Face to face with hydrogen
The reality behind the hype

An EEB position paper for a better-informed approach to hydrogen

Abstract

Hydrogen from renewable electricity is the only form of hydrogen that is fully compatible with the Paris agreement. It can play an important role in the decarbonisation of some industrial processes, long distance shipping and aviation. But we should refrain from presenting hydrogen as a technological solution to all problems for four reasons: first all forms of hydrogen (grey, blue, turquoise, purple and green) come at an environmental cost, (i.e., water use, impacts on nature). Second, the production of hydrogen entails significant energy losses reducing its effectiveness as an energy carrier relative to direct use of electricity. Third, this makes it more expensive than electricity from renewables, potentially absorbing more public funds that can more effectively be used elsewhere. And fourth, before addressing projections of energy demand in the future with supply options, we should focus first on efficiency and sufficiency – promoting energy efficiency, savings through circular economy and demand reductions by rethinking our consumption and production patterns. This will help depollute and decarbonise our economy and bring our resources use to within the boundaries of sustainability for our planet. This, together with a preference for electrification over gas, will make it easier to match the supply and demand for hydrogen by reducing demand, keep investment needs manageable, and avoid competition for and impacts from supply. Only in that framework can hydrogen play a role, with production being located as close as possible to consumption and grids to be put in place only at a second stage to connect clusters. Imports of hydrogen should be avoided in order not to undermine decarbonisation efforts of other economical areas and should in any case be submitted to strict environmental, social and democratic screening.

The questions behind the European hydrogen narrative

Hydrogen has gained momentum at European level. Over the past three years, hydrogen has risen on top of the EU's political agenda - with the publications of both the EU strategy for Energy System Integration and the European Hydrogen Strategy on 8 July 2020, and the launch of the European Clean Hydrogen Alliance. The EU wants to build its global leadership in this domain, which is seen as a key instrument for making the transition to climate neutrality.
Indeed hydrogen, despite being currently used to produce mainly fertilisers and plastics -two highly polluting products whose production and consumption the European Commission is aiming to reduce - is said to become a transformative fuel enabling a decarbonised future. In a nutshell, this is the new hydrogen narrative. However, there are a range of political, economic implications as well as environmental risks linked with this strategy.

Firstly, the hydrogen-focused decarbonisation narrative is at the core of the gas industry lobby and it is backed by many governments that seek to decarbonise the gas sector in order to maintain the profitability of natural gas infrastructure and investments while catching up with the more advanced decarbonisation of the electricity sector through renewables. This is seriously threatening the end of fossil fuels imports and exploitation in Europe, that should take place as soon as possible.

Secondly, in its strategy the European Commission (EC) aims to boost the technology and infrastructure needed to produce, store and transport hydrogen: although hydrogen has been used for decades, the massive scale of planned investments is a game-changer and is intended to turn the hydrogen market (both production and use) into a key component of the EU Green Deal. This implies the unlocking of large funds for investments -both private and public- a significant amount of which risks being channelled from the EU's post-coronavirus Recovery Plan and Green Deal. European Commission's Vice-President, Frans Timmermans, has stated: "*We will be investing a lot in making clean hydrogen part of our energy mix in the future*".

