THE EUROPEAN FILES

February - March 2021 - n°65

UNLOCKING THE FULL POTENTIAL OF HYDROGEN IN EUROPE

1000 EFFICIENT SOLUTIONS TO PROTECT THE ENVIRONMENT IN A PROFITABLE WAY.

> *“Today, thousands of solