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HYDROGEN FOR A CLEAN EUROPEAN ECONOMY

FOCUSING THE EU'S FRAMEWORK TO CAPTURE THE OPPORTUNITIES OF HYDROGEN

RHEANNA JOHNSTON & MARION REVEST

High energy prices and fossil fuel price volatility make reducing fossil fuel dependence key to achieving a resilient and competitive EU economy. Direct electrification will play the leading role across sectors, including for 90% of industrial energy demand.[1] Yet hydrogen produced from renewable energy will be critical for key applications. Making the most of hydrogen's potential will require an EU framework that focuses on delivering hydrogen to where it has the most value for a decarbonised and competitive economy.

Reducing dependence on fossil fuels and decarbonising the economy is now understood as the route to competitiveness for the EU.[2] Hydrogen produced from renewable sources[3] will need to be part of this picture, decarbonising industrial sectors where electrification will not be possible.

The EU has introduced a framework of policies and regulations relating to hydrogen since the European Green Deal in 2019. Yet, hydrogen remains small in

[1] E3G, 2024, **An Electrification Action Plan to secure EU industry's future**

[2] E3G, 2024, **Mario Draghi's recipe for competitiveness: decarbonise, invest, industrial policy, and more Europe**

[3] Renewable hydrogen is the only form of hydrogen that can support long-term decarbonisation. While low-carbon hydrogen, which includes blue hydrogen, may be useful in the short term, it is not climate neutral. Further information on types of hydrogen production can be found in the Annex.

scale and high in costs, driving uncertainty around production and demand uptake as well as future costs. While the current framework sets important definitions and kicks off development of an EU hydrogen market, insufficient prioritisation and planning processes risks hydrogen failing to reach the places it is most needed.

In particular, network planning fully independent from incumbent interests and aligned with climate targets is needed to avoid public money and time being spent on developing infrastructure for applications where hydrogen is not the best option. The EU needs a strategic approach to hydrogen, based on clear prioritisation of where hydrogen is most needed, to seize its opportunities for decarbonisation and competitiveness.

Recommendations

To take full advantage of the opportunities of hydrogen for a clean, competitive economy, the EU should:

1. **Set out priority use cases for hydrogen**. This could be done via EU level guidance to support member states in prioritising end uses in their national hydrogen strategies and updating national demand figures accordingly.
2. **Embed hydrogen in an independent, holistic and integrated energy system planning approach** that plans across the changing needs of the electricity and fossil gas systems, and better targets infrastructure and funding towards the identified priority end uses. A first step is ensuring that hydrogen planning processes align with national and EU energy and climate objectives, with guidance from independent climate bodies.[4]
3. **Maintain the definition of renewable hydrogen** and **adopt a robust definition of low-carbon hydrogen** that ensures strong emissions reductions. This will ensure predictability and clarity for the hydrogen market and support its development.

[4] As recommended by ACER in its opinion on the European Network of Network Operators of **Hydrogen (ENNOH)**

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Hydrogen for a competitive EU economy: taking advantage of the opportunities

The EU's climate targets have presented European industry with an urgent challenge to decarbonise, an imperative exacerbated by the increased volatility of fossil fuel prices.[5] Dependence on fossil fuels is now understood as a root cause of Europe's struggle to remain competitive, and decarbonisation a major economic opportunity.[6] There is increasing recognition of the future benefits of greening industry, including reduced exposure to volatile gas prices, more stable electricity prices from high renewables energy systems, and increased competitiveness from clean technology leadership. However, for industry and the EU economy to benefit from this shift away from fossil fuels, the short-term challenges of decarbonisation – including changes to production processes, infrastructure, and high costs – will need to be overcome.

Decarbonising industry, in most cases, means electrification – either directly or indirectly. The potential for direct electrification is growing, as renewable electricity generation ramps up and the costs and availability of electrification improve: more than two-thirds of industry process heat emissions can be cut via direct electrification. An estimated 90% of industrial energy demand can be directly electrified with technologies set to mature by 2035 and policy efforts should focus on supporting the business case for this materialise.[7]

However, a share of industry will remain for which direct electrification will not be an option. In these cases, indirect electrification will be required for these industries to remain a part of Europe's decarbonised economy, including through hydrogen produced with energy from renewable sources ("green hydrogen" or "renewable hydrogen", see Annex for definitions).

Strategic use cases for hydrogen

Hydrogen is best used where there is limited potential for direct electrification or where there are few or no other alternatives to decarbonise (Figure 1). This is where hydrogen will have the greatest potential to support the EU economy's decarbonisation. Factors that favour hydrogen use include where it is used as a chemical feedstock, or in some cases high-temperature heat requirements.

[5] The EU's 2050 Climate Neutrality target and other elements of the Fit for 55 package set long-term decarbonisation targets for industry.

[6] E3G, 2024, **Mario Draghi's recipe for competitiveness: decarbonise, invest, industrial policy, and more Europe**

[7] E3G, 2024, **An Electrification Action Plan to secure EU industry's future**

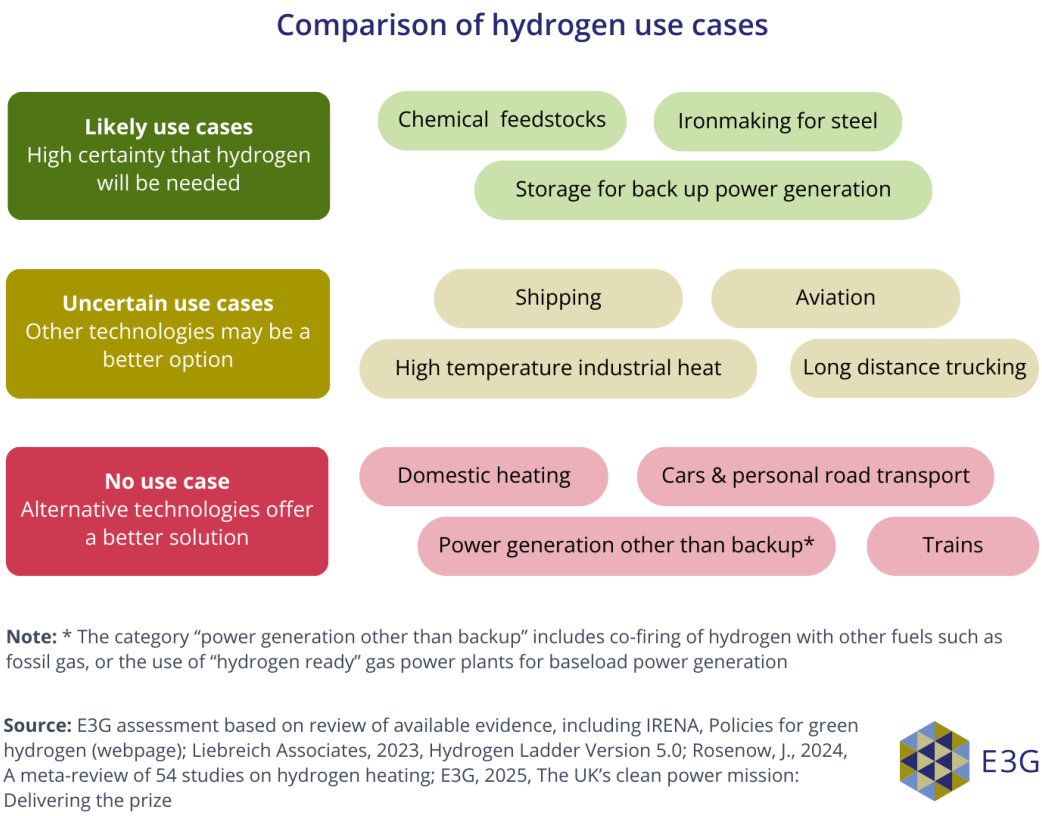


Figure 1: Hydrogen can be used in a range of use cases but not all of them make sense when considering decarbonisation potential, cost-effectiveness and energy efficiency. For most potential applications, direct electrification is more feasible, efficient and/or cost effective.

