

Policy Brief: A sustainable hydrogen strategy for the EU



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Key points

- The production, transportation, and use of hydrogen come with significant environmental impacts, will require large public subsidies, and pose risks of fossil lock-in.
- High production costs, uncertain technology uptake, and intrinsic inefficiencies of hydrogen as an energy vector highlight that direct use of renewable electricity is preferable for most end uses – especially domestic heating and light-duty transport.
- Renewable hydrogen is set to play a role in the decarbonisation of industrial and transport applications where direct electrification is not possible.
- Stringent criteria must be adopted in relevant EU legislation to ensure that renewable electricity used to produce hydrogen comes from additional renewable generation capacity and does not compete with the decarbonisation of the energy system. A uniform system of guarantees of origin for renewable hydrogen must be put in place. Any flexibility provision to stimulate the uptake of electrolysis in the short term must be time-limited.
- EU and state funding should follow these strict sustainability criteria and focus strategically on no-regret hydrogen uses. EU targets for renewable hydrogen use in industry and transport must be proportional to the demand from indispensable uses, and public subsidies in transport infrastructure must only support electric recharging.

About this report

This policy brief was developed by the European Environmental Bureau in the context of the PAC 2.0 project, supported by Germany's Federal Ministry for Economic Affairs and Climate Action (BMWK). The PAC 2.0 project investigates the technical, political, and societal framework conditions that must be established to implement an ambitious and rapid energy system decarbonisation.

The opinions expressed within this Policy Brief are solely the EEB's and should not be taken to necessarily reflect the views of the funder or partners.

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The use of fossil fuels needs to be reduced drastically and very swiftly. As a carrier of clean energy, hydrogen may help in this transition. As an inefficient fuel serving to justify fossil infrastructure, it is also a potential danger to rapid decarbonisation.

The European Union (EU) is promoting production capacities and infrastructure for hydrogen as a central building block for decarbonising the EU's economy under the Fit-for-55 programme¹, in the European Hydrogen Strategy², and launched the European Clean Hydrogen Alliance. Most recently, the European Commission (EC) proposed a 'hydrogen accelerator' under the REPowerEU plan³ aimed at stepping-up **renewable hydrogen production targets to 10 million tons (Mt) produced annually in the EU, plus 10 Mt of imports annually by 2030.**

Given that hydrogen is currently not commercially competitive with other sources of energy, achieving these targets will require significant public subsidies and investments. A large part of the latter could be drawn from EU funding instruments such as the EU's post-coronavirus Recovery and Resilience Facility (RRF), Connecting Europe Facility (CEF), Cohesion Funds, Innovation Fund, Just Transition Mechanism, and InvestEU. The support of the hydrogen industry via EU funds comes with the responsibility to ensure that the increase in hydrogen capacities is actually in the societal interest and does not divert funds from more cost-effective climate solutions.

This Policy Brief argues that public policy must carefully direct subsidies to ensure hydrogen is produced sustainably and, given its high environmental and fiscal cost, only in the most productive uses.

While zero-emission gases (in particular hydrogen produced using renewable electricity) will undoubtedly have a role to play as part of the EU's decarbonisation toolbox, for environmental and economic reasons these plans should be considered with great caution. In particular, **the use of hydrogen should be limited to specific applications in the industrial and transport sectors.**

Detailed modelling of the EU's energy system in the Paris Agreement Compatible (PAC) scenario shows that switching to direct electrification, coupled with increasing energy efficiency in buildings, industrial processes, and transport modes can deliver most of the progress needed to decarbonise our energy systems. Excessive reliance on hydrogen would be an expensive and environmentally damaging error – by

¹ Under the "Fit for 55" package, the European Commission (EC) aims to review the EU's climate policies to meet the European Union's (EU) target of a 55 per cent net reduction in greenhouse gas (GHG) emissions by 2030 relative to 1990 levels.

² For instance, the European Hydrogen Strategy called for 40GW of electrolysers to be installed in Europe by 2030, with a further 40GW in Europe's neighbourhood.

³ The "REPowerEU" plan, published by the EC in May 2022, sets out a series of measures and recommendations to rapidly reduce the EU's dependence on Russian fossil. It includes several legislative initiatives aimed at accelerating the roll-out of renewable energy and reducing energy consumption throughout the EU, supported by a financial envelope to be mobilised using funds from the Recovery and Resilience Facility (RRF) in the EU countries' National Recovery and Resilience Plans (NRRPs) to support the needed investments.

requiring more state subsidies than direct electrification, consuming vast amounts of resources, and delaying the end of fossil gas use. The PAC scenario results in an uptake of renewable hydrogen of 8,9 Mt by 2030 in Europe's final energy demand⁴.

Considering those results, **the current EU goals of 20 Mt by 2030** – including 10 Mt in domestic production and 10 Mt in imports – **look very high** with respect to the EU's Paris Agreement-compatible decarbonisation pathway and expected demand for renewable hydrogen. Meeting the electricity needs for such a large production of hydrogen must not distract from the priority of energy savings and renewables rollout: Even if the ambitious hydrogen targets are met, 20 Mt of hydrogen will cover around 5% of the EU's final energy demand in 2030 (how much precisely depends on success in reducing energy demand). Given the REPowerEU's target of 45% renewables share in the EU energy mix by 2030, hydrogen is close to irrelevant for most of the use cases over the coming decade. **For environmental, economic, and climate reasons, hydrogen use must be limited and well-regulated, and public subsidies well-targeted.**

1. Hydrogen comes with significant environmental and financial costs

Hydrogen impacts the environment

Hydrogen production has significant environmental impacts in terms of carbon emissions, water use and leakage.