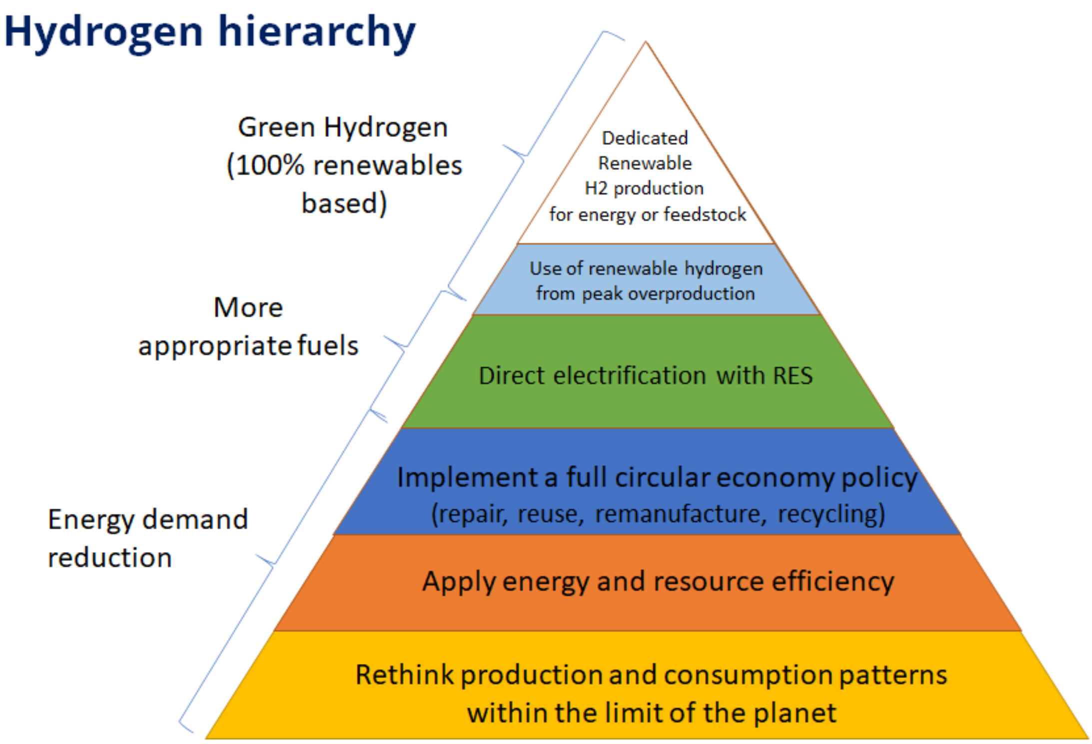
Thirdly, although hydrogen is not yet in the pipes, it is already being promoted to keep fossil gas in the EU's economy: the EU economy is still highly dependent on natural gas (29.8% of all fuel imports according to EC E*U Energy in Figures 2018*) and the recently activated Trans Adriatic Pipeline and the upcoming Nord Stream 2 project will allow higher gas volumes into the EU, in blatant inconsistency with the EU decarbonisation goals. Unsurprisingly, in its guidelines for the Recovery and Resilience Plans the EC, pressured by some Member States, has allowed to finance new fossil gas infrastructure provided that it is "hydrogen ready".

Doubts and vision

It is then not in vain that we wonder: is the EU hydrogen strategy fit for the task? And what exactly is the role of the hydrogen market in the decarbonisation? Will there ever be enough renewable energy or renewable hydrogen to decarbonise our economy if our production and consumption projections levels remain unsustainably high?

At EEB we believe that the EU needs to deeply rethink the way it produces goods/commodities as well as the business models behind their production, with the aim to switch from single use to reuse, from property to sharing, from overconsumption to sustainable levels that ensure our wellbeing, thus requiring less resources and reducing energy consumption.

Only in this scenario, will H2 have a role to play in the decarbonisation of the EU economy. There is a clear need of a hydrogen hierarchy, that embraces sufficiency, efficiency and waste reduction first, a use of other fuels where more suitable for public funding and planet and develop hydrogen niches and applications where its added value is clear and proven.



Img 1: Hydrogen role in our economy

The labelling around hydrogen and the locking-into solutions from the past

It is worth stressing that while the use/consumption of hydrogen as a fuel is in itself climate-neutral (no CO2 emissions generated) , the manufacturing of this energy carrier can be carbon-intensive. Hydrogen must be extracted from an existing substance (fossil fuels, ammonia or water) through a process which can release greenhouse gas emissions, depending on the method employed. Due to the different technologies used for hydrogen production, industry has proposed a color-coded classification of H2 based on the carbon impact of the production method:

- "**Grey**" hydrogen refers to hydrogen produced by using natural gas, therefore emitting CO2 in the process.
- The similar process coupled with Carbon Capture and Storage (CCS) technologies is known as "**blue**" hydrogen, which is often referred to as "low carbon hydrogen".
- "**Green**" hydrogen is sourced from water and the use of renewable energies for the electrolysis process; hence it is the only one with no emissions during its production (except waste heat).
- **Turquoise** hydrogen is produced by splitting natural gas into its components, hydrogen and carbon by pyrolysis. This is induced by high temperature obtained from electric heating. Instead of CO2, solid carbon is produced, which is then materially bound. This technology is at an early stage and can potentially be coupled with nuclear energy.

- Lastly, **purple** is the colour that refers to hydrogen produced by high temperature steam from nuclear power or via electrolysis from nuclear electricity, therefore with the associated environmental risks linked to nuclear power.

The vast majority of hydrogen in use today is grey hydrogen, with around 8 million tons used each year in the EU alone and accounting for 95% of current production.

Hence, when we talk about hydrogen use today in Europe, we talk about fossil fuel-based hydrogen.

The debate around hydrogen at European and national levels has been centred around the use of this colour code. However, this code blurs the reality as it does not specify how hydrogen is produced and the wider environmental impacts caused by its production. Such coding should not be used in official documents.

There is no such thing as "No Impact hydrogen"

Another commonly used term is "clean hydrogen", which encompasses both blue and green forms of hydrogen. As it disguises fossil hydrogen under a cloak of cleanliness, this term is misleading, and we should be wary of its misguided use to serve certain interests. Only hydrogen from renewable electricity can qualify as "clean" hydrogen, as far as "clean" can go and within certain limits of which we need to be aware: this form of hydrogen also has a high impact on resources.