When considering the cost effectiveness, energy efficiency and decarbonisation potential, green hydrogen will most likely be critical in decarbonising industries such as steel and chemicals. In the longer term, hydrogen may play an important role in long-duration energy storage, where hydrogen generated during periods of high renewables output is stored for back-up electricity generation. Hydrogen may also have potential to support the transition of international aviation and shipping, via the production of sustainable aviation fuels (e-kerosene).[8] Conversely, the use of hydrogen in home heating (where alternative technologies such as heat pumps and district heating are readily available) is an

[8] Transport and Environment, **2023, Hydrogen Use In UK Aviation**

extremely inefficient use case for hydrogen that does not meaningfully support the wider energy transition.

Prioritisation for industrial competitiveness

Green hydrogen production continues to be small in scale and high in cost. Ensuring its uptake in key sectors will require targeted public financial support. To avoid wasting public resources and provide certainty, decision makers must prioritise support for industries where hydrogen will become necessary, while avoiding the use of public funds in sectors where more cost-effective and energy efficient alternatives are available.

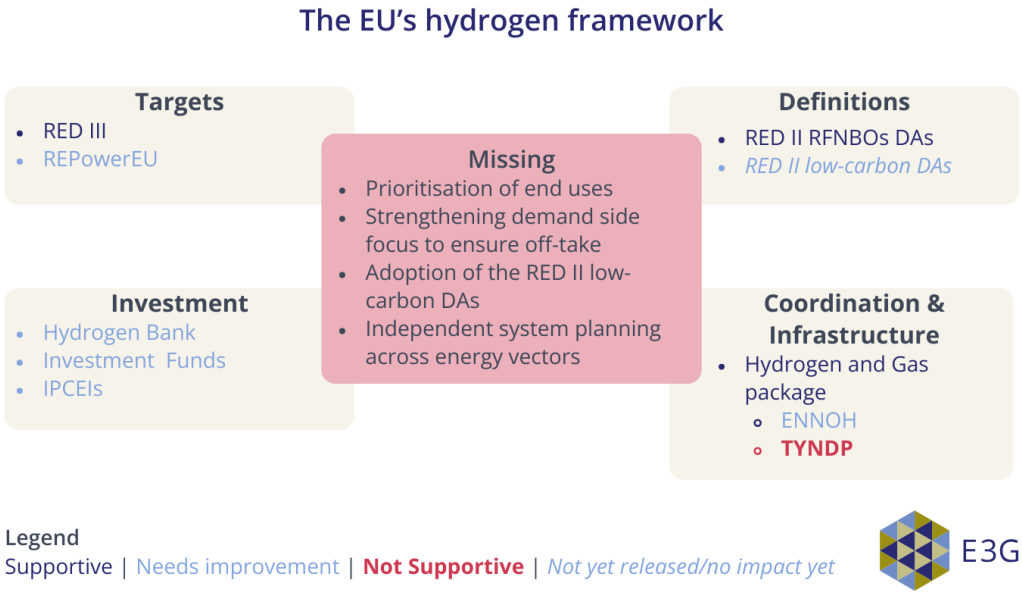
Determining the energy demand and thus hydrogen needs of these priority industries will require planning to become much more holistic. Rather than assuming a direct replacement of existing industry demand (energy or feedstock) with hydrogen, assessments will need to consider improvements in electrification and energy efficiency technologies, changes to industrial supply and value chains, and impacts on geographic location of industry, to accurately determine expected hydrogen demand.

A well-designed policy framework that ensures hydrogen is prioritised and enables such holistic energy system planning, is therefore crucial to a competitive and supported energy transition for EU industry.