While the consumption of hydrogen does not generate carbon dioxide (CO₂) emissions, its **production can be carbon intensive**. Hydrogen is classified in different colours depending on the method of production:

- **Grey** hydrogen is produced using fossil gas, therefore emitting CO₂ in the process.
- **Blue** hydrogen is produced using fossil gas, if CO₂ emissions are captured and stored.
- **Green** hydrogen is produced using renewable electricity; this is the only type with no emissions during its production.
- **Turquoise** hydrogen is produced by splitting fossil gas into its components, hydrogen and carbon, by pyrolysis at high temperatures. Instead of CO₂, solid carbon is produced, which is then materially bound. Turquoise hydrogen is at an early stage of development.
- **Purple** hydrogen is produced using nuclear energy, with the associated environmental risks, unresolved waste issues, and uncontainable costs.

Today, most hydrogen produced worldwide is “grey”, emitting vast amounts of carbon dioxide. Producing fossil gas also releases methane, which has a particularly high global warming potential. While the fossil

⁴ The figures in the PAC scenario – i.e. 3,9 Mt in transport and 4,9 Mt in industry's final energy demand by 2030 – refer to the EU-28, i.e. including the UK. Excluding UK would result in an even lower figure. Original figures in TWh, dataset available [here](#).

gas industry has pushed for adopting carbon capture and storage (CCS), even such blue hydrogen could emit more carbon dioxide across its entire supply chain than simply burning fossil gas unless strict sustainability criteria are put into place – enforcing a high carbon capture rate and low methane leakage.

In addition to greenhouse gas (GHG) emissions, hydrogen entails environmental costs stemming from **water use and hydrogen leakage**:

Water is crucial for hydrogen production. The electrolysis process at the origin of most hydrogen consumes up to 9 litres of water for every kg of hydrogen. The EC's Joint Research Centre (JRC) estimates that using 16-20% hydrogen in the EU's energy mix would result in freshwater use equal to a third of what the EU's energy sector consumes today. Moving to CCS could further increase water use in power generation by almost 60%, leading to additional water consumption by 200% in 2050. Not only is the energy sector already competing for freshwater resources with food production and drinking water needs, but climate change is also reducing the availability of freshwater resources. Water for electrolytic hydrogen production can also be obtained through the desalination of seawater. Today, the most efficient technology in that respect is reverse osmosis, which requires between 3.5 and 5 KWh of energy per cubic meter of clean water produced. Although negligible when compared to the energy needed to power the electrolyzers themselves, desalination of seawater also increases the energy requirements of renewable hydrogen production cycles.

Leakages may occur during production, transport, and consumption of hydrogen. Unlike carbon dioxide, hydrogen does not have a direct effect on the climate. However, it is considered an indirect GHG since it **can affect the behaviour of other pollutants**. Increased hydrogen in our air means that methane, the second most important global warming gas, would stay in the air for longer and have a stronger climate impact. More hydrogen would also increase ozone levels - the third most important climate warming gas - in our atmosphere. Close to the ground, ozone is unhealthy and attacks plants, reducing crop yields. Hydrogen can also damage the climate by affecting water vapour in the atmosphere. While the extent of these indirect effects appears limited, addressing them drives up the costs of climate mitigation via hydrogen.

Developing sufficient renewable electricity capacity to allow the EU's domestic production of 10 Mt/y by 2030 renewable hydrogen is a challenge and may hinder the decarbonisation of the EU's energy system. Producing 10 Mt/y of renewable hydrogen will require around 500 TWh/y⁵ of electricity – more than 60% of the additional wind and solar capacity planned for 2030 under the REPowerEU plan⁶. In absence of strict additionality criteria, the **production of renewable hydrogen in Europe will thus compete for renewable electricity** meant to decarbonise other segments of our economy and ultimately thwart the EU's climate ambition. Furthermore, should electricity sourced from fossil fuels be used to power

⁵ For comparison, in 2020 the EU's total electricity production from wind turbines and solar panels was 537 TWh.

⁶ i.e. roughly 885 TWh/y of new renewable electricity generation capacity by 2030.

electrolysers, the hydrogen produced would result more carbon intensive than hydrogen obtained directly from fossil fuels.

Furthermore, there are **resource-use implications** in the hydrogen production value chain. Using renewable hydrogen rather than direct electrification requires more renewable electricity generation capacity to achieve the same final energy delivery⁷. This means more photovoltaic (PV) cells and wind turbines and, consequently, more raw materials for their production and more land and sea surfaces for their installation. The manufacture of electrolysers entails further concerns regarding the scarcity and environmental footprint of iridium – a rare mineral used to produce the components of proton exchange membrane (PEM) electrolysers – and nickel – used to produce alkaline electrolysers.

Hydrogen is expensive

In addition to the environmental footprint is the cost of hydrogen production. Although hydrogen is the most common element in the universe it is mostly bound up in compounds such as hydrocarbons and water. Energy is needed to break the chemical bonds to release it. **Energy costs are thus crucial to determine the costs of hydrogen production.**

For hydrogen produced via electrolysis with electricity from the grid – presumably the most common set-up for the foreseeable future – electricity prices are crucial: Electricity costs account for more than 50% of renewable hydrogen production costs. The recent increase in electricity prices due to increased fossil fuel prices has thus led to increases in the cost of hydrogen also – even if this hydrogen is renewable. Odenweller et al. (2022) forecast costs for hydrogen in Germany of 150-200€/MWh for the coming decade including cost reductions due to significant technological progress. With these costs in mind, **hydrogen will find it difficult to compete with electricity for all use-cases for which direct electrification is an option**. However, for industrial uses requiring high temperatures where direct electrification is difficult, hydrogen is competing with fossil gas in particular. Importantly, hydrogen costs are currently around four times higher than fossil gas. The cost disadvantage of hydrogen is predicted to decrease, but hydrogen costs are predicted to be more than double the cost of fossil gas in 2050. This cost disadvantage could be overturned by carbon pricing – however, CO₂ prices of over 750€ per ton are necessary for cost parity today, decreasing to 460 in 2030 and 341 in 2050. This compares to current CO₂ prices of under 100€. Based on a scenario of rising CO₂ prices, cost parity will not be reached before the early 2040s in Germany. If electricity consumption for hydrogen production is exempted from the grid connection component of electricity prices, cost parity can be achieved in 2030 with CO₂ prices of 200€.

As a result, consumers and firms will think carefully about where to employ hydrogen. The high costs are partly a result of intrinsic inefficiencies stemming from the production, transport, and storage of hydrogen. For comparison, using renewable electricity stored in a battery requires between 14 and 29 kWh to cover

⁷ Typical efficiencies of electrolysers lie between 75 and 80%. Further losses of between 5 and 35% result from the compression or cooling of hydrogen in order to store and transport it. For on-site use, a conversion efficiency of 70% can be assumed. In the case of a reconversion of hydrogen into electricity through fuel cells, another 50% of the energy is lost as heat, resulting in an overall process efficiency of 35%.

a 100 km distance, while using a hydrogen fuel cell car requires between 48 and 63 KWh. In other words, an electric vehicle is more than twice as energy efficient as a hydrogen car.

Extremely energy intense products are often located close to places where energy is abundant – for example this has led to Iceland, home to plentiful geothermal resources, becoming a major exporter of aluminium. However, producing hydrogen in such locations creates the next challenge: not only is the production of hydrogen costly, **transportation is a challenge too**, as hydrogen at room temperature is a very voluminous and flammable gas. One option is to transform hydrogen into ammonia. While transporting hydrogen in form of ammonia has the advantage of a much more energy dense vector, the overall cost-efficiency of this solution is unclear, as cracking ammonia to turn it back into hydrogen requires large amounts of electricity and heat, thereby making this form of conversion highly inefficient⁸. Moreover, ammonia is toxic and requires stringent safety procedures. The associated costs and risks again favour direct electrification wherever possible, especially for more dispersed uses like transport and heating. Note that high transport costs of hydrogen may make it much more interesting to import energy-intensive fuels and materials such as green ammonia to replace grey ammonia or e-kerosene for aviation.

For all these reasons, several scenarios⁹ modelling an energy system consistent with the Paris Agreement include only a small role for hydrogen in the EU's energy mix, limited to the decarbonisation of hard-to-abate sectors.

2. Current hydrogen policies risk delaying the end of fossil fuels in Europe

Hydrogen as a justification to keep investing in fossil gas

Renewable hydrogen is set to play a role in the decarbonisation of industry, aviation, and maritime shipping. Infrastructure planning and the creation of clusters of production and use are thus important to minimise the need of transporting hydrogen and secure sufficient renewable energy supplies. However, oversized plans for a hydrogen economy are currently being used to justify further investments in fossil gas infrastructure. The EU Hydrogen Strategy strongly mirrors the fossil gas industry's wish list: subsidising an oversized European fossil gas infrastructure on the formal grounds of transporting hydrogen, insufficiently prioritising renewable 'green' hydrogen over fossil-based 'blue' hydrogen in the name of "technology neutrality", and a strong focus on hydrogen imports. Therefore, financial resources labelled as investments in renewable hydrogen might in fact be used to artificially extend the life cycle of fossil gas infrastructure and result in the lock-in of fossil fuels use in Europe.

Furthermore, following the recent energy price crisis, the EU has allowed countries to invest EU funds provided under the Recovery and Resilience Facility on new fossil gas infrastructure provided that it is

⁸ Catalytic cracking of ammonia to generate hydrogen for fuel cell applications results in an overall conversion efficiency of 61 to 68.5%.

⁹ Besides the PAC scenario, examples include the IEA's Energy Technology Perspectives (ETP) scenario, the JRC's Global Energy and Climate Outlook (GECO) 1.5, Navigant's "minimal gas" scenario.

“hydrogen-ready”. But the concept of “hydrogen-ready” infrastructure is problematic. As the different properties of methane and hydrogen require very different components to handle their flow, hydrogen-ready infrastructure built today would still need to be retrofitted to handle increasing volumes of hydrogen while addressing the risk of leakages¹⁰. In absence of clear plans to actually move toward hydrogen use, infrastructure investments justified by the hydrogen economy would essentially finance new gas infrastructure, thereby posing serious **risks of carbon lock-in**.