Indeed, for those who support Carbon Capture and Storage[1], the next decade is a "now or never" moment to promote CCS technologies, as they would provide an opportunity for fossil hydrogen and attract the huge amounts of funds which have been lacking in the past to make CCS profitable.

As CCS cannot trap all carbon emissions and continued emissions of methane occur along the value chain due to leakage[2] or gas flaring, these technologies are not 100% efficient and this type of H2 cannot be defined climate neutral as of today. Their scaling would hamper the uptake of fossil-free solutions and the untapped potential of renewable energy. It is not a coincidence that this technology has been strongly supported by the oil & gas industry: it was originally developed as a method to squeeze out more oil from nearly-exhausted oil fields, and its use in that context would still fulfil the same purpose, leading to even more emissions.

Investing billions of euros in this technology to decarbonise fossil fuels would be a huge mistake: Europe must prioritise the most efficient, sustainable and cost-effective pathways to decarbonize its economy and create jobs and phase out fossil fuels by 2040 to reach climate neutrality by 2040 as contribution to the achievement of the Paris Agreement 1.5C climate target. Only renewable hydrogen is Paris Agreement compatible. Moreover, relying on fossil gas will lock Europe in a scenario of dependency from external imports, and unsustainable resource exploitation.

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[1] this is an example of CCS being promoted for climate purposes

[2] https://www.bloomberg.com/news/articles/2021-02-12/new-climate-satellite-spotted-giant-methane-leak-as-it-happened?srnd=green

However, only NGOs in Europe seem to be questioning the "hydrogen as a silver bullet" narrative. The current EU's hydrogen strategy will slow down the pace of our decarbonisation. It will lock our economies in fossil-based solutions, creating stranded assets and wasting huge amounts of public and private money for the massive reconversion of gas infrastructure to fit a H2 grid, increasing environmental impacts beyond climate and finally delaying the needed deeper penetration and uptake of renewable electricity in the EU.

It is time for a reality check on gas as a transition fuel and on fossil-based hydrogen. We badly need a science-based, cost-effective and environmentally-sound approach to hydrogen to avoid mistakes already made in the past when promoting doubtful decarbonisation options such as diesel and biofuels.

The environmental impacts of hydrogen

In the EU, the energy sector accounts for around 18% of total freshwater abstraction. While the introduction of renewable energy sources, such as wind and concentrated solar power, are predicted to decrease the energy sectors water demand, certain energy low-carbon energy technologies, such as nuclear and carbon capture, are highly water-intense.

Water plays a crucial role in the production of hydrogen, JRC estimates that an introduction of 16-20% hydrogen in the total EU energy share (scenarios considered under the European Commission Long Term Strategy) would result in a hydrogen freshwater use equal to a third of what the EU energy sector consumes today. However, the water use for renewable and fossil hydrogen differ. A recent report from the Hydrogen Council mentions that hydrogen produced via Steam Methane Reformation (SMR) requires up to twice as much water as hydrogen produced via electrolysis, but according to IRENA's report, the numbers presented by the Hydrogen Council only take into account the pure stoichiometric water use (i.e. excludes cooling water needs) so the real numbers are higher.

The electrolysis process can consume up to 9 litres of water for every kg of hydrogen[3]. In Germany, if we imagine a scenario where industrial energy consumption is down to 500 TWh, this will translate into an increase of 3% to 4% of per capita water consumption.

The water consumption increase linked to CCS is due to cooling water and process water requirements related to the CO2 capture and compression systems. JRC predicts that the penetration of CCS technologies could drive up water use for power generation almost 60% and water consumption by over 200% in 2050.

Freshwater resources are essential to ensure food and water needs, as well as preserving the natural environment, and the energy sector is already competing with these aspects. Climate change is resulting in increased occurrences of drought, which has made the power sector itself aware of its water footprint in order to secure production. The EU needs to ensure ambitious decarbonisation scenarios that take water resource management into account.

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[3] This estimation comes from https://www.bund.net/. They also provided the following studies confirming these figures, carried out in NL and AUT https://www.sciencedirect.com/science/article/abs/pii/S0960148120303487 https://www.kwrwater.nl/en/projecten/water-demand-a-hydrogen-economy/
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There are also considerable resource use implications in the hydrogen production value chain as the required energy input for final useful energy output is higher for green hydrogen than from direct use of renewables electricity. More wind turbines, and more PV cells will be needed for the same final energy delivery. Hence, more resource extraction and associated impacts. If poorly located, such renewable infrastructure can have significant impacts on both land based and marine ecosystems. This argues for electrification rather than hydrogen, and the need to take into account spatial planning, SEA and EIA to minimise impacts.