The EU's hydrogen framework: what it does and how to improve it

Kicked off by the European Green Deal in 2019 and accelerated by the energy crisis at the end of 2021 and Russia's invasion of Ukraine in 2022,[9] ambitious policies and regulations have emphasised the potential of hydrogen to help achieve the EU's decarbonisation objectives. In recent years, the EU has put in place a broad framework to support the introduction of hydrogen in various sectors of its economy. However, a fully planned approach that prioritises no-regret end uses is not yet in place (Figure 2). **This framework now needs focussing to best address the EU's competitiveness challenge – and key gaps must be filled for it to be effective and make the most of hydrogen's decarbonisation impacts.**

[9] The energy crisis refers to the significant rise in energy prices across Europe, exacerbated by supply chain disruptions and the Russian invasion of Ukraine in 2022.



Note: Important Projects of Common European Interests (IPCEIs); recast Renewable Energy Directive II (RED III); Renewable Energy Directive II (RED II); European Network of Network Operators for Hydrogen (ENNOH); Ten Year National Development Plans (TYNDP); Delegated Act (DAs).

Figure 2: The current EU Hydrogen Framework and its missing pieces for a competitive economy. While some of the legislation is supportive of developing a hydrogen market that captures the full benefits of hydrogen for a clean and competitive economy, other pieces need additional improvements or are not supportive. The RED II low-carbon Delegated Act has yet to be agreed.

Targets

The EU has set itself strong targets for the deployment of hydrogen in its economy:

> Total renewable hydrogen consumption 20 Mt by 2030, set as part of the REPowerEU plan to phase out Russian fossil fuels.[10] This doubled the EU Hydrogen Strategy's original target of up to 10 Mt of renewable hydrogen by the same year.[11]

> At least 42% of the hydrogen used in industry to come from Renewable Fuels of Non-Biological Origins (RFNBOs) by 2030, increasing to 60% by 2035,[12] and hydrogen and e-fuels to account for at least 1% of all fuels used in the

[10] European Commission, 2022, **REPowerEU**

[11] European Commissions, 2020, **A hydrogen strategy for a climate-neutral Europe**

[12] RED III, Article 22a

transport sector by 2030.[13] These legally binding targets were introduced in the recast Renewable Energy Directive (RED III).

RED III missed the opportunity to incentivise or oblige member states to specify which industrial or transport sub-sectors will require the use of hydrogen within their economy. The industrial targets aim to prioritise green hydrogen to displace existing grey hydrogen demand in Europe, implicitly focusing on a limited number of sectors such as refining and fertilisers.[14] The long-term suitability of this approach remains uncertain however, as it is questionable whether this focus will ensure that European industry can decarbonise -- it misses opportunities to prioritise hydrogen's use in sectors where it offers the greatest value.

Furthermore, the ambitious hydrogen consumption projections set during the energy crisis of 2022 now appear overly ambitious – only 12% of the expected 2030 hydrogen production has identified an off-taker,[15] while the stated hydrogen demand assumption of member states by 2030 fall far short of the EU's REPowerEU targets (Figure 3).

