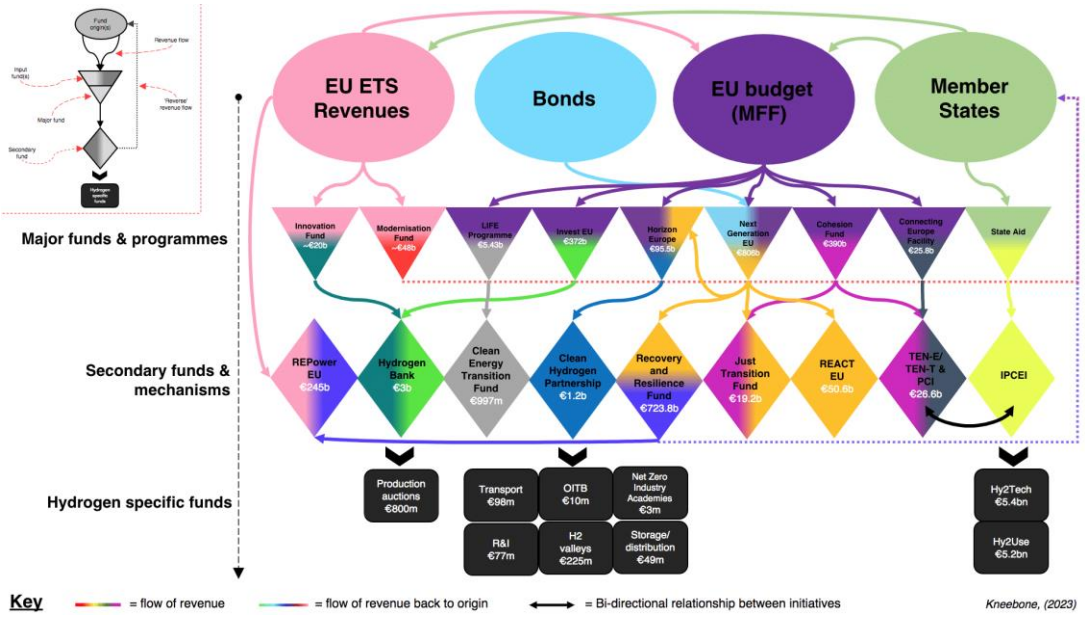
The success of the EU's hydrogen vision to a large extent hinges on the actions of Member States. With limited resources of its own, the EU will not be able to jumpstart a thriving hydrogen economy on its own. On the other hand, excessive reliance on Member States (meaning, in practice, on wealthy member states) carries its own risks, such as entrenching structural inequalities in the EU and undermining competition as a fundamental principle of the European single market. The EU's hydrogen vision will need to be integrated into national strategic planning at the Member State level, with the Commission acting as a coordinator. Indeed, the EU Hydrogen Strategy states that the Commission will "exchange" with Member States on their hydrogen plans using a dedicated informal platform run by DG ENER (European Commission, 2020a, p. 9), yet little coordination has taken place so far. Moving forward, however, Member States will be expected to include information on hydrogen-related developments as part of the updates in their National Energy and Climate Plans (NECPs), which would help the Commission to better steer the alignment process.

3. Policies for domestic hydrogen development

The EU has been developing a mix of policy instruments to support a hydrogen economy. It has a strong track record of funding RD&D on hydrogen and has also launched a dedicated industrial alliance to promote hydrogen projects along the entire value chain. While seeking to strengthen carbon pricing as a key market mechanism, the EU is in parallel designing a dedicated regulatory framework for hydrogen and other renewable gases. This includes both supply-side and demand-side measures as well as infrastructure regulations. While there is a consensus in the EU on the importance of the green transition and the need to position Europe better in the global net zero economy, the three EU institutions involved in the legislative procedure – the European Commission, the European Parliament, and the Council of Ministers - often hold differing views on the design of relevant policies. Some points of disagreement have included the definition of renewable hydrogen, key sources of funding for the EU's green industrial policy (state-level versus EU-level), and rules for a future hydrogen infrastructure.

Aware of the intensifying global cleantech race, the EU and Member States have made billions of EUR available for the transition to net-zero and for hydrogen specifically. However, navigating the EU's complex and fragmented funding landscape is a serious challenge for businesses (Fig. 1). Permitting and licensing delays are another problematic issue for hydrogen investors, which the European Commission is currently trying to address.

Fig. 1. Hydrogen funding in the EU



Source: Kneebone, Florence School of Regulation (2023). https://fsr.eui.eu/hydrogen-funding-flows-in-the-european-union-2023/. Reproduced with permission.

3.1 Research and innovation

Funding research and innovation has been, for years, the most established and visible way in which the EU has supported hydrogen development. In doing so, the EU has put an emphasis on close cooperation with the private sector. Already in 2002, amidst an earlier wave of interest in hydrogen, the EU established the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), which remained active even when the interest ebbed away elsewhere in the world. In November 2021, the EU's Clean Hydrogen Partnership (also known as the Clean Hydrogen Joint Undertaking) was launched as a flagship European public-private partnership and a successor of the FCH JU. Its members include the European Commission and two partners: the fuel cell and hydrogen industrial grouping called Hydrogen Europe and the research community called Hydrogen Europe Research. The Partnership's goal is to promote R&I in hydrogen technologies, with a special focus on their development, commercialization, and scaling, while applying an integrated European value chain approach. The Clean Hydrogen Partnership (CHP) has been allocated 1 billion EUR in public funding from the EU's Horizon research funding framework for the period from 2021 until 2027; this amount will be supplemented with an additional 1 billion EUR from the private partners. The Partnership puts a strong focus on developing so-called "hydrogen valleys" in the EU, i.e. regional hydrogen ecosystems combining several hydrogen uses and often involving research as well. Hydrogen valleys offer a way to pool hydrogen demand and match it with on-site supply, which is especially important for early projects in the absence of a hydrogen transport infrastructure. The Commission's REPowerEU package of proposals presented in May 2022 dedicates an additional 200 million EUR in funding to the CHP to double the number of hydrogen valleys in Europe.

3.2 Regulation

Internationally, the EU has emerged as a pioneer in developing a comprehensive regulatory framework for a hydrogen economy, a process that is still ongoing and faces frequent delays due to the presence of conflicting interests. The EU's approach features a combination of stringent sustainability requirements for renewable and other types of low-carbon hydrogen, sectoral quotas, a reform of its emissions trading system, and rules for the future renewable gas infrastructure.

3.2.1 Defining and certifying clean hydrogen

Consistent with its ambitious climate agenda, the EU has chosen early on to prioritize renewable hydrogen both for domestic production and imports. Other types of low-carbon hydrogen (e.g. blue or nuclear-based) can play a role too, provided they can offer a minimum of 70 percent reduction in GHG emissions compared to unabated fossil-based hydrogen based on steam methane reforming, but they have until now received less political attention compared to green hydrogen.

Having a clear definition under what conditions hydrogen qualifies as renewable is essential for investors as they plan projects and prepare for final investment decisions (Hydrogen Europe & Renewable Hydrogen Coalition, 2022). For a long time, EU institutions and key hydrogen stakeholders wrangled over a compromise on how to design rules and safeguards to ensure that renewable hydrogen is genuinely climate-friendly. Supported by leading climate NGOs, the Commission has consistently called for a stringent set of rules and requirements based on three principles: additionality, temporal correlation and geographic correlation. Additionality requires that renewable hydrogen is produced with new renewable energy capacity, rather than with existing installations, in order to prevent cannibalizing much-needed green electricity from other important decarbonization uses. Temporal correlation refers to matching hydrogen production with the availability of renewable electricity in the grid; in its strictest form it would translate into running electrolyzers only when the wind is blowing or the sun is shining. Finally, geographic correlation requires that the electrolyzer and the renewable energy facility are located close to each other.