The production of hydrogen

A recent study indicates that most European regions have today the renewable capacity to replace the production of fossil hydrogen with the hydrogen produced from renewable electricity. Although this does not specifically target future needs for energy intensive industries and other hard-to-abate sectors, it would nevertheless cover most of these uses. It is also worth stressing that simply producing hydrogen from the grid on the base of future renewable energy deployment should in no way be labelled as sustainable.
Indeed the production of H2 with Renewable Energy Sources seems to be more at hand than foreseen by the EC in its H2 strategy and could be available in grid parity in as soon as 5 years, according to some utilities that are working on H2 for industrial applications and this market analysis.
If framed correctly (what are we using this H2 for? are those uses strictly necessary in an economy that falls within the boundaries of the limited resources of the planet ?) both in time and availability the production of hydrogen could do without the contribution of fossil fuels.

Hydrogen deployment and distribution

Even when renewable, hydrogen will require a strategic and quick upgrade of both production and distribution of renewable electricity to provide for its integration in sectors such steel and cement; this upgrade will have to be dealt within the framework of the Energy Union governance, namely the upcoming Strategy for Smart Sector Integration. This shall include a clear roadmap on the deployment of Hydrogen facilities and variable renewables capacities, and the adaptation of targeted demand sectors.
Should the Commission propose a target on hydrogen production in the framework of the EU's energy policy review, it must be limited to the production of renewable hydrogen.
We believe that production of hydrogen should be, as much as possible, close to the consumption site, namely those industrial installations with high demand. Dedicated hydrogen local networks serving industrial clusters will allow for industries to transition to dedicated hydrogen zero-carbon processes.
Building on that, in the mid-term a hydrogen transport network could be set up according to growing needs and projected demand.
When thinking of hydrogen transport, though, the overall safety and efficiency of the infrastructure should be taken into consideration: i.e., transporting H2 in the form of ammonia (for higher energy density) could prove less efficient than producing it on the consumption site.
It is also important to create a temporal and/or geographic connection between RES generation and hydrogen production: with such a connection, it would be perfectly fine to produce H2 on

any grid (including those relying more on fossil fuels such as coal) as it would be linked closely to real-world renewables.

Blending of hydrogen with fossil gas in the fossil gas grid still poses some technical issues, it will not result in the required emission reductions and will preclude dedicated hydrogen uses by prolonging the use of fossil gas. Blending, if anything, would serve to un-target the use of hydrogen.

Hydrogen is and will continue to be for at least a decade a scarce and expensive resource, as scaling up will take time. As such, it should be used in a targeted and prioritised way.

Hydrogen and employment

Often raised in support of the transitional gas narrative is the concern that a move to a decarbonized economy will create significant job losses. Yet, IRENA studies show that the deployment of renewable energy capacities worldwide is already leading to important job generation. A comprehensive policy package can help support the workforce reskilling that our move to a carbon-neutral economy requires. These include deployment policies (which provide a stable policy environment for new installations), integrating policies (which allow for the incorporation of renewable energy technologies into the existing grid system) and just transition policies (which support people and businesses in a smooth transition with social protection and up/reskilling of the workforce). A low-carbon economy can provide long-lasting employment with the right policy impulse.

Hydrogen in the global arena

As mentioned above the production of green hydrogen should be as closest to the point of consumption as possible. This implies that Europe should produce green hydrogen locally and limit hydrogen imports from areas such as Russia and north Africa as much as possible. As the current energy demand of the whole EU is too high, Europe should reduce its energy consumption level to be able to cover energy needs with local production coming from RES and green hydrogen.