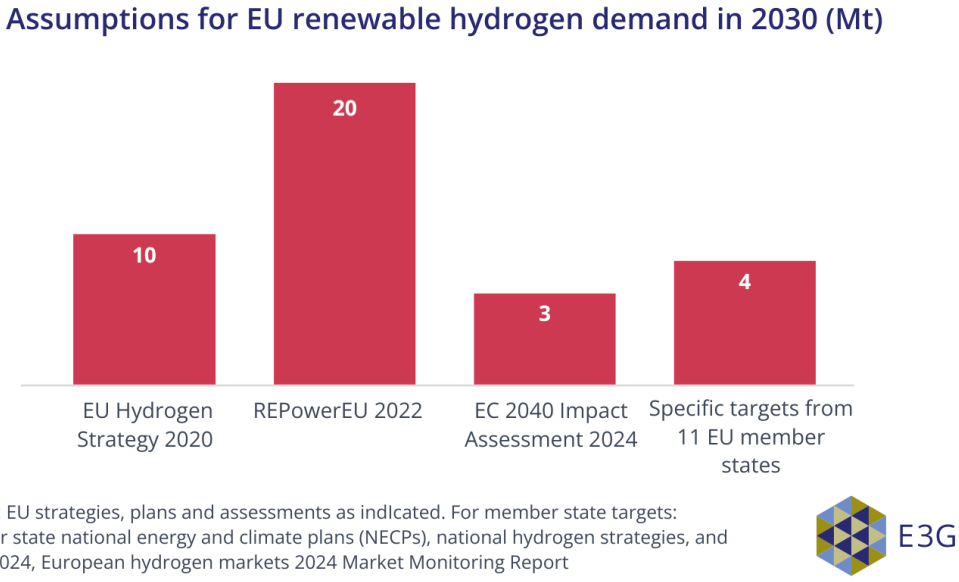


Figure 3. The projected demand for renewable hydrogen shows significant variations in anticipated demand and policy ambition in recent years.

[13] RED III, Article 25

[14] EIA, 2019, **the future of hydrogen: seizing today's opportunities**

[15] Renewable Hydrogen Summit, 2024, **Bloomberg NEF Hydrogen Market Outlook Presentation**

The lack of clear prioritisation and overambitious targets have created uncertainty for the EU's hydrogen market. This makes it harder for investments in supply, network infrastructure and demand to align and to proceed at sufficient pace, and potentially leaves the door open to wasting resources in sectors where alternatives to decarbonisation may become available.

Identifying and prioritising existing and new use cases for hydrogen, for instance, as part of national hydrogen strategies, would support a better understanding of future hydrogen demand as well as the geographic location of demand. It is additionally critical to now develop sector-specific guidance to direct hydrogen deployment toward sectors where it offers the greatest value, as well as set realistic hydrogen targets for 2030 and beyond to provide clarity and direction for the EU's hydrogen market.

Definitions

By setting out clear and ambitious definitions for hydrogen, the EU ensures both legal certainty and the clarity needed to help attract the necessary investments to meet targets and to decarbonise the EU economy.[16] Definitions are important: hydrogen is produced in different ways, and only hydrogen produced without relying on fossil fuels is in line with an electrified future (see Annex).

To meet the ambitious RED III targets, the EU has developed definitions and criteria for renewable hydrogen and low-carbon hydrogen. These are set out in RED II Delegated Acts (DAs).

Renewable hydrogen is defined in the RFNBOs DAs, adopted in 2023. These set out the conditions under which hydrogen production can be considered renewable, including the "additionality" of renewable electricity generation for hydrogen production, as well as "temporal" and "geographic" correlation of renewable electricity generation. However, the low-carbon DAs are still to be adopted by the Commission. The definition of low-carbon hydrogen should be determined based on robust emissions intensity thresholds for all production pathways. For blue hydrogen production in particular, high CO_2 capture rates, regulation around permanence of CO_2 storage, strict standards for methane leakage and transparent, thorough reporting requirements are needed to ensure real emissions reductions[17] (see the Annex for more on the types of hydrogen production). Furthermore, the Hydrogen and Decarbonised Gas Market package

[16] European Commission, DG Energy, 2023, **Renewable hydrogen production: new rules formally adopted**

[17] Joint letter facilitated by the Renewable Hydrogen Coalition, 2024, **Only a robust low-carbon hydrogen definition will reduce emissions and increase security in Europe**

introduced a system of terminology and certification of low-carbon hydrogen, which will only become applicable once the low-carbon DAs are adopted.[18]

EU-level hydrogen investments

Unlocking major investment is necessary to trigger the development of a hydrogen market that can meet the ambitious objectives set by the EU. To that end the European Commission has established a range of funding programmes and initiatives to support the development of a hydrogen market, including for transport and infrastructure development, and research and innovation (see Table 1 in the Annex). The new hydrogen market has thus far been primarily financed through two key mechanisms: the European Hydrogen Bank and the Important Projects of Common European Interest initiative (IPCEIs).