The requirements are meant to ensure hydrogen's positive impact on lowering emissions. The downside, however, is that tighter requirements translate into fewer hours electrolyzers can run, lowering their load factor and thereby raising the levelized cost of renewable hydrogen (LCOH). Moreover, proving compliance with the requirements – for example, documenting the provenance of electricity used for hydrogen production on an hourly basis – imposes a significant bureaucratic and economic burden on firms (Parkes, 2022). For this reason, the hydrogen industry and the European Parliament repeatedly voiced concerns – especially after the US adopted the IRA in 2022 – that introducing too stringent rules from the outset would overburden the nascent industry and slow down market ramp-up, risking the flight of potential investors. They thus called for laxer rules and/or longer transition periods.

After a constant back-and-forth between the Commission and the Parliament and repeated delays, the compromise was finally achieved in July 2023 with the adoption of two delegated acts[1] amending Articles 27 and 28 of the Renewable Energy Directive (RED II) on so-called RFNBOs. The acronym stands for "renewable liquid and gaseous fuels of non-biological origin" and includes renewable hydrogen and its derivatives such as green ammonia and green methanol. The delegated acts contain a detailed description of conditions when electrolytic hydrogen is recognized as renewable (see Text Box 1), as well as a methodology for calculating related emissions savings. Importantly, these requirements will also apply to hydrogen imported into the EU.

Agreeing on the definition of renewable hydrogen was an important step. However, at the moment the EU still lacks a harmonized certification scheme for green hydrogen which businesses in Europe (and abroad) could use to prove compliance with the requirements set out in the delegated act. Nor are there any certification bodies accredited by the European Commission to provide such services. The hydrogen industry has been calling for such a scheme, as well as for EU guidance for certification and accreditation bodies (Parkes, 2023a). Currently, two schemes are applying for accreditation with the Commission, including CertifHy, a voluntary European scheme developed by the Clean Hydrogen Partnership. In the meantime, some Member States like Denmark are moving forward with their own national schemes. Harmonized standards and transparent certification mechanisms are also important for international hydrogen projects that are expected to cater to the European market.

[1] A delegated act is a "non-legislative act adopted by the Commission to supplement or amend certain non-essential elements of a legislative act". Delegated acts have the advantage of being easier to adopt compared to a full-scale revision of a legislative act.

Text Box 1. Defining renewable hydrogen in the EU

Green hydrogen, by definition, is produced with renewable electricity. The EU's Delegated Acts to the Renewable Energy Directive Recast (RED II) that came into force in July 2023 set out conditions when electrolytic hydrogen is recognized as renewable (a "RFNBO"). In some cases, proving this attribute is straightforward. This is, for example, when the electrolyzer is directly connected to a dedicated renewable energy facility. Another option is to source grid electricity in a bidding zone where the share of renewables exceeds 90 per cent. However, very few countries in the European Economic Area can satisfy this condition: this mainly applies to Sweden and Norway. In most cases, electrolyzers will have to be connected to the grid in countries with a large share of non-renewable power generation. In this case, hydrogen producers will have to comply with the requirements of additionality, temporal correlation and geographic correlation to have their hydrogen recognized as a RFNBO.

The additionality requirement, which will enter into force in January 2028, is satisfied if the hydrogen producer concludes a power purchase agreement (PPA) with a new renewable energy facility (defined as not older than 36 months). Early movers that begin producing hydrogen before 2028 have the advantage of only needing to comply with the additionality requirement starting from 2038. There is also a special exception for low-carbon bidding zones (mainly nuclear-dominated) with an emission intensity below 18 gCO2eq/MJ. In such zones, hydrogen producers will not have to prove additionality but they will still need to sign renewable PPAs and comply with temporal and geographic correlation.

Temporal correlation requires that hydrogen is produced only when there is sufficient renewable electricity available from the installation with which it has signed the PPA. In a hard-won compromise, the delegated act introduces monthly matching until 1 January 2030 and hourly matching afterwards. Finally, geographic correlation is satisfied when the electrolyzer and the renewable energy facility are located in the same electricity bidding zone (in a majority of cases in the EU, bidding zones are defined by national borders), in a neighboring zone with a higher electricity price, or an offshore bidding zone.

3.2.2 Carbon pricing

Putting a price on CO2 emissions in a cap-and-trade system is a fundamental element of the EU's approach to promoting decarbonization. Currently, the EU's Emissions Trading System (EU ETS) covers some 40 per cent of the EU's emissions. Revenues from the auctioning of ETS allowances are channeled to the EU Innovation Fund and the Modernization Fund (see sections below), which are

important sources of funding for many of the EU's energy transition and hydrogen-related actions. In its present form, however, the EU ETS cannot yet serve as a sufficient incentive for hydrogen investments. Even though the CO2 price temporarily exceeded the 100 EUR threshold in February 2023, it is still not high enough to encourage capital-intensive investments into clean hydrogen in industries like steel or fertilizers. Secondly, the producers and consumers of unabated hydrogen in the EU (e.g. in refineries or ammonia and methanol production) are currently benefiting from free emission allowances issued to protect them from "carbon leakage", i.e. competition from jurisdictions that do not use carbon pricing. Carbon contracts for difference (CCfDs) planned in the EU and already launched in the Netherlands and Germany, are designed to compensate the difference between the current ETS price and the real cost of abatement, strengthening the incentive to decarbonize.

Moving forward, however, carbon pricing will become more important for hydrogen development in the EU. As part of the wide-reaching reform of the EU ETS agreed in May 2023, free allowances for energy-intensive industry will be gradually phased out, while the total number of allowances in the system overall will be steeply reduced, resulting in higher CO2 prices. In parallel, in October 2023, the EU launched the first phase of the carbon border adjustment mechanism (CBAM) for a number of energy-intensive imports, including iron and steel, fertilizers, aluminium, and hydrogen. It mandates EU importers to report on embedded emissions in their products and, from 2026, purchase ETS allowances to compensate for these embedded emissions. The ETS will also be expanded to include maritime shipping (a hard-to-abate sector that is expected to use hydrogen-derived clean fuels in the future), and a separate emissions trading system will be set up for buildings, road transport, and fuels, increasing the pressure to decarbonize.

3.2.3 Incentivizing hydrogen demand

Stimulating demand for clean hydrogen is one of the most difficult challenges at this early stage of hydrogen development. The EU has been ahead of other global actors in developing several policies aimed at incentivizing demand in industry and transport. A central instrument are sector-specific RFNBO quotas for industry and transport, which are included in the new Renewable Energy Directive (RED III) adopted in October 2023. For industry, the quotas are a 42 percent share of RFNBOs in total hydrogen use (both as a fuel and feedstock) by 2030 and 60 percent by 2035, with some caveats.[2] In the transport sector, member states will be obliged to implement a combined quota of 5.5 percent of biofuels and RFNBOs (of which at least 1 percent must be RFNBOs) by 2030.

Despite growing evidence that hydrogen mobility is unlikely to compete with battery electric passenger vehicles in the future, the EU is also introducing mandatory deployment targets for hydrogen refueling infrastructure. The Alternative Fuels Infrastructure Regulation (AFIR), which became law in September 2023, requires member states from 2030 onwards to deploy hydrogen refueling infrastructure serving both cars and trucks in all urban nodes and every 200 km along the entire European TEN-T core network. By providing a sufficiently dense refueling network across the EU, AFIR is expected to raise consumers' interest in hydrogen vehicles and thereby in hydrogen-derived fuels.