As presented in the REPowerEU plan, the European Commission expects that 1.3 Mt of green hydrogen¹¹ will be blended into the fossil gas network by 2030, raising the spectre of even **higher heating costs for consumers with only marginal emissions reductions**. In its analysis, the EC states that this would replace Russian gas by only 4.7 billion cubic metres (bcm), i.e. around 3% of total Russian volumes imported in 2021. In fact, blending 20% hydrogen into the fossil gas grid – the maximum technical limit for existing boilers and cookers – would raise consumer costs by one third while, according to the International Renewable Energy Agency (IRENA), it would only reduce carbon emissions by 6-7%. This is because hydrogen has roughly three times less energy density by volume than fossil gas. Often portrayed as an intermediary step towards full substitution of fossil gas with hydrogen, **blending hydrogen into the fossil gas grid would rather serve to greenwash the gas industry’s activities** through the use of hydrogen-ready or hydrogen-mix boilers, which would prevent the switch to more efficient and cost-effective options such as electric or geothermal heat pumps.

The danger of relying on expensive energy products with the promise of enabling current technologies to continue functioning has also been highlighted in the context of hydrogen-based e-fuels, where Ueckerdt et al. (2021) note that **“Neglecting demand-side transformations threatens to lock in a fossil-fuel dependency if e-fuels fall short of expectations.”**

A future hydrogen transport network should reflect growing needs and projected demand. However, that network will be smaller than the current fossil gas network – the reduction in size is likely to be more than 50%.

3. Towards sustainable use, production, and grids for renewable hydrogen

Building on the decarbonisation pathway identified in the PAC scenario, we present a no-regret vision for hydrogen use, production, and infrastructure development needs to guide the uptake of renewable hydrogen in and beyond Europe.

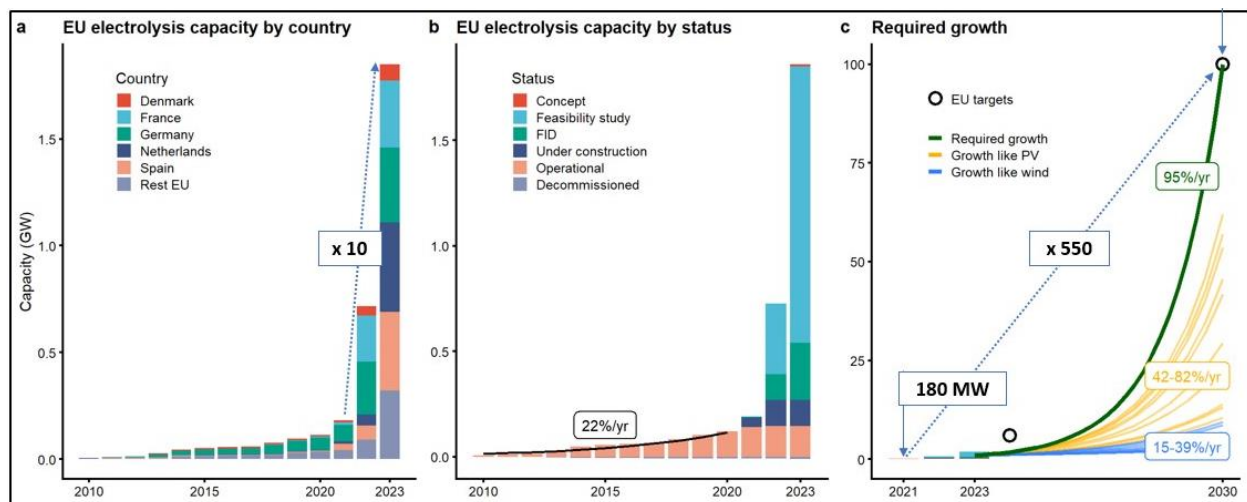
Renewable hydrogen should only be dedicated to the decarbonisation of sectors and applications where direct electrification is impossible. It is also crucial to ensure that renewable hydrogen actually comes from

¹⁰ Due to the fact that hydrogen molecules are much smaller than methane, i.e. hydrogen weighs roughly 1/8th with respect to a methane molecule.

¹¹ Producing 1.3 Mt of green hydrogen translates into 65 GW of renewable generation capacity needed to cover the electricity need of electrolyzers.

additional renewable electricity generation capacity, while any hydrogen network development will have to be limited and aimed at clustering consumption and production sites.

Producing hydrogen through electrolysis not only entails high financial and environmental costs, but there are also **uncertainties surrounding the feasibility of developing significant electrolysis capacity** in the near future¹². In fact, reaching the EU’s 2030 goals as outlined in REPowerEU for domestic renewable hydrogen production would require an installed electrolysis capacity of 90-100 GW by the end of this decade. As highlighted in graph 1 below, this trajectory entails an unprecedented growth rate (i.e. in the order of 95% annual growth) of electrolysis capacity – much higher than the historical growth of wind and solar power, used as a benchmark.