The European Hydrogen Bank's main objective is to lower the cost of hydrogen production, attract private investment and bridge the investment gap through regular pilot auctions: producers submit bids for hydrogen production at a specific cost per unit of hydrogen and winning bids are then supported by EU money, in the form of a fixed premium per kg of renewable hydrogen, to further lower the cost.[19] By directly subsidising the production costs of renewable hydrogen, these bids aim to enable producers to bridge the gap between the cost of production and the price buyers are willing to pay.[20]

The IPCEIs initiative enables state support for hydrogen projects without conflicting with EU State aid rules.[21] Until the end of 2024, member states could receive money from the Recovery & Resilience Facility (RRF) to support IPCEIs as a mechanism to manage the economic consequences of the coronavirus pandemic.

These two mechanisms are joined by several other initiatives and funding sources. While these have collectively facilitated the unlocking of €18.8 billion over 2021–2027[22] to support new European hydrogen projects, they form a complicated web of funding sources and lack targeted prioritisation of specific applications. Rather than a coherent, strategic approach to make the most of

[18] European Commission, 2025, **Hydrogen and decarbonised gas market**

[19] European Commission, 2024, **European Hydrogen Bank pilot auction: 132 bids received from 17 European countries**

[20] ACER, 2024, **European hydrogen markets 2024 Market Monitoring Report**

[21] European Commission, **IPCEIs on hydrogen**

[22] European court of auditors, 2024, **The EU's industrial policy on renewable hydrogen – Legal framework has been mostly adopted – time for a reality check**

public funds, the current watering can approach misses the opportunity to ensure hydrogen funding supports decarbonisation. These investment mechanisms need a more strategic approach, focusing funding on high-value hydrogen applications and the right infrastructure in the right locations. er, the web of potential funding sources and platforms also creates barriers for new projects or smaller producers, who may lack the resources to understand the processes or access the available incentives. Better planning and more transparent funding mechanisms would therefore ensure public funds are spent effectively and with maximum impact.

Coordination and infrastructures

Despite important legislative advancements, barriers still exist to the development of cost-effective and cross-border hydrogen infrastructure – a key prerequisite for the uptake of hydrogen production and off-take. The newly revised Hydrogen and Decarbonised Gas Market package plays a major role in facilitating the establishment of optimal and specialised infrastructure for hydrogen and to ensure more integrated network planning between the current electricity, gas and hydrogen networks. To that end, a new industry body representing network operators of hydrogen (ENNOH) was established to develop a dedicated hydrogen infrastructure in the EU and enable the cross-border trade of hydrogen.[23] ENNOH will formally begin its work in 2025 and should cooperate closely with the EU electricity network operators (ENTSO-E) and the EU gas network operators (ENTSOG) to plan and facilitate the efficient transport of hydrogen across EU borders.

While the establishment of ENNOH is a positive step towards a dedicated hydrogen infrastructure, concerns remain about its independence and impartiality. ENNOH's membership largely overlaps with ENTSOG, the body responsible for gas infrastructure in Europe. This raises questions about whether ENNOH can objectively plan hydrogen infrastructure without undue influence from vested interests in the gas sector. To address these concerns and ensure it is fully aligned with the EU's climate and energy goals, ENNOH should explicitly include climate-related objectives in its purpose, and should involve independent climate expert bodies like the European Scientific Advisory Board on Climate Change (ESABCC) in developing technical rules and network codes, as recommended by the recent ACER opinion on ENNOH.