The EU has also adopted policies that are likely to incentivize demand in the maritime and aviation sectors. The FuelEU Maritime Regulation, which entered into force in October 2023, does so indirectly by setting stricter carbon intensity reduction targets for vessels above 5000 tons calling at European ports (which are responsible for 90 percent of total GHG emissions from the maritime shipping sector) from January 2025. The targets progressively increase from 2 percent by 2025 to 80 percent by 2050. In addition, the regulation introduces a 2 per cent renewable fuels usage target by 2034[3]. In turn, the

[2] It is possible for member states to discount the contribution of RFNBOs in industry use by 20 per cent under two conditions: a) the member state has contributed to the EU's overall renewable energy target of 42.5 per cent by 2030; and b) if the share of hydrogen from fossil fuels consumed in the member state does not exceed 23 per cent in 2030 and 20 per cent in 2035. This caveat has been introduced to give nuclear-based hydrogen a role in industrial decarbonization.

[3] If the Commission reports that in 2031 RFNBO amount to less than 1% in fuel mix.

ReFuelEU Aviation regulation aims at decarbonizing aviation through biofuels and synthetic fuels (also known as e-fuels, such as e-kerosene made by combining carbon with green hydrogen). The regulation, which will apply for the most part from January 2024, introduces an obligation for aviation fuel suppliers to ensure that all fuel made available to aircraft operators at EU airports contains a minimum share of sustainable aviation fuels (SAF – currently consisting primarily of biofuels) from 2025 including a minimum share of synthetic fuels. SAF quotas progressively increase until 2050, from 2% by 2025 to 70% by 2050, and synthetic fuel shares in the blend should reach 1.2% in 2030, progressively increasing until reaching 35% in 2050.

3.2.4 Regulating future hydrogen infrastructure

If the EU is to use hydrogen at scale, developing some form of a cross-border hydrogen transport infrastructure will be necessary in order to connect renewables-rich areas, e.g. Spain, with industrial demand centers, such as those in northwest Europe. This will most likely be done as a combination of repurposing some natural gas pipelines, building new dedicated ones for hydrogen and adapting sea ports for handling clean fuels. There is a choice to be made between a leaner, "no-regret" infrastructure accompanied by a strong focus on regional hydrogen valleys that would bundle demand, and a dense – and costlier - network that intersects the entire European continent. The latter vision is supported by European gas TSOs, which are understandably interested in securing a future use for their gas pipeline network assets and have launched a "European Hydrogen Backbone" initiative (currently uniting 33 members, including those in the European neighborhood) mapping hydrogen corridors in Europe up until 2040.

Infrastructure regulation is a highly complex terrain, as the Commission has to navigate the diverging interests of Member States, gas TSOs and users. Important and cost-heavy decisions will have to be taken in the absence of clarity on the expected volumes of future hydrogen supply and demand as well as the possibility that some industries will relocate closer to hydrogen production sites. For businesses, on the other hand, not knowing whether there will be hydrogen infrastructure available in a given region has a significant impact on the project design and final investment decisions. There are difficult political choices to be made, such as on how to deal with the valuation and decommissioning of no longer needed gas pipelines, given the expected fall in gas demand in the EU in net zero scenarios. Whereas to date electricity and gas regulation has been designed in silos, hydrogen development requires energy system integration, which will pose a number of difficult governance questions and require skillful EU-level coordination. Also, unlike the EU's ambitious climate target horizons reaching until 2050, infrastructure development planning has shorter timespans: gas network planning is set out in so-called "ten-year network development plans" (TYNDPs) that are developed by gas TSOs. The 2022 edition of the TYNDP included, for the first time ever, plans for hydrogen infrastructure (ENTSOG, 2022).

The Commission's Hydrogen and Decarbonised Gas Package proposal, which was first presented in December 2021 and was still being discussed in trilogues[4] as of November 2023, is supposed to bring clarity to most of the key questions related to hydrogen network regulation. The package offers incentives for expanding hydrogen infrastructure throughout the EU, such as freeing cross-border hydrogen flows from taxes. It also allows the blending of up to 5 per cent of hydrogen into natural gas networks, which is likely to encourage the integration of hydrogen into the gas infrastructure but has been criticized for promoting an inefficient use of the limited hydrogen that is available. Importantly, the package also proposes opening LNG terminals and gas storage facilities for hydrogen, in the EU's bid to make sure its fossil fuel infrastructure is "hydrogen-ready" (European Commission, 2021a). The policy package envisions the creation of the European Network of National Hydrogen Operators (ENNOH), similar to the existing network of gas transmission system operators (ENTSO-G). ENNOH

[4] Trilogues are informal meetings to discuss legislative proposals with the participation of representatives of the European Parliament, the Council and the Commission. Their aim is to reach a provisional agreement on a text acceptable to all parties before the legislative proposal proceeds to the next stage. Trilogues are not limited in number and can take place at any stage of the legislative process.

would be responsible for coordinating hydrogen infrastructure on the basis of Ten-Year Network Development Plans (TYNDPs). Applications for ENNOH are ongoing; until ENNOH is set up and running, ENTSO-G will be responsible for such planning.

In essence, the Commission's approach is to regulate the hydrogen infrastructure in the same way as natural gas markets are regulated today. This includes an important set of consumer rights, unbundling of transmission and distribution, open third-party access, integrated network planning, and independent regulatory authorities. Critics point out, however, that this model, developed over the span of decades, may be overly restrictive for the fledgling hydrogen system (Stam et al, 2023). There need to be sufficient incentives for future hydrogen network operators, as well as ample space for learning and experimentation.

3.3 Investment support and production subsidies

In addition to research funding and regulation, the EU has focused on investment support, production subsidies and promoting an industrial alliance for a hydrogen economy. Currently, two key EU-level sources of funding for the green transition are revenues from trade in emissions allowances within the EU ETS, as well as the Recovery and Resilience Facility, the centerpiece of the NextGenerationEU pandemic recovery package. Funds from the RRF are allocated to and administered by Member States. The EU also offers budget guarantees to leverage private capital for investment in hydrogen. Furthermore, the EU determines conditions under which Member States are allowed to subsidize hydrogen projects from their national budgets though so-called “state aids”.

With the expected rise in CO2 prices, revenues from emission allowances are likely to increase in the future. RRF-based funding, however, is scheduled to run out by the end of 2026, with no possibility of new borrowing in the absence of a major crisis. (Some remaining funds from the RRF are likely to be integrated into new support schemes though). There is thus an open question of how to sustain a sufficiently high level of green investment in the EU beyond 2026, with analysts estimating the resulting gap in green investment at 34-35 billion EUR annually until 2030 (Pisani-Ferry et al., 2023).

In gauging hydrogen investment needs, the EU has put an emphasis on close cooperation with the industry. In July 2020, the Commission launched the Clean Hydrogen Alliance, which brings together a wide range of hydrogen stakeholders from around Europe with the aim to “promote investments and stimulate clean hydrogen production and use” (European Commission, n.d.). The Alliance has identified a large pipeline (750+) of viable hydrogen projects in Europe ready for investment. In 2022, it also organized the important Electrolyser Summit, where European manufacturers pledged to increase the combined electrolyzer manufacturing capacity tenfold, to 17.5 GW by 2025, to put the EU on the path to meeting its REPowerEU targets (European Commission, 2022e).

3.3.1 EU-Level support schemes

Among existing EU-level instruments, some target hydrogen directly and others can support hydrogen-related initiatives as part of their broader mandate to promote energy transition. The Innovation Fund is the most important EU-level funding instrument for low-carbon technologies, including hydrogen. It is also one of the world's largest support programs of its kind. The Innovation Fund was launched in 2020 and has been endowed with the revenues from the auctioning of 450 million EU ETS allowances between 2020 and 2030. Its budget thus depends on the future development of the CO2 price in the EU. Current estimates put it at ca. 40 billion EUR until 2030, a figure that might increase in the future. The Fund focuses on commercializing innovative clean technologies that are past the research stage but are not yet bankable; the EU’s contribution is capped at 60 per cent of the CAPEX+OPEX costs. Since its inception, the Innovation Fund has issued three calls, each of them explicitly open to hydrogen projects. The latest call, issued in November 2022 with a budget of 3 billion, includes a dedicated pillar on innovative electrification in industry and hydrogen, with a price

tag of 1 billion EUR. The Innovation Fund is open to all Member States, as well as Norway and Iceland.

The Innovation Fund is also the main source of funding for hydrogen production subsidies that the EU launched in November 2023. The European Hydrogen Bank, a newly established vehicle with an initial budget of 3 billion EUR, will grant subsidies to domestically produced green hydrogen (and in the future, to imported hydrogen as well). The first pilot Renewable Hydrogen Auctions were launched on 23 November 2023, with a budget of 800 million EUR. They will provide a fixed-premium subsidy of up to 4.5 EUR/kg for renewable hydrogen produced in the EU, Iceland or Norway over a period of max. 10 years. Bids can be submitted until 8 February 2024, and the final selection is expected to be made in April 2024. The second round of hydrogen auctions is planned for spring 2024, with a budget of 2.2 billion EUR (Parkes, 2023b). While European hydrogen stakeholders have welcomed the long-awaited launch of the auctions, there are fears that successful bidders may turn out to be those that use lower-cost Chinese electrolyzers. This would result, in essence, in subsidizing the Chinese electrolyzer industry. There is an ongoing debate in the EU on whether to introduce additional ESG requirements for equipment in order to compensate for the unfair advantage of Chinese elelectrolyzer makers, who have lower labor costs and less stringent environmental requirements (Collins, 2023b).

Another important planned subsidy to be funded out of the Innovation Fund are Carbon Contracts for Difference (CCfDs) announced in the REPowerEU package. The goal of CCfDs is to derisk investment in climate-friendly technologies and processes in hard-to-abate sectors such as steel processing, cement production, and the chemical industry, including green ammonia and green methanol production. CCfDs offer-long term contracts to compensate for the difference between the actual CO2 abatement cost[5] and the reference CO2 price in the EU ETS that companies would have to pay if they kept using conventional fuels. As such, CCfDs facilitate the switch from conventional to renewable hydrogen in industrial processes and promote the deployment of clean hydrogen and its derivatives to decarbonize industry. While EU-level CCfDs have not been introduced yet, some member states such as Netherlands and Germany have already launched their own CCfD-type schemes.

Most projects that have received support from the Innovation Fund are implemented in the more developed Member States, reflecting their better capacity for innovation. Addressing such structural imbalances in the EU is one of the aims of the Modernization Fund, which was set up in 2020 with the goal of supporting ten lower-income Member in their transition to climate neutrality. The Fund's beneficiaries include Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia. The Modernization Fund's budget is funded with revenues from the auctioning of 2 per cent of EU ETS allowances between 2021 and 2030, as well as additional allowances transferred by five beneficiary states (Croatia, Czechia, Lithuania, Romania and Slovakia). A wide range of hydrogen-related actions are eligible for funding of up to 70 per cent of project costs, including renewable hydrogen production and use, hydrogen mobility and the repurposing of natural gas infrastructure for low-carbon or renewable hydrogen. The investments out of the Modernization Fund are managed by the beneficiary Member States themselves and are thus subject to state aid clearance by the Commission. Support can be granted in the form of grants, premiums, guarantee instruments, loans or capital injections, depending on the decision of the beneficiary Member States.

The Just Transition Fund, in turn, focuses on regions most affected by the transition to climate neutrality, especially those with a strong presence of the coal industry. The Fund has a budget of 17.5 billion EUR for 2021-2027 (in 2018 prices; this includes 10 billion EUR from NextGenerationEU) and offers grants, loans and guarantees to promote economic diversification and retraining. It is open to all member states but its main beneficiaries have been Poland, Germany, Spain, and Eastern European Member States. To access support from the Fund, Member States need to identify regions most in need of support and draw up territorial just transition plans up to 2030. Hydrogen-related projects

[5] The abatement cost is the actual cost of deploying climate-friendly fuels or technologies and is fixed in the contract as the CO2 strike price.

can be supported by the Fund if they meet other eligibility requirements, such as assisting in the transition of industries or businesses to a greener model.

Yet another support instrument is InvestEU, a strategic blended finance program. It facilitates the EU's transition to climate neutrality by offering repayable loans to riskier and more innovative projects, with the European Investment Bank acting as the main financial partner. The program offers an EU budget guarantee of 26.2 billion EUR with the aim of leveraging 372 billion EUR in public and private investment. Under its sustainable infrastructure window, InvestEU can support a wide range of hydrogen projects including hydrogen production, supply and storage, hydrogen refueling infrastructure, and others. One prominent example is the EU-Catalyst Partnership, which is managed on the EU side by InvestEU and is funded by Horizon Europe and the Innovation Fund. The partnership promises to mobilize up to 820 million EUR for EU-based projects in four areas, including clean hydrogen (European Commission, 2021c).

In the area of infrastructure, a key strategic investment instrument is the Connecting Europe Facility (CEF). Under the TEN-E (Trans-European Networks for Energy) regulation, cross-border energy infrastructure projects in the EU recognized as Projects of Common Interest (PCI) are eligible for EU funding from the Facility (European Commission, 2021d).[6] The revised TEN-E regulation, which entered into force in 2022, also introduces a new category called Projects of Mutual Interest (PMI) to promote infrastructure links with third countries. Supported types of infrastructure include hydrogen, electrolyzers, smart gas and electricity grids, CO2 networks and energy storage.

The amount of EU funding available for infrastructure projects is relatively limited: the Connecting Europe Facility (CEF), which has an energy pillar for financing PCIs, has a budget of only 5.84 billion EUR for the energy sector for the years 2021-2027. For this reason, obtaining a PCI or PMI status is no guarantee of receiving CEF funding; in fact, most PCIs in the past were implemented without CEF support. However, PCI/PMI projects still benefit from other important advantages, such as political support and faster permitting and environmental assessment procedures. In November 2023, the European Commission published a list of 166 infrastructure projects selected for the PCI/PMI status, including 65 hydrogen and electrolyzer projects (European Commission 2023i). Some examples include the proposed H2Med hydrogen pipeline connecting Portugal, Spain and France, the AquaDuctus pipeline that aims to bring green hydrogen from North Sea offshore wind farms to German industrial consumers (Buljan, 2023), as well as various electrolyzer facilities, hydrogen storage projects, and cross-border hydrogen valleys in Denmark, France, Germany, the Netherlands, Spain, and other countries (European Commission 2023h). The list will still need to be approved by the European Parliament and the Council, with the final decision expected no later than March 2024.

On the whole, the amounts of EU funding available are dwarfed by the gargantuan investment needs for a future hydrogen infrastructure. The Commission estimated that achieving the REPowerEU 2030 goals on hydrogen would require investments in the range of 28-38 billion EUR for EU pipelines and 6-11 billion for storage (European Commission, 2022b, p. 7). Further into the future, the projected costs are even higher. In 2022, the European Hydrogen Backbone Initiative estimated the investment needs for a 53,000 km backbone by 2040 at 80 to 143 billion EUR. This would include some 60 per cent repurposed pipelines and 40 per cent new ones (European Hydrogen Backbone 2022). In a November 2023 report based on updated data, the EHB revised the estimates upwards, citing the rising costs of all components (Martin 2023b). Given the sheer scale of the investment needed, the EU's task of developing a clear regulatory framework and creating the right incentives becomes all the more crucial.