Graph 1: Current and required growth of electrolysis capacity. Figures A and B describe the historical development and future announcements of electrolysis projects in the EU, by country and project status. Figure C outlines the required growth in electrolysis capacity in the EU consistent with the REPowerEU goal of 10 Mt of domestic renewable hydrogen production. In the same figure, the trajectory is compared to historical growth rates observed for solar photovoltaic (PV) and wind power technologies. Source: Odenweller et al. (2022). *Probabilistic feasibility space of scaling up green hydrogen supply. Nature Energy, 7(9), 854-865.*

¹² Uncertainties associated with both near-term deployment of electrolysis capacity and feasible growth rates in the medium to long-term imply a substantial risk of a long-term gap between the availability of renewable hydrogen supply and potential demand. For a significant roll-out of electrolysis capacity, the timing of this breakthrough is uncertain, but unlikely to happen before 2036 in Europe and 2043 globally. See Odenweller, A., Ueckerdt, F., Nemet, G. F., Jensterle, M., & Luderer, G. (2022). Probabilistic feasibility space of scaling up green hydrogen supply. *Nature Energy, 7(9), 854-865.* <https://doi.org/10.1038/s41560-022-01097-4>

The adoption of the electrolysis technology may not be the only bottleneck though, as uncertainties related to the cost-competitiveness of renewable hydrogen could make the ramp-up of demand and infrastructure very difficult to predict and consequently hinder investments in production capacity.

Defining clear uses for renewable hydrogen

To minimise the risk of misallocation of considerable public and private funds, it is important to identify end uses where hydrogen use is crucial for achieving climate neutrality. As represented in figure 1 below, we believe that our energy system should be based on a clear hierarchy where targeted hydrogen production and use do not compete with either direct electrification of most economic activities or reduction of energy demand through circularity, efficiency, and sufficiency.

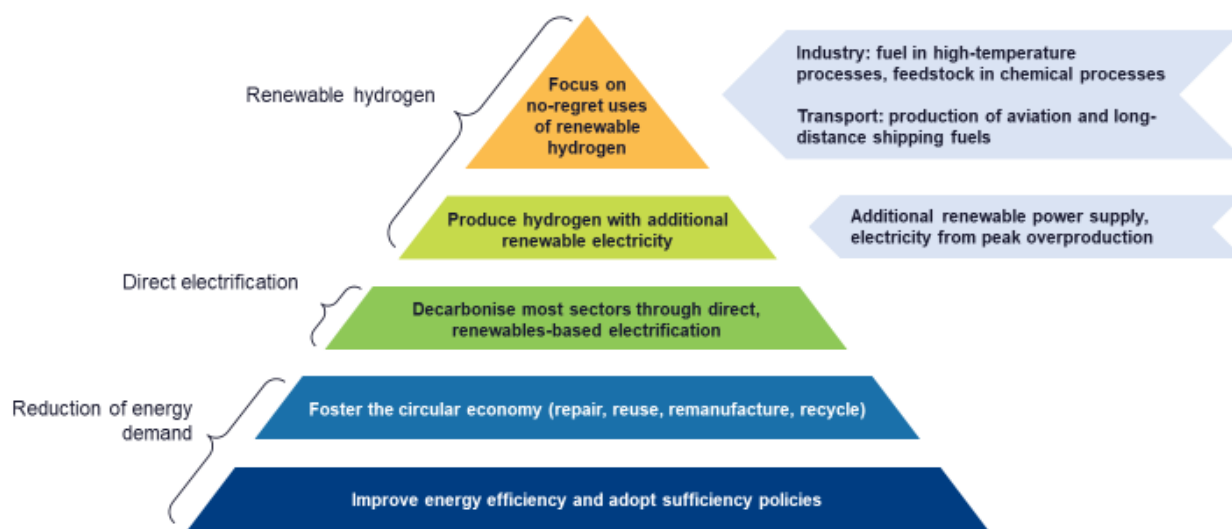


Figure 1: Energy system hierarchy.

The [results of the PAC scenario](#) can help us understand in what sectors and applications future hydrogen demand is a no-regret option consistent with a 1.5 degrees pathway.

Hydrogen demand from the industrial sector will be largely driven by industrial processes that are impossible to electrify directly. This includes: (1) processes in which hydrogen is used as a chemical reagent, such as the production of ammonia, fertilizers, methanol, or the direct reduction of iron ore¹³; (2) high-temperature processes which require combustion, such as the production of cement, steel, glass, ceramics; (3) refining processes where hydrogen is used to lower the sulphur content of diesel fuel.

¹³ The production of ammonia and fertilizers are examples of chemical reactions in which hydrogen serves for the synthesis of products in which it is a molecular constituent. In the reduction of iron ore, hydrogen is not a constituent of the final product.

Currently, over 90 percent of hydrogen produced in Europe is used in oil refining, ammonia and methanol production. The possibility of replacing fossil fuels used in steel production is one of the most promising future¹⁴ uses for hydrogen, especially when considering that the steel industry is responsible for around 5% of total EU carbon emissions. Combined, the steel, ceramics, glass, and cement production cause almost 20% of total EU industrial carbon emissions¹⁵.

However, energy demand from those industrial segments would remain strikingly high and unlikely to be met with renewable hydrogen unless **a sharp transition towards circular economy through demand reduction, reuse, recycling and material efficiency takes place, coupled with a robust progress in energy sufficiency**. Rather than focusing only on supply-side measures such as carbon contracts for difference (CCfDs), ambitious circular economy policy measures are key: including waste prevention targets, recycled content targets, ambitious recycling quotas and taxes on use of virgin materials. The steel industry is a case in point. Some facilities currently producing primary steel could convert their operations to recycling, while the rest of currently operational blast furnace plants could be converted into plants producing Direct Reduced Iron (DRI) using renewable hydrogen. If secondary steel production is maximised, the University of Lund estimates that only 15 blast furnaces for primary production would be required in the EU in 2050 – down from the current number of 65. This would drastically drive down the amount of renewable hydrogen needed for steel production. In the same vein, a reduction in the use of fertilisers due to more efficient and environmentally friendly agroecological practices can help limit the demand for hydrogen as a chemical reagent.

In the power sector, renewable hydrogen might play a role as an **instrument of long-term energy storage** and thus help to accommodate the increasing fluctuations of distributed and variable renewable energy sources such as solar and wind in the electricity system. Surplus renewable electricity produced during periods of off-peak demand can power electrolyzers to produce hydrogen, i.e. load levelling. This hydrogen can be stored and converted back to electricity when demand peaks, hence providing balancing power for the grid, i.e. seasonal load shift¹⁶. While avoiding curtailment of excess renewable electricity generation might seem a no-regret option in itself, a more efficient grid and increased cross-border exchange of electricity can help preventing power shortages or curtailment too. Excessive reliance on renewable hydrogen as an energy storage medium and a grid balancing tool risks hindering or delaying much-needed investments in upgrade, expansion, and interconnection of the power transmission and distribution grids throughout Europe. Hence, renewable hydrogen should play a very limited role – i.e. as a tool of last resort – as a grid flexibility option.

¹⁴ It is worth noting that the use of hydrogen in steel production is already at a quite mature development stage. See, for example, the HYBRIT Project implemented by SSB, LKAB, and Vattenfall in collaboration with the University of Lund and the Stockholm Environment Institute (SEI) and aiming at reaching commercial status by 2026.

¹⁵ The production of ceramics, glass, steel, and cement amounted to 19,39% of total verified carbon emissions by all stationary installations covered by the EU's Emission Trading Scheme (EU ETS) in 2021, i.e. excluding aviation. Data accessible at EEA's EU ETS data viewer.

¹⁶ As opposed to short-term peak shaving, which will most likely be performed through a mix of utility-scale battery storage and demand response management.

In the transport sector, there is overall agreement in European and global scenarios that **hydrogen will play a role in long-haul aviation and long-distance shipping**, where liquefied hydrogen, synthetic fuels derived from hydrogen, and ammonia show the greatest decarbonisation potential. For short-distance flights of less than 3,000 kilometres¹⁷, hydrogen could make a contribution, either in electric planes with hydrogen fuel cells or through direct combustion of hydrogen. Battery electric planes may also become competitive, however. Longer distance flights require fuels with higher energy densities, here synthetic fuels derived from hydrogen are the most promising option, as they can be a drop-in replacement for current jet fuel.

There is more disagreement and uncertainty regarding hydrogen use for trucks, buses, short-haul aviation, and shipping, where hydrogen-based solutions compete to varying degrees with battery-electric technologies. However, depending on the vehicle's range requirements and local geographic context, the long-term economics – e.g. total cost of ownership (TCO) and energy operating cost – of running battery-electric buses and trucks already look more favourable than those of hydrogen fuel cell options.

Ensuring renewable hydrogen is actually renewable

For hydrogen to be considered as renewable and supportive of the transition to climate neutrality, its production needs to be based on **additional renewable electricity**. Additionality means that renewables-based electricity used in electrolyzers for the production of renewable hydrogen is additional with respect to the renewables-based electricity used to meet the final electricity consumption needs. Remarkably, the development of renewable energy for hydrogen production should happen in synergy, and not in competition with the decarbonisation of other sectors.

How to ensure additionality has been the focus of much debate over the last year. Ongoing policy negotiations at the EU level focus on defining additionality in both the Delegated Act on Renewable Fuels of Non-Biological Origin (RFNBOs)¹⁸ and in the revision of the Renewable Energy Directive (RED)¹⁹.

A first method to ensure additionality requires a **physical link between newly deployed²⁰ renewable electricity generation facilities and electrolyzers** consuming that renewable electricity. However, besides obvious geographical constraints, this approach requires limiting the operation of electrolyzers to the periods when the physically linked renewable electricity generation asset is actually able to produce

¹⁷ encompassing most European flights, e.g. Madrid to Helsinki is 2950km.

¹⁸ Draft Delegated act supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by establishing a Union methodology setting out detailed rules for the production of renewable liquid and gaseous transport fuels of non-biological origin. Draft text available [here](#).

¹⁹ Proposal for a directive of the European Parliament and of the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources. Text of the proposal available [here](#). The text adopted by the European Parliament's plenary is available [here](#).

²⁰ Additionality must be based on newly developed renewable generation capacity to avoid the risk that existing renewable energy power plants are taken offline to serve electrolysis needs instead of supplying renewable electricity to the grid for other end uses.

power. This reduces the efficiency of renewable hydrogen production from solar or wind technologies, thus reducing the number of hours in which the electrolyser would be working, hence decreasing its industrial value.

A second method to ensure additionality is to **establish a commercial link** between renewable electricity production and the electricity consumption by the electrolyser. This could be achieved through establishing power purchase agreements (PPAs) – whereby the grid is used to bring contracted renewable electricity from the producer to the electrolyser – with newly developed renewable energy power plants that entered in operation around the same time as the electrolysis facilities concerned. To this end, the producer and consumer would have to be located in the same bidding zone, ensuring that a grid connection exists between them. However, to guarantee that hydrogen is indeed renewable, the electrolyser would be permitted to produce hydrogen only when the contracted renewable electricity is generated, and this raises the question of how to ensure the required temporal correlation between renewable electricity generation and the electrolysers' consumption.