[23] ENNOH, 2024, **ENNOH**

Furthermore, ensuring hydrogen TSOs are fully certified and unbundled from their parent gas companies is essential for maintaining ENNOH's independence and preventing conflicts of interest in planning the hydrogen infrastructure.[24]

Additionally, ENTSOG's current Ten-Year Network Development Plan (TYNDP) has sparked concerns due to its overly broad approach to hydrogen infrastructure planning. The TYNDP proposes extensive hydrogen networks across Europe without sufficiently addressing critical factors such as trade-offs, regional production capabilities, and specific infrastructure needs aligned with prioritised end-uses and demand scenarios. This lack of strategic focus risks misallocation of hydrogen resources and may lead to inefficiencies in developing an integrated and cost-effective hydrogen network. The mandated collaboration between ENNOH and ENTSOG for the 2025 and 2027 TYNDPs will be a key stress test for their ability to deliver robust analysis,[25] identify infrastructure investments aligned with real economy needs, and set clear timelines for the decommissioning of redundant fossil gas pipelines.

Focusing the EU's hydrogen framework for competitive decarbonisation: recommendations

While the EU has taken significant steps forward, more is needed to make the most of the opportunities hydrogen offers to decarbonise the EU's economy. The EU's framework does not adequately plan for nor prioritise the uptake of hydrogen in the applications that will need it most. Only by clearly prioritising where hydrogen will be needed, can the necessary investments be taken with confidence, coordination between stakeholders be streamlined, and new infrastructure be planned effectively.

The EU can ensure it seizes the opportunities of hydrogen for a competitive and clean economy by:

1. **Setting out priority use cases for hydrogen** to ensure the strategic development of a hydrogen market where infrastructure needs are right-sized and public funds are used most effectively to deliver the greatest value to the European economy. This could be done via EU level guidance for

[24] Council of European Energy Regulators, 2024, **Status review TSO/DSO unbundling Update on implementation of TSO and DSO Unbundling Provisions & "Hydrogen and Decarbonised Gas Markets Package" Outlook**

[25] Gas regulation, Article 43a

member states to include clear prioritisation of end uses in national hydrogen strategies and update national demand figures accordingly.

2. **Embedding hydrogen in an independent, holistic and integrated energy system planning approach** that plans across the changing needs of the electricity and fossil gas systems, and better targets infrastructure and funding towards the identified priority uses. Ensure that hydrogen planning processes such as European Network of Network Operators for Hydrogen (ENNOH)'s Ten-Year Network Development Plans (TYNDPs) align with national and EU energy and climate objectives, and involve independent climate bodies, such as the European Scientific Advisory Board on Climate Change (ESABCC), to provide guidance on these aspects.[26]

3. **Maintaining the definition of renewable hydrogen** and **adopting a robust definition of low-carbon hydrogen** that ensures strong emissions reductions to ensure predictability and clarity for hydrogen market stakeholders. Clear and ambitious definitions will support development of a market which can capture the full decarbonisation benefits of hydrogen and support the competitiveness of industry and the EU's economy.

[26] As recommended by ACER, December 2024, **Opinion 10/2024 on ENNOH's statutory documents** (PDF)

Annex

Common hydrogen definitions based on production methods

The following three hydrogen "colours" are among the most used terms to differentiate between types of hydrogen production. Further colours (including pink, turquoise or white) exist to describe additional production methods not covered here. While these colour terms are commonly used, it is important to set clear definitions for hydrogen production based on emissions intensity to ensure hydrogen use supports decarbonisation.

Green or renewable hydrogen

Hydrogen obtained via electrolysis using renewable electricity to split water into hydrogen and oxygen.[27] Not all hydrogen produced via electrolysis will be renewable – the emissions intensity depends on the source of the electricity generation. Renewable hydrogen therefore requires significant and accelerated deployment of renewable energy.[28] The delegated act of the Renewable Energy Directive's 2023 update,[29] sets out the conditions under which hydrogen production can be considered renewable, including the "additionality" of renewable electricity generation for hydrogen production and the temporal and geographic correlation of renewable electricity generation.[30] Renewable hydrogen is considered to have no associated emissions, resulting in an emissions threshold of 0 kg CO_2eq/kg H_2.[31]