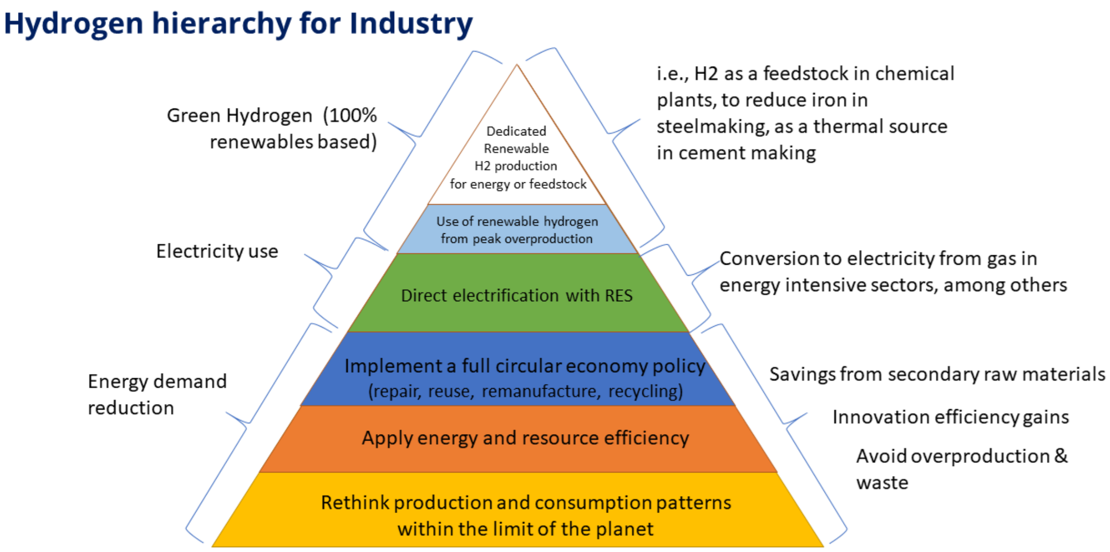
If despite the EU efforts to reduce energy consumption, still some energy must be imported into the EU from the Global South, then this energy must by no means be taken from the needed supply of that country and should only be based on renewable sources. Credible certification schemes will be essential to ensure that hydrogen sold as green hydrogen will actually be 100% renewables. Besides, a detailed analysis of this scenario vs the improved electrical connections between Europe and Africa should be carried out.

In case new green hydrogen plants were to be built in developing countries to satisfy European demand, a proper environmental impact assessment following EU standards must be carried in the area where the hydrogen energy plant is to be built. All affected stakeholders must be consulted about the plant construction in advance with special attention to local communities, who must be heard about the future of their homes. Once the environmental impact assessment result is positive and the construction of the energy plant begins, the EU must monitor that labour rights and the environment are respected in the process.

We believe that it is important that other economies, particularly in the Global South, develop in a sustainable way and do not commit the same past errors of the developed countries. Their development process should leave no one behind and should not be based on short-term economic profit schemes. As some developing countries do not currently have enough resources to develop their own renewable energy supply, the EU should renew and strengthen its effort to help them achieve this development objective. This will benefit all countries, including the EU, in the long term as climate change effects do not stop at national borders.

A pragmatic use of hydrogen in industry

As mentioned, H2 is a rather inefficient energy carrier in most cases, due to energy losses. In several sectors there are alternatives to hydrogen which are drastically more efficient and reliable (e.g., heat pumps for heating, electric vehicles using renewable electricity for everyday transport) and Europe should count on these already scalable solutions. Yet, hydrogen may play a critical role in those sectors that do not yet have a credible non-fossil substitution.
In light of decreased industrial production and consumption, current hydrogen production costs and limited availability, the deployment of renewable hydrogen will be an exception rather than the rule, hence requiring strategic assessment (see image 1 below). A cost-effective role for renewable hydrogen would be in the decarbonization of Europe's most energy-intensive industries and transport – particularly steel and cement manufacturing, along with shipping, aviation. The focus should be on sectors where there is a clear role for hydrogen and where regulatory action has been so far limited.



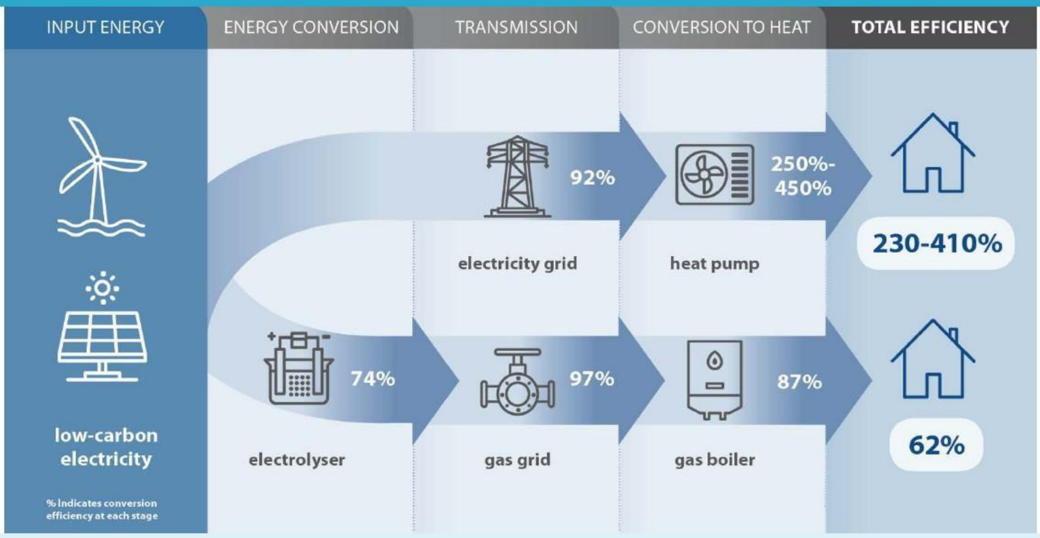
Img 2 - Targeted use of hydrogen in Industry

The Paris Agreement Compatible scenario, a mapping project conducted by the EEB and CAN Europe, shows that electricity made from renewables, coupled with increasing energy efficiency of buildings, industrial processes and consumer products, can deliver most of the progress needed to decarbonize our energy systems. The scenario builds on strong restructuring of consumption and production models and highlights the little need for hydrogen in our transition to neutrality.

Hydrogen in heating

Several studies have demonstrated that hydrogen has a limited role in heating, as it is not competitive as of now with existing decarbonisation technologies. For instance, recent studies (*Fraunhofer institute*, *UK's CCC*, among others) have clearly demonstrated that the use of hydrogen for domestic heating is neither economically compatible nor environmentally desirable. The use of hydrogen-ready or hydrogen-mix boilers for heating homes will have the sole result of preventing the switch of the home heating systems to overall more efficient and more cost-effective options such as heat pumps and renewable electricity. Policy makers should be careful of diverting precious financial resources away from immediately applicable heat decarbonization solutions.

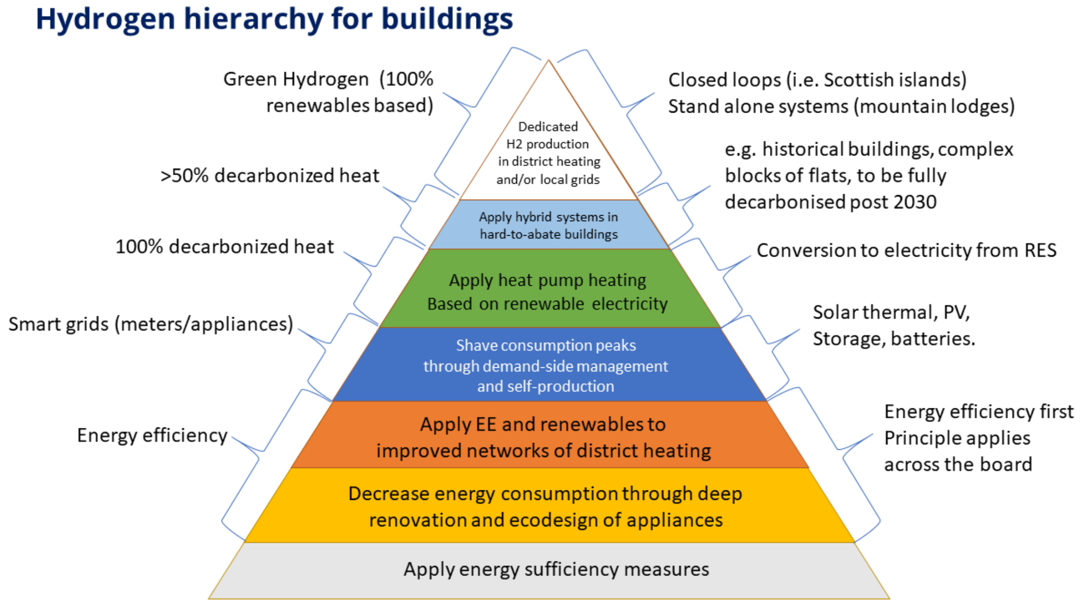
Figure 1.2. Relative efficiency of heating: electricity in heat pumps vs. electrolytic hydrogen in boilers



Source: CCC analysis.
Notes: The diagram shows the indicative efficiency of using a given amount of zero-carbon electricity in delivering heat for buildings. Whilst in practice each of the efficiency numbers could vary, this would not be sufficient to change the conclusion that heat pumps provide a much more efficient solution for providing heat from zero-carbon electricity than use of electrolytic hydrogen in a boiler.

Img3 - Overall efficiency of H2 vs Heat Pumps in heating

The direct use of hydrogen for heating on a large scale is problematic due to the many uncertainties linked to its scalability, costs of production and inefficiencies. We need to measure hydrogen against alternatives and consider the broader energy transition and industrial strategy. In the medium to long-term, to optimize the process of heat decarbonization, the options that combine energy efficiency with direct electrification must be favoured because they can immediately deliver real carbon savings, while accommodating a growing share of renewable sources.



Img 4 - The role of hydrogen in buildings

While hydrogen for heating may seem an easy solution to decarbonise European dwellings because it can fit into existing equipment (radiators, pipes), upgrading the infrastructure will entail a high cost which has not yet been fully defined. Current estimates are provided by the gas distribution companies[4], whose interest is to keep their business, hence have a clear conflict of interests.