Finally, the EU has worked on bolstering its industrial policy and promoting cleantech manufacturing. In June 2023, the Commission presented a proposal for the Strategic Technologies for Europe Platform

[6] To meet this requirement, they need to fulfil the following requirements: have a significant impact on at least two member states and contribute to promoting market and network integration, enhancing security of supply, promoting energy market competition, and/or contribute to the sustainability transition.

(STEP) to support the uptake and manufacturing of key strategic technologies. STEP focuses on three priority areas: deep and digital technologies, clean technologies (including hydrogen) and biotech. In cleantech, STEP states its aim as supporting "the rapid development and deployment of home-grown clean energy technologies, energy storage system innovations and decarbonisation solutions in the EU and enhance cost-effective, climate friendly and socially fair response to geopolitical challenges (European Commission, 2023f). Initially, this was imagined as the "European Sovereignty Fund" and was expected to become a major EU-level facility open to all Member States and a key tool of European industrial policy. In the shape proposed in June 2023, however, STEP has not lived up to the expectations. It does not come with significant amounts of new funding but rather aims at reshuffling available instruments to use them more efficiently. In practice, this mostly applies to the remaining funds left from NextGenerationEU. It also calls on Member States to provide a top-up contribution of 10 billion EUR, which would go to key instruments like InvestEU. The hope is that this public financing will be able to attract up to 160 billion EUR in private capital (Bourgery-Gonse, 2023).

3.3.2 Leveraging Member State support

Due to the limitations of EU-level funding, much of the public financing for hydrogen-related measures in the EU will have to come from Member State budgets. Acknowledging this, the EU has made it easier for Member States to grant national subsidies (known as "state aids") in the area of green transition. Member States have also made active use of funds from the Recovery and Resilience Facility (RRF). In fact, it was in the national Recovery and Resilience Plans developed to access RRF funds that many member states included support for hydrogen development (some of them for the first time ever), with the combined amount reaching 10 billion EUR (European Commission, 2023c).

Important Projects of Common European Interest (IPCEI), introduced in 2014, are a prominent strategic instrument to support R&D and first industrial deployment of strategically important technologies as well as to promote infrastructure links. IPCEI projects are required to have a strong European component and involve at least four Member States. Obtaining the coveted IPCEI status makes projects eligible for state aids, which has the potential to unlock a significant amount of additional private funding. IPCEI undertakings typically bundle tens of individual projects united by a common theme; each project involves participating companies from several member states. Since 2014, only seven undertakings in total have succeeded in obtaining the IPCEI status, and two of them involve hydrogen. The two large-scale IPCEI, H2Tech (5.4 billion EUR) and H2Use (5.2 billion EUR), both approved in 2022, involve a large number of participating states, companies and projects (H2Tech: 35 companies and 41 projects in 15 Member States (European Commission, 2022g); H2Use: 29 companies and 35 projects from 13 Member States (European Commission, 2022h). They are expected to unlock an additional 15.8 billion EUR in private investment. The two IPCEI support a wide range of projects along the entire hydrogen value chain, including production, transport, storage, infrastructure, and end uses. Yet IPCEI are no silver bullet: applying for an IPCEI status requires a great deal of time and administrative effort, and chances of success are limited. In addition, even when selected, project developers often face long waiting times in accessing the funds to be disbursed by national governments (Martin, 2023a).

Going beyond IPCEI, in reaction to the subsidies announced under the US's Inflation Reduction Act in 2022, the EU has significantly relaxed constraints on granting national subsidies to green transition projects. In March 2023, the European Commission adopted a new Temporary Crisis and Transition Framework (TCTF) to enable Member States to provide support measures in key sectors of the transition to net-zero. It introduces the strongest loosening of state aid rules in the EU to date. The new TCTF extends and amends the Temporary Crisis Framework originally adopted in March 2022 (and subsequently prolonged) to help Member States deal with the economic consequences of Russia's war on Ukraine. The TCTF allows state aid for the production and use of both renewable hydrogen and renewable hydrogen-derived fuels. In addition to prolonging support for renewable energy and energy storage and industrial decarbonization (both of which are relevant to renewable hydrogen), the TCTF introduces a new component in the form of support for the manufacturing of a wide range of green

technologies, including electrolyzers. TCTF enables Member States to provide aid in the form of direct grants or, alternatively, tax incentives, loans or guarantees up to a certain percentage of eligible costs. It is likely to become a key instrument guiding "green" state aid in EU countries. The TCTF allows grant support measures until 31 December 2025.

In parallel, the Commission has also revised the General Block Exemption Regulation (GBER). Under GBER, Member States can implement certain aid measures without going through the time-consuming notification and approval procedure. Going forward, this will also apply to IPCEI projects receiving aid up to 50 million EUR (European Commission, 2023d). The targeted amendment was adopted in June 2023, allowing Member States to support key sectors for the net zero transition, including hydrogen, carbon capture and storage, zero-emission vehicles and energy performance of buildings (European Commission, 2023e). In addition, it has increased the limits for state aid for undertakings in less-developed regions in the EU.

The loosening of state aid rules has been controversial. A number of Member States - including Central and Eastern European states, but also Belgium, Denmark, Finland, Ireland, the Netherlands, and Sweden - have called on the Commission to avoid a subsidy race and emphasized the importance of preserving a competitive single market (Euractiv, 2023). Indeed, these measures bear the risk of creating a multi-speed transition, where stronger and larger economies use their resources to support their industry and harness the benefits of decarbonization, while poorer states fall behind (Quitzow et al 2023).

4. External dimensions of EU hydrogen policy

International cooperation is one of the cornerstones of the EU's vision of a future hydrogen economy. The EU and the European Commission (as well as individual Member States) have sought to shape the rules of engagement in the future international hydrogen market and have actively participated in various multilateral governance fora. In the REPowerEU package of proposals, the EU explicitly acknowledged the need for future large-scale imports of clean hydrogen, both for decarbonization and energy security purposes. It also put in place a (non-binding) import target of up to 10 million tons of hydrogen annually by 2030. In this vein, the EU has begun to develop clean hydrogen partnerships with a range of third countries; this includes not only those countries that are well-positioned to emerge as early exporters but also those with a high renewable energy potential and export ambitions but which find themselves at a very early stage of hydrogen development.

4.1 Multilateral governance

At the global level, the European Union and the European Commission have sought to actively participate in a number of international bodies and fora promoting a hydrogen economy. The EU is a member of the prominent Mission Innovation global initiative, which is a global forum for the governments of leading economies committed to speeding up energy transition. Mission Innovation puts a strong emphasis on public-private partnerships and has a dedicated work stream on hydrogen ("Clean Hydrogen Mission") where the EU plays a key role as a co-lead (together with Australia, Chile, the UK and the US). The Clean Hydrogen Mission has several key priorities, including R&D promotion, reducing the final costs of clean hydrogen to 2 USD per 1 kg by 2030, and reaching 100 hydrogen valleys globally by 2030. The EU, through its Clean Hydrogen Partnership R&D initiative discussed above (in the section on Research and Innovation), plays a particularly important role in the latter effort. It co-funds the Mission Innovation Hydrogen Valley platform, which showcases flagship hydrogen projects around the world to promote global cooperation (Clean Hydrogen Partnership, n.d.). The EU itself is an undisputed leader in the number of developing hydrogen valleys compared to other global regions.