A third alternative is **system-level matching**, whereby the hydrogen produced by electrolysers is considered as renewable only in those hours when renewables are the marginal technology in the market merit order and thus an increase in electricity consumption is likely to be met by otherwise-curtailed renewable electricity. However, as long as the share of renewable generation is not very large, renewables will hardly ever be the marginal technology. Thus, this criterion would lead to only very limited renewable hydrogen production, possibly even smaller potential than in the case of physical or commercial links.

Regardless of the method chosen to implement additionality, the technical and economic feasibility of modulating electrolysis operations in such dynamic ways – i.e. allowing electrolysers to operate based on variable renewable electricity generation patterns – appears to be challenging at best. Most electrolysers would in fact suffer substantial performance degradation from frequent load changes and idle periods during which no electricity is supplied. To maintain a stable load and avoid such wear and tear effects, electrolysis facilities would likely require either running partly on non-renewable electricity taken from the grid – thereby making the hydrogen produced carbon-intensive to varying degrees – or be equipped with large-scale electrical storage capacity – something which would further add to the cost and resource-intensity of renewable hydrogen production.

Without the necessary safeguards in place, producing hydrogen today on most European grids would result in the cannibalisation²¹ of the renewable energy production capacity that was deployed to decarbonise other parts of our economies, thus hampering the transition of the electricity system and increasing emissions. In fact, based on detailed scenario modelling of energy system, Zeyen et al. (2022) show that “if hydrogen is produced without additionality or locational and temporal matching, its carbon emissions impact can be worse than that of grey hydrogen.”

²¹ The expression is drawn from Bellona Europa's Impact Assessment of REDII Delegated Act on Electrolytic Hydrogen CO₂ Intensity. See Lovisolò, M., Whiriskey, K. (2021) *Cannibalising the Energiewende? 27 Shades of Green Hydrogen*. Full text available [here](#).

Clustering hydrogen production and consumption facilities

Considering the environmental and economic sustainability profile of hydrogen transportation and storage, planning the location of hydrogen production facilities and related distribution networks is of strategic importance. The production of hydrogen should be located as close as possible to the consumption site, specifically to those industrial installations with high hydrogen demand. By clustering hydrogen production and consumption, **dedicated and localised hydrogen distribution infrastructure serving industrial clusters or ports characterised by high hydrogen demand** will allow for several industrial and transport applications to transition to dedicated zero-carbon hydrogen processes.

When thinking of hydrogen transport, the overall safety and efficiency of the infrastructure should always be taken into consideration. For instance, transporting hydrogen in the form of ammonia (for higher energy density) could prove less efficient than producing it on the consumption site. Blending of hydrogen with fossil gas in the fossil gas grid still poses some technical issues, as it will not result in the required emission reductions and will likely slow down dedicated hydrogen use by prolonging the use of fossil gas. Blending, if anything, would result in broadening the use of hydrogen beyond what is efficient or indispensable.

4. The policies – Benchmarking PAC scenario results on hydrogen and relevant EU legislation

Building on the recommendations identified in previous sections, the table below summarises the main proposed changes and upgrades in relevant EU legislation and initiatives:

	PAC scenario results	Relevant EU legislation and initiatives	What needs to be removed/improved/introduced in the relevant EU legislation
Hydrogen key uses	<p>Transport</p> <ul style="list-style-type: none"> For private cars, the PAC scenario results in a fully electrified fleet by 2040. Road freight will also be covered in priority by electrification (either through batteries, highways with overhead catenary lines or switch to rail), followed by renewable hydrogen for heavy duty. Shipping will be covered by electricity for short-distance, a mix of electricity and renewable hydrogen for mid-distance (intra-EU), and a mix of renewable hydrogen and ammonia for long-distance. Aviation will be mostly covered by liquid synthetic fuels and marginally by second-generation biofuels, until the progressive development of electric aircrafts post-2040. <p>Industry</p> <ul style="list-style-type: none"> Wherever possible, production processes are electrified through direct use of renewable electricity. Energy-intensive industrial sectors' such as steel, ceramics, glass, cement will shift to using renewable hydrogen to obtain high temperature heat. 	<ul style="list-style-type: none"> Gas Market Decarbonisation Package – i.e. Gas and hydrogen markets Regulation and Directive Revision of the Renewable Energy Directive (REDIII) Revision of the Industrial Emissions Directive (IED) Best Available Techniques (BAT) Reference Document (BREF) on Inorganic Chemicals Alternative Fuels Infrastructure Regulation (AFIR) Net Zero Industry Act Revision of State aid rules 	<ul style="list-style-type: none"> Only consider renewable hydrogen produced through electrolysis Only support the use of renewable hydrogen in hard-to-decarbonise sectors and applications where direct electrification is not possible Align subtargets for RFNBOs in the industry and transport sector with essential, targeted uses in no-regret applications Subject any fast-tracking of permitting procedures for hydrogen production facilities and infrastructure to solid sustainability conditions Provide for robust and ambitious BAT Conclusions on production of green hydrogen and use of green hydrogen in the review of the Inorganic Chemicals BREF Avoid oversized infrastructure for hydrogen in transport. Public subsidies for infrastructure to focus only on electric recharging