Blending H2 and other green gases into the grid will have the result of locking us in a technology (heating based on burning) which is already on its way out, based on the unlikely arrival on the market of future decarbonised gases. This would only provide an alibi to the gas industry (from importers to heaters manufacturers) to keep the business as usual. This would be incompatible with the timely and cost-efficient achievement of 2030 European climate targets.

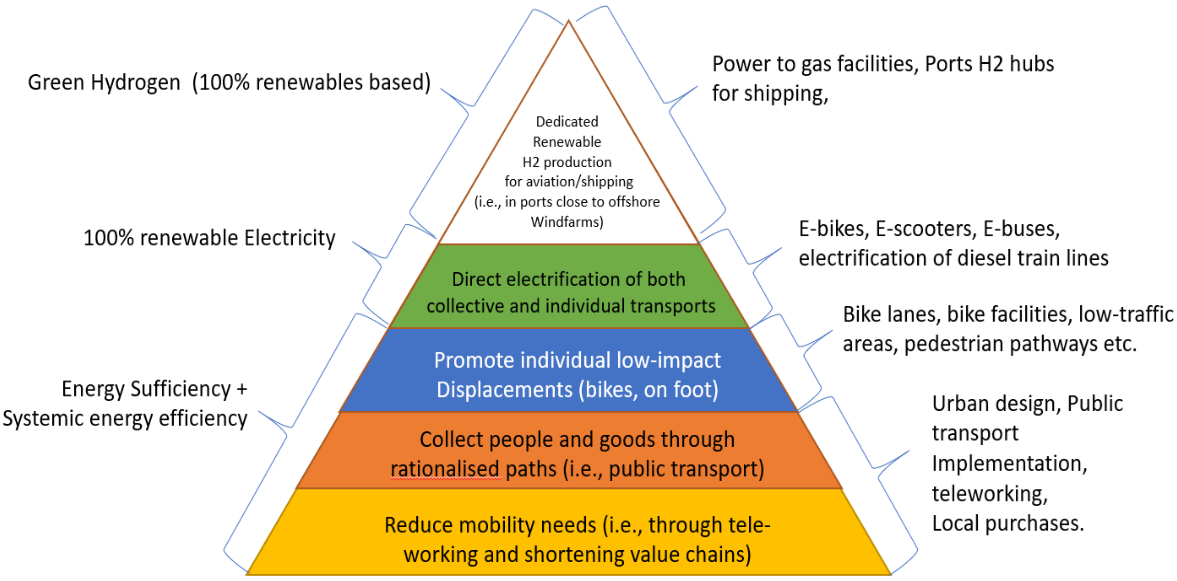
We conclude that hydrogen for heating can only play a role in closed loop networks where abundant RES production would come with massive storage and hence, availability, i.e., in the isles of the North Sea.

Hydrogen in transport

Renewable hydrogen will play an important role in long-distance transport, namely aviation and shipping. In fact, e-hydrogen produced from green electricity and its derivative e-ammonia are the only sustainable and scalable alternative fuels for long-distance shipping; unlike advanced biofuels, these electrofuels can be scaled to meet demand by 2050. According to industry announcements, hydrogen propulsion is expected to be available for ocean-going vessels already in 2025 and could be available by 2035 for short and medium-haul air travel. Hydrogen also serves as the basis for e-kerosene, which is a drop-in ready fuel that can power aircraft for any range. Targeting hydrogen to these transports would also prevent competition with other mature technologies such as battery-based mobility, but it should by no means be