As a member of the Group of 7 (G7), the EU is now also a party to the Hydrogen Action Pact adopted in May 2022. The Pact has the goal of facilitating joint action in the area of Power-to-X, promoting the use of hydrogen and its derivatives and streamlining the implementation of existing multilateral initiatives. The EU also participates in the newly launched G20's International Hydrogen Economy Initiative. In July 2023, G20 members adopted "G20 High Level Voluntary Principles on Hydrogen", where they pledge to promote collaboration on the global harmonization of standards and certification, technological acceleration, information sharing, mobilization of investment and finance, and hydrogen trade in alignment with WTO rules (G20 Energy Ministers, 2023, pp. 15–16).

Furthermore, the European Commission is one of the 25 contracting parties in the International Energy Agency's influential Hydrogen Technology Collaboration Programme (Hydrogen TCP), which dates back to 1977 and facilitates and coordinates information exchange and innovative R&D activities in the area of hydrogen (IEA, n.d.-b). The Commission is also a member of the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), established in 2003, which works on accelerating market deployment of hydrogen and fuel cells as well as policy and regulatory activities. IPHE has two task forces dedicated to hydrogen: the Hydrogen Production Analysis Task Force and the

Hydrogen Trade Rules Task Force. In the past years, IPHE has issued several working papers developing a methodology for determining greenhouse gas emissions associated with hydrogen production. This is likely to have an impact on international clean hydrogen standards. The studies were designed and directed by several individuals, including Tudor Constantinescu, Principal Adviser to DG Energy at the European Commission (IPHE, 2021, 2023, p. 11). Finally, the European Commission is a member of the Clean Energy Ministerial Hydrogen Initiative (CEM H2I), a voluntary multi-government initiative launched in 2019 and coordinated by the International Energy Agency. CEM H2I aims at promoting international collaboration "on policies, programs and projects to accelerate the commercial deployment of hydrogen and fuel cell technologies across all sectors of the economy" (IEA, n.d.-a). Some examples of areas of work include the Global Ports Hydrogen Initiative, a global forum to promote clean hydrogen use in industrial port areas.

4.2 Bilateral hydrogen cooperation within EU climate and energy diplomacy

The EU's plans to import hydrogen has led the bloc to assign this clean energy carrier a more prominent place in its international partnerships. The EU's nascent hydrogen diplomacy is informed and shaped by the Union's wider climate and energy diplomacy. It is also influenced by the Union's interest in greater energy security and diversification of suppliers, reflecting rising geopolitical tensions, growing supply chain risks and the accelerating global competition on clean technologies and manufacturing.

As a self-identified global climate leader, the EU has declared climate and energy diplomacy a "core component" of its foreign policy (Council of the EU, 2023a). As noted in the European Council's conclusions in 2021, "the coherent pursuit of external policy goals is crucial for the success of the European Green Deal" (Council of the EU, 2021). The overarching goal of the EU's climate and energy diplomacy is to accelerate the global energy transition and keep the global temperature rise to under 1.5 degrees Celsius by facilitating the uptake of renewable energy and energy efficiency technologies as well as assisting other nations with climate readiness and adaptation and advocating the phaseout of coal (Council of the EU, 2023a, 2021). In line with these efforts, the EU, together with its member states, has emerged as the world's leading provider of public climate finance (Council of the EU, 2023b). In addition, the EU is planning to use Horizon Europe funds to fund research and innovation cooperation in the area of renewable energy and green hydrogen in partnership with the Union of the Mediterranean and the African Union.

In its External Strategy for Engagement with Energy Partners, adopted in May 2022, the European Commission announced its intention "to conclude hydrogen partnerships with reliable partner countries to ensure open and undistorted trade and investment relations for renewable and low carbon fuels" (European Commission, 2022a). Yet for now, hydrogen diplomacy is still a novel field of engagement for the EU, where it lags behind proactive Member States like Germany or the Netherlands, which have signed a slew of hydrogen accords with nations around the globe (see Nunez and Quitzow, 2023; Stam et al, 2023). Still, the EU has been expanding its cooperation on hydrogen with other states. In November 2022, at COP27 the EU signed memorandums of understanding on hydrogen development with the host nation Egypt, as well as with Namibia and Kazakhstan. (With the latter two, parallel accords on cooperation on critical raw materials were signed as well). In February 2023, the EU signed a Memorandum of Understanding with Ukraine on cooperation in the area of renewable gases, including hydrogen and biomethane. Notably, all these partner countries find themselves at very early stages of clean hydrogen development and energy transition more generally, lack developed infrastructural transport links to Europe or are facing serious geopolitical challenges, most notably Ukraine. Given these obstacles, these partnerships are thus unlikely to result in hydrogen exports to Europe in the near future but have longer time horizons.

In parallel, the EU has also undertaken some efforts to develop cooperation with international hydrogen frontrunners. In 2021, the EU and Japan set up "the Green Alliance", aiming at promoting a green

economy, including hydrogen development. This was expanded in December 2022, when the two signed a Memorandum of Understanding to “spur innovation and develop an international hydrogen market”. However, until now, there have been few activities on that front (EU-Japan Memorandum of Cooperation on Hydrogen, 2022).

Furthermore, the External EU Energy Strategy mentions developing cooperation on hydrogen and other renewable gases with today’s natural gas exporters (European Commission, 2022a). This would allow the EU to build on the existing cooperation and political ties and contribute to the green transition in those fossil fuel-dependent countries. It might also involve the use of (repurposed) fossil fuel infrastructure, such as natural gas pipelines, LNG terminals (Schreiner et al., 2022), and storage facilities, thus avoiding stranded assets. However, progress in this area has been limited so far. In May 2022, the European Commission launched a "Strategic Partnership with the Gulf Cooperation Council", which emphasized the region's role as a potential supplier of renewable hydrogen to Europe. Indeed, the Gulf monarchies like Saudi Arabia, Oman and the UAE are increasingly likely to emerge as early hydrogen exporters. Yet in practice, the EU has actually been criticized for “de-prioritising” relations in the area of energy transition with these countries, failing to engage in serious discussion on hydrogen partnerships with any of them (Bianco, 2023). For now, the GCC countries have mainly focused on developing exports to Asia as well as on efforts to build local green industries, as part of their hydrogen development plans.

Yet even closer to home, hydrogen cooperation with neighbors has uncertain prospects. The UK has an ambitious hydrogen strategy and good gas infrastructure links to Europe, yet it has prioritized the development of a domestic hydrogen market and production facilities, with little attention paid to potential exports to the EU. That said, devolved administrations such as Scotland have shown strong interest in supplying the EU with green hydrogen or derivatives in the future (Weko, 2023). Norway may be a more promising partner, even though its preference for exporting blue hydrogen while using green hydrogen domestically (Skjærseth et al., 2023; see also Kilpeläinen, Quitzow and Tsoumpa 2023) is somewhat at odds with the EU’s emphasis on renewable hydrogen. Still, in November 2023, the planned RWE-Equinor pipeline aiming to bring Norwegian blue hydrogen (and later possibly green hydrogen) to Germany was granted the status of a Project of Mutual Importance (PMI) by the European Commission. This was the only hydrogen infrastructure project in the list of 10 PMIs selected by the Commission (European Commission 2023h).

Canada is another potentially significant future hydrogen producer. Soon after Russia’s invasion of Ukraine, the European Commission and the Canadian Government set up a dedicated working group on the green transition and liquefied natural gas (LNG) (European Commission & Government of Canada, 2023). The group also aims at "lay[ing] the foundation for the development of reliable hydrogen supply chain between Canada and the EU as well as to develop common approaches to standards and the certification of hydrogen” (European Commission, 2023a). However, Canada currently does not have the infrastructure in place to transport LNG or hydrogen to Europe and thus is unlikely to emerge as an early hydrogen supplier to Europe.