Blue hydrogen

Hydrogen produced from fossil gas combined with carbon capture and storage (CCS) to capture the carbon dioxide released in the process. Blue hydrogen is also sometimes referred to as low-carbon hydrogen, but not all low-carbon hydrogen is "blue".[32] This production route is not climate neutral, because the technology cannot achieve 100% capture of CO_2 emissions. Technically, CO_2 capture efficiency is expected to reach at best 85–95%, but real-world rates are far lower, in the range of 40–80%. The CO_2 must also be stored permanently and

[27] European Commission, 2024, **Renewable Hydrogen**

[28] E3G, 2021, **Hydrogen Factsheet – Supply**

[29] European Union, 10 February 2023, **Commission Delegated Regulation (EU) 2023/1184 establishing a Union methodology setting out detailed rules for the production of renewable liquid and gaseous transport fuels of non-biological origin**

[30] European Commission, 2024, **Renewable Hydrogen**

[31] IEA, 2023, **Towards hydrogen definitions based on their emissions intensity**

[32] Low-carbon hydrogen may also refer to other forms of hydrogen production which do not meet the criteria set out by the EU's renewable hydrogen definition. This could for example include hydrogen produced by electrolysis but using grid electricity that is not sufficiently renewables-based.

without leakage.[33] In addition, upstream emissions from methane leakage (during production and transport) are a significant share of the emissions intensity of hydrogen production from fossil gas.

Based on a typical carbon capture rate of around 60%, the emissions intensity of blue hydrogen would likely be in the range of 5–8 kg of CO_2eq/kg H_2, including methane leakage.[34] The EU is currently finalising the delegated act that will set out a definition of low-carbon hydrogen.

Grey hydrogen

Hydrogen produced from fossil gas without use of CCS to capture the carbon dioxide produced. This is currently the most common form of hydrogen production. The average emissions intensity of grey hydrogen is estimated to be in the range of 10–14 kg CO_2eq/kg H_2,[35] twice the emissions of blue hydrogen.

EU hydrogen funding programmes and initiatives

Table 1: EU hydrogen funding

EU funding programme / initiative	Funding period	EU fund (€bn)	Project type
Innovation fund – Hydrogen bank	2023	0.719	Market development
Innovation fund – projects	2021–2023	2.202	Market development
Important Projects of Common European Interest (Recovery & Resilience Facility)	2020 onwards	13.62	Market development
Connecting Europe Fund	2021–2027	0.2524	Transport & infrastructure deployment
LIFE programme	2021–2027	5.43*	Market development; Research & innovation development
European Regional Development Fund & Cohesion Fund	2021–2027	73.21*	Transport & infrastructure deployment; Research & innovation development

[33] E3G, 2022, **Making carbon capture work a framework to facilitate high-value uses in Europe**

[34] IEA, 2023, **Towards hydrogen definitions based on their emissions intensity**

[35] IEA, 2023, **Towards hydrogen definitions based on their emissions intensity**

EU funding programme / initiative	Funding period	EU fund (€bn)	Project type
Horizon Europe – Clean Hydrogen Partnership	2021–2027	1.2	Research & innovation development
Total	**2021–2027**	**18.8**	

Notes: *Not exclusively earmarked for hydrogen projects

Sources: ACER, 2024, **European hydrogen markets 2024 Market Monitoring Report**; European Commission '**Horizon Europe**' ; European Commission '**LIFE programme**' ; European Commission '**European Regional Development Fund, Cohesion Fund and REACT-EU**'; Special Court of Auditors, 2024, **The EU's industrial policy on renewable hydrogen 2024**

About E3G

E3G is an independent climate change think tank with a global outlook. We work on the frontier of the climate landscape, tackling the barriers and advancing the solutions to a safe climate. Our goal is to translate climate politics, economics and policies into action.

E3G builds broad-based coalitions to deliver a safe climate, working closely with like-minded partners in government, politics, civil society, science, the media, public interest foundations and elsewhere to leverage change.

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