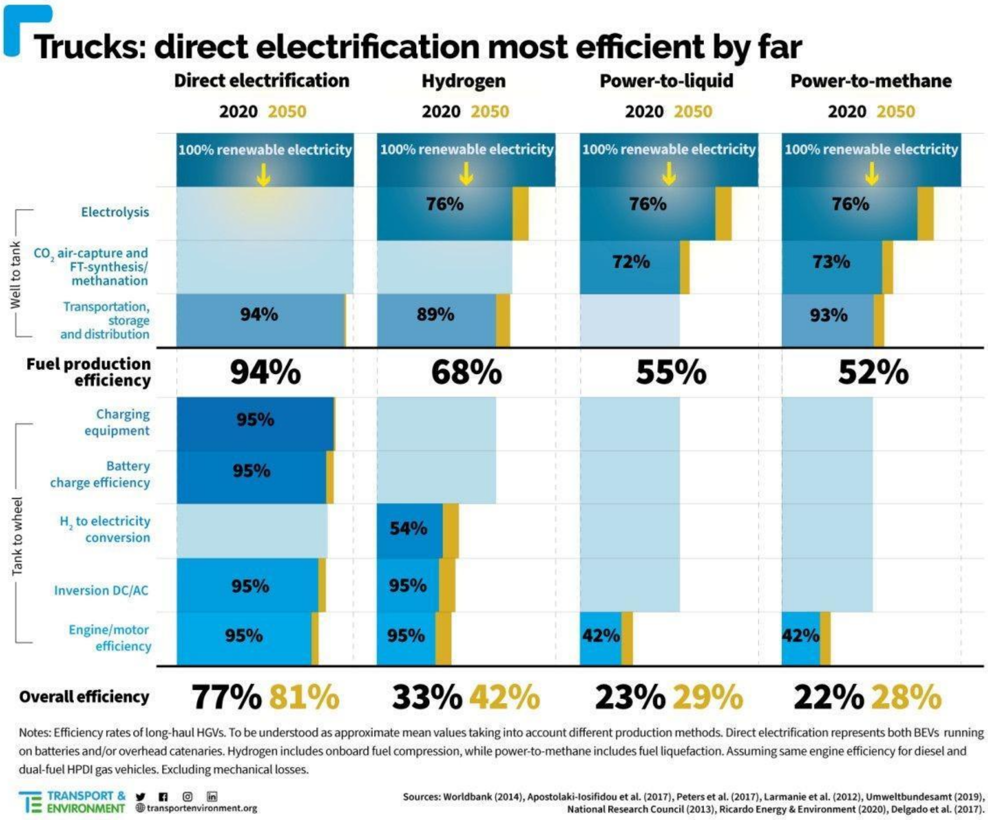
[4] ttps://gasforclimate2050.eu/wp-content/uploads/2020/03/Navigant-Gas-for-Climate-The-optimal-role-for-gas-in-a-net-zero-emissions-energy-system-March-2019.pdf

an excuse to prevent the re-thinking of unnecessary travel and transport, such as low-cost flights and overseas shipping of unsustainable goods that can be produced locally.
The needed uptake of renewables to produce the hydrogen supply for shipping and aviation should be financed by the fuel producer, to prevent energy shifting from i.e., industry or heating to these two sectors. By no means should H2 be produced from mixed electricity, as the resulting emissions in these sectors could be higher than the existing ones.
On the other hand, everyday mobility both individual and collective, seems to have a much quicker solution with the existing e-vehicle technology that would guarantee a more efficient use of energy (see image 2 below). Moreover, the new urban planning trends already favour short distances and tele-working, thus reducing the need of mobility at urban scale too.



Img 5 - Role of hydrogen in transports

Short distance freight, usually carried out by trucks and vans, can also rely on e-solutions, which are already the standard choice for last-mile deliveries in several economies (such as China). Long distance freight trains should run on electrified lines, rather than relying on hydrogen to substitute diesel.



Img 6 - efficiency of H2 compared to other fuels in trucks. Figure from T&E

The need for a balanced and inclusive decision-making in the EU

The EU Hydrogen Strategy set up the Clean Hydrogen Alliance which was meant to bring together various stakeholders from industry, governments, and civil society to oversee the implementation of the strategy. Yet, the Alliance is regrettably known to almost exclusively consist of energy company representatives and utilities and does not properly ensure a balanced representation of all societal interests. With vested interests in the continued use of fossil fuels and in light of the prevailing influence of gas lobbies, the Alliance cannot be expected to promote an agenda that is ambitious enough for the climate. To make things worse, Civil Society Organisations such as EEB that have applied to take part in the round tables of the Hydrogen Alliance are bound to not disclose the content of such discussion by a privacy statement. This provision will not allow to share important information with the wider public, which will be primarily affected by the EU strategy to promote hydrogen. We call on the EC to ensure full participation of civil society organizations and independent experts in the delivery of the Strategy on Hydrogen for Europe and to improve transparency and reporting of the Hydrogen Alliance. Only with balanced public, societal and private interests can a democratic alliance flourish to address the multiple social, economic, and ecological challenges associated with the development of hydrogen and avoid the locking into solutions from the past.

Conclusions

Europe has the opportunity to radically transform its economy and, while doing this, change its energy mix by building its independence from fossil-fuel hungry corporations and from many regimes propped up by fossil-fuel revenues.

We need a systemic change to start as soon as possible, and we cannot afford to rely on false solutions such as fossil hydrogen, which will delay the transition to a climate-neutral and zero-pollution economy.

There is an opportunity for renewable hydrogen and an opportunity for EU leadership, but to make a success of this, and make best use of public funds and political capital, this should focus on those uses where hydrogen can truly make a difference and avoid the many risks of over-stating its potential.

Europe's priority should be reshaping its economy in accordance to the planet's limits and deploying hydrogen according to this principle. Straying from this priority could undermine the hydrogen promise, the European Green Deal, and our real chance to build back better and decarbonise our economies for a sustainable future.