As for the United States, its relationship with the EU in the area of energy transition has been complex, marked both by rivalry and cooperation. Some points of disagreement included President Trump's 2018 decision to impose import tariffs on EU steel and aluminium (the tariffs were scrapped in 2021), the US's criticism of the Carbon Border Adjustment Mechanism, or the EU's criticism of the Inflation Reduction Act's protectionist elements. Cooperation, by contrast, has tended to center on issues where the US needs the EU as an ally to counterbalance China, or where the EU needs the US to bolster its energy security. Since 2021, the EU and the US have been involved in complicated negotiations aimed at establishing a transatlantic market for green steel and aluminium, with import tariffs linked to CO2 emissions - a market that is likely to disadvantage Chinese producers. In 2021, they also established the EU-US Trade and Technology Council (TTC), a forum aimed at deepening transatlantic trade and securing critical supply chains, especially for semiconductors. While the TTC does not directly focus on hydrogen, it was within its framework that the US and EU launched the “Transatlantic Initiative on Sustainable Trade” and the “Clean Energy Incentives Dialogue”, which can serve as potential

platforms to discuss a transatlantic hydrogen market in the future. Finally, in October 2022, the EU and US set up a joint Task Force on the IRA in order to address the EU's concerns about the Act's trade-distorting nature. At the same time, the IRA can also benefit Europe: by providing generous subsidies for hydrogen production, it may transform the US into an attractive supplier of competitively priced clean hydrogen to European offtakers, helping the latter achieve their climate targets (Urbasos 2023). This would require close cooperation between the EU and US on aligning rules, standards and certification mechanisms. In the end, however, it remains uncertain whether the US will actually export subsidized hydrogen to Europe in the future.

4.3 Cross-border hydrogen trade

While the EU has set a very ambitious hydrogen import target for 2030, a European framework for trade with third countries is still in the making. There is a benefit to having a coordinated, European-level approach: as Europe's experience during the gas crisis of 2022 painfully demonstrated, the scramble to individually secure energy supplies by Member States led to ballooning prices. In this spirit, the EU is planning to include hydrogen imports in the EU Energy Platform, initiated in April 2022 for joint energy purchases (European Commission, 2022d). The platform is intended to promote security of supply, pool demand and coordinate infrastructure use, with the first-ever EU tender for natural gas successfully taking place in May 2023. However, the timeline for including hydrogen in this mechanism is still unclear.

Another proposed measure is Europeanizing and expanding Germany's H2 Global mechanism, a scheme for subsidizing hydrogen imports from third countries. H2Global features double-sided auctions – for producers of hydrogen and its derivatives on the one end and for hydrogen offtakers on the other. The price difference between the two is compensated by the specially created intermediary company, Hint.co. H2Global offers ten-year guaranteed offtake contracts, helping to derisk investments in hydrogen production and supply to the European market. H2Global's first tender, for green ammonia, took place in November 2022. In June 2023, the EU Commissioner for Energy Kadri Simson and Germany's H2Global foundation announced plans to link the European Hydrogen Bank and H2Global to organize auctions open to funding from all Member States for hydrogen imports from third countries. The details of the scheme are currently being determined. While H2 Global's procedures have been criticized for being excessively bureaucratic, it will play an important role in testing and streamlining processes that may be later introduced in the EU.

4.4 Investing into hydrogen economy in third countries

As a major provider of climate and development finance, the EU engages in a series of bilateral and multilateral initiatives in support of investments in the decarbonization of the energy sector. The EU's Neighbourhood, Development and International Cooperation Instrument – Global Europe (NDICI-GE) framework launched in 2021 is the main instrument for financing the EU's external actions in third countries and includes grants, guarantees and blended finance (Rizzi and Varvelli, 2023). A prominent part of this instrument is the European Fund for Sustainable Development Plus (EFSD+), which may also finance hydrogen-related projects.

The EU's Global Gateway, a major connectivity initiative launched in December 2021 as a response to China's Belt and Road Initiative (Lau & Moens, 2022), is expected to play a stronger role in EU support for hydrogen development abroad as well. Climate and Energy are one of the five priority areas of the initiative, which has been described as a "geopolitical instrument for long-term, sustainable infrastructure investments" (German Federal Foreign Office, 2023). It is supposed to offer partner countries – especially in the Global South – long-term sustainable partnerships that go beyond resource extraction or aid. Aiming to mobilize 300 billion EUR in private and public investment between 2021 and 2027, the Global Gateway adopts a Team Europe approach, pooling the resources of the EU, the Member States, and key European and national financial institutions such as the EIB, the EBRD or

KfW (European Commission, 2021e). To what extent the goal of leveraging large-scale funds will be successful remains uncertain, however. Past efforts have shown that the amounts of private sector finance that EU facilities have leveraged in partner countries is extremely modest (Prontera & Quitzow, 2023).

Global Gateway has recently added a focus on investing in hydrogen economy in partner countries in various regions, although many of the announced projects are still at a very early stage. It is also uncertain how exactly these projects will be financed, although green bonds to be issued by the European Investment Bank and the European Central Bank are reportedly under consideration (Collins 2023c). In Africa, flagship projects include a hydrogen power plant in Morocco, as well as green hydrogen production in Namibia based on the construction of an 85 MW solar plant equipped with electrolyzers (Team Europe, 2023a). According to a joint declaration signed with the Namibian government, the European Investment Bank (EIB) will potentially provide a loan of up to €500 m to finance renewable hydrogen and renewable energy investments (Green Hydrogen Organization, 2023, p. 9). In Kenya, the EU is planning to invest 3.4 billion EUR in climate and nature, with 12 million EUR in grants committed to leverage investment into green hydrogen. Another partner is Mauritania: in October 2023, the EU launched a Team Europe initiative in the country, with the goal of supporting its ambition to become a green hydrogen hub. The initiative is expected to fund capacity building and green energy infrastructure, as well as promote job creation and help put in place an appropriate "legal and fiscal framework" (Shumkov 2023). In particular, the EU Technical Assistance Facility is assisting the country with developing a legal framework for hydrogen called the "hydrogen code" (Weko et al 2023). In Latin America, the EU is planning to support the production of green hydrogen in Chile, Uruguay, Costa Rica, Argentina and Paraguay (Team Europe, 2023b). As part of these plans, in June 2023, the EU launched two cooperation initiatives on hydrogen with Chile. The first is the Team Europe Renewable Hydrogen Funding Platform for Chile, where the EIB and the German development bank KfW pooled 200 million EUR to support Chile's renewable hydrogen industry. The second is the Team Europe technical assistance program that will strengthen the conditions for the promotion of the renewable and sustainable hydrogen economy in the country. Finally, at the European Hydrogen Week in November 2023, the European Commission announced plans to make 2 billion EUR available under the Global Gateway initiative to support the development of the hydrogen value chain in Brazil. This would involve the construction of a 10 GW green hydrogen and ammonia production facility in the Brazilian state of Piaui, to be shipped to industrial offtakers in southeastern Europe (European Commission 2023g).

India, with its much-touted hydrogen potential, is expected to become another important partner. In February 2023, the European Investment Bank officially joined the India Hydrogen Alliance, promising to support large-scale hydrogen hubs and other green hydrogen industrial projects throughout the country with up to 1 billion EUR in indicative investment and a dedicated credit facility (EIB, 2023).

Finally, the EU has also joined forces with other major donors in engaging with a number of fossil fuel-dependent emerging economies on hydrogen and energy transition as part of so-called Just Energy Transition Partnerships (JETPs). JETPs are a financing mechanism offering grants and loans to promote green transformation in partner economies, especially those that are highly dependent on coal or other fossil fuels. The most prominent example is the Just Energy Transition Partnership (JETP) with South Africa. It represents an 8.5 billion USD agreement between the South African government and France, Germany, the US, UK, and the EU to promote the decarbonization of the South African energy sector. In line with the JETP priority areas, the South African government has published a JETP Investment Plan, which includes an investment plan for green hydrogen infrastructure and development projects. The EU is also a partner donor in several further JETPs, with Indonesia, Vietnam, and Senegal; some of these (e.g. the agreement with Vietnam) mention green hydrogen development among other measures (European Commission, 2022f).

4.5 International repercussions of EU hydrogen policies

In addition to the EU's targeted international engagement on hydrogen, its policies and regulations in themselves play an important role in shaping hydrogen developments globally. Sustainability requirements for hydrogen are a prominent example. While in the EU, the prolonged debate preceding the adoption of the definition of renewable hydrogen has been viewed as problematic, the very same concerns about ensuring hydrogen's positive impact on climate are now fueling the debate in the United States. Leading US climate and energy think tanks like Energy Innovation Policy & Technology, the Princeton and MIT research centers (Bergman, 2023), as well as climate NGOs and some business groups, all call for the implementation of strict sustainability requirements. They insist on the same principles that the EU has implemented: additionality, time matching (temporal correlation in EU parlance), and deliverability (analogous to geographic correlation in the EU) (Esposito et al., 2023). In one form or another, the three principles are likely to become part of the US guidelines to be issued by the Treasury as well. In fact, the G20 Voluntary Principles on Hydrogen adopted in July 2023, which mention the harmonization of hydrogen standards, suggest that the US might be moving towards embracing EU rules (Collins, 2023a). Emerging economies like Brazil are also strongly drawing on the EU's sustainability requirements as they design their own regulatory framework for hydrogen.

In addition, given that the EU is expected to become a major import market for clean hydrogen, complying with its rules and regulations will be essential for any potential exporters. In the delegated acts on RFNBOs, the EU has made it clear that the strict definition of renewable hydrogen will apply to imported hydrogen as well. In fact, given that many potential hydrogen exporters have highly fossil-reliant grids (e.g. the Gulf States, Morocco or Australia), compliance with the additionality requirement will be particularly important in these contexts to ensure a positive climate impact (Bellona 2023). Another oft-overlooked requirement is that grid-connected renewable energy facilities supplying an electrolyzer may not have received any other type of production subsidy (King & Spalding, 2023). Thus there are some concerns that the burden of complying with EU requirements may lead potential exporters to opt for other, less demanding, destinations, such as Asia.

Finally, the Carbon Border Adjustment Mechanism (CBAM), in itself the first instrument of its kind globally, has a clear external dimension and will impact international trade flows. The CBAM entered its transitional phase in October 2023. This means that European importers of hydrogen are now obliged to report embedded emissions in their products. In the next stage, from 2026 onward, they will have to pay an EU ETS price for emissions in their imported products (including hydrogen and several industrial goods using hydrogen). This is expected to incentivize non-EU producers to reduce the carbon footprint of their goods to remain competitive.

5. Conclusion

The European Union has invested a great deal of effort in promoting an ambitious vision of a European hydrogen economy. Major shocks like the Covid-19 pandemic and Russia's invasion of Ukraine, but also the US's adoption of the Inflation Reduction Act in 2022, have all served as strong accelerators for the EU's hydrogen plans. The EU is developing a pioneering regulatory framework for hydrogen, complete with stringent sustainability standards, production subsidies and demand quotas for industry and transport. The impacts of EU energy transition and hydrogen policies reverberate far beyond its borders. At the same time, intra-European divisions on issues like the definition of renewable hydrogen, sources of funding for European industrial policy or the future shape of the hydrogen infrastructure have repeatedly delayed the legislative process, affecting investor confidence. There are also fears that with the introduction of hydrogen auctions, European production subsidies may end up supporting Chinese electrolyzer manufacturers. In addition, there is a large looming gap in green transition investment once the RRF funding runs out in 2026. As EU-level funding is limited, the financial backing for the emerging hydrogen economy hinges to a significant degree on Member States' readiness to support it. The intensifying global cleantech race has led the EU to significantly relax its restrictions on Member State-level subsidies in the area of green transition. At the EU level, however, the bloc has not been able to agree on an ambitious new industrial policy instrument. The hydrogen funding landscape in Europe is fragmented and difficult to navigate, and accessing the funds comes with a protracted bureaucratic process. It remains to be seen whether the EU will be able to compete with other global players like the US, which offer sizeable and easily accessible support schemes.

Internationally, the European Commission and the EU are actively involved in the emerging multilateral hydrogen governance. Key focal points have included the harmonization and mutual recognition of hydrogen standards, as well as facilitating the creation of hydrogen valleys worldwide. When it comes to hydrogen diplomacy, however, the EU as a bloc lags behind its proactive Member States like Germany or the Netherlands. The EU's stated ambition is to go beyond securing hydrogen supplies by promoting the "green transformation" of the partner countries' economies, capacity building and local value addition. Focusing on co-benefits and supporting local socioeconomic development is important for attracting partners, especially in the Global South. However, to move from declarations to reality, the EU will need to prove its ability to mobilize large volumes of public and private financing. These efforts are still in their very early phase, and much more will have to be done. The EU will also need to decide on how to best address the IRA-related developments in the US in order to nurture a mutually beneficial energy transition and hydrogen partnership.

Finally, the EU's ambition to import 10 million tons of hydrogen by 2030 has been criticized for being unrealistic and misguiding expectations in partner countries. For large-scale imports to materialize, the EU would need to engage much more proactively with prospective exporter nations, including both emerging frontrunners, like the Gulf states, and future exporters in the Global South. While the latter may have excellent renewable energy endowments, they are faced with much higher costs of capital compared to Europe, the difficulties of mobilizing investment into hydrogen exports in the absence of an international hydrogen market, and a skills gap. Infrastructure for large-scale hydrogen imports to Europe is missing, too. Moving forward, potential exporters will also need to comply with the EU's stringent hydrogen sustainability requirements, which will require close cooperation with the EU on developing and harmonizing or accrediting hydrogen certification schemes. In addition, a number of high-potential hydrogen hopefuls are increasingly interested in downstream value creation, using green hydrogen or derivatives to manufacture industrial goods domestically. This potential reconfiguration of green industrial value chains is likely to have implications for the EU's hydrogen import plans and, more generally, for its green industrial strategy on the whole.

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7. About the author

Yana Zabanova is a research associate at the Research Institute for Sustainability – Helmholtz Centre Potsdam (RIFS Potsdam). As part of the project "Geopolitics of the Energy Transformation – Implications of an International Hydrogen Economy" funded by the German Federal Foreign Office, she focuses on EU hydrogen policy, as well as on the geopolitics and geoeconomics of energy transition and hydrogen more broadly. She is currently completing her PhD at the University of Groningen, where she analyzes renewable energy and hydrogen development in Eurasian hydrocarbon-rich countries from a comparative perspective.

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Contact:
Yana Zabanova: yana.zabanova@rifs-potsdam.de

Address:
Berliner Strasse 130
14467 Potsdam
Tel: +49 (0) 331-28822-340
Fax: +49 (0) 331-28822-310
Email: media@rifs-potsdam.de
www.rifs-potsdam.de

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Prof. Dr Mark G. Lawrence,
Scientific Director, Speaker

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