	PAC scenario results	Relevant EU legislation and initiatives	What needs to be removed/improved/introduced in the relevant EU legislation
	<ul style="list-style-type: none"> Industrial processes such as the production of ammonia and fertilizers, and refining will use renewable hydrogen as a chemical reagent. 		
Hydrogen production and grids	<p>The PAC scenario assumes no carbon capture and storage/usage (CCS/CCU) technology is introduced. Hence, only renewable hydrogen produced through electrolysis should be produced.</p>	<ul style="list-style-type: none"> Gas Market Decarbonisation Package – i.e. Gas and hydrogen markets Regulation and Directive Revision of the Renewable Energy Directive (REDIII) Delegated act on RFNBOs Revision of the Industrial Emissions Directive (IED) Net Zero Industry Act Revision of State aid rules 	<ul style="list-style-type: none"> Provide for a uniform system of guarantees of origin to be issued for renewable hydrogen Adopt strict criteria to ensure that the additionality principle to produce renewable hydrogen is respected and that no electricity is taken from the grid in absence of actual renewables curtailment Adopt strict criteria to ensure the sustainability of blue hydrogen. A minimum of 90% carbon capture rate and less than 0.5% methane leakage rate are needed Remove the 5% cap for blended hydrogen in the fossil gas network Remove the grandfathering clause exempting hydrogen production plants online before 2027 from respecting the additionality requirement Include waste prevention targets, recycled content targets, ambitious recycling quotas and taxes on use of virgin materials
Hydrogen sourcing and trade	N/A	<ul style="list-style-type: none"> Commission staff working document implementing the REPowerEU action plan: Investment needs, hydrogen accelerator and achieving the biomethane targets Clean Hydrogen Mission Africa-EU Green Energy Initiative 	<ul style="list-style-type: none"> Limit hydrogen imports from the Global South – and particularly African countries - as much as possible Establish credible certification schemes to ensure that imported hydrogen is actually 100% renewable Monitor the respect of labour rights in exporting, extra-EU countries Only import hydrogen produced by facilities and power installations subject to full and transparent environmental impact assessments

5. Conclusion and recommendations

As part of the European Green Deal, the European Commission has put forward several proposals that set a framework for the development of renewable hydrogen production and use in Europe.

Regardless of its production method however, hydrogen is associated with **environmental impacts** that raise doubts about its sustainability profile. The potential for deploying **significant electrolysis capacity also remains highly uncertain** both in and beyond the EU, while **high production costs** for renewable hydrogen using electricity also appear as a major constraining factor. Subsidies risk distorting the economy towards inefficient technologies, creating high energy prices in the long run and significant emissions in the short run as hydrogen capacity only slowly ramps up.

The EU must strike a balance between providing regulatory certainty to foster investments in renewable hydrogen and maintaining a realistic judgement on the long-term prospects of hydrogen production and use, especially when considering how **investing in direct electrification and energy efficiency provide for a more efficient alternative** to simply transforming our gas-centred energy system into one dominated by hydrogen.

Structural decisions should leave the field of possibilities open and not prematurely commit the European energy system to paths that could turn out to be dead ends. To decarbonise our economy as quickly as possible in line with the transition pathway outlined in the PAC scenario, relevant EU legislation should be shaped according to the following principles:

- **Focus regulatory instruments and financial support on targeted, indispensable uses** of renewable hydrogen such as hard-to-decarbonise industrial and transport applications.
- **Make sure that hydrogen produced and used in the EU is actually renewable** – i.e. produced through electrolysis using strictly additional renewable electricity.
- **Only foster the development of essential and decentralised hydrogen infrastructure** serving hydrogen consumption clusters and **avoid blending** in the current gas infrastructure.
- **Ensure that low-carbon hydrogen production is subject to strict sustainability criteria:** a minimum of 90% carbon capture rate and a maximum of 0.5% methane leakage rate are needed.

In light of the environmental and financial costs, restricted no-regret applications, and the expected need for subsidies for the foreseeable future, we suggest decreasing **the EU's target for the uptake of hydrogen** production and imports from 20 Mt – as outlined in REPowerEU – to 10 Mt by 2030.

Renewable hydrogen should play a role in the decarbonisation of our energy system by **complementing renewables-based electrification, improved circularity and energy efficiency, and adoption of energy sufficiency** measures and behaviours. Europe's priority must be to reshape its economy without crossing ecological boundaries or overburdening public finances. The deployment of renewable hydrogen must be informed by that principle.

Next steps and further information

This document constitutes an assessment of the role that renewable hydrogen should play to achieve a successful energy transition in the European Union while respecting environmental boundaries. For its development, the [results from the Paris Agreement Compatible \(PAC\) scenario](#) have been used as a benchmark.

This policy brief constitutes an EEB deliverable under the PAC 2.0 project, implemented by the partnership comprising RGI, REN-21, EEB, and CAN Europe which looks at ways to implement the PAC scenario in relevant policy files and modelling activities. The opinions expressed within this Policy Brief are solely the EEB's and should not be taken to necessarily reflect the views of the funder or partners.

Other policy briefs released and foreseen under the PAC 2.0 project include:

- “Taking the Paris Agreement Compatible (PAC) energy scenario to the next level: the revision of the Renewable Energy Directive (RED III) as a key milestone towards a 100% renewable grid” (published in February 2022, available [here](#))
- “Policy measures towards Nature-Positive Renewable Energy in the EU using PAC scenario results” (published in July 2022, available [here](#))
- “Sustainability criteria for biomass under the PAC Scenario” (*upcoming EEB policy brief*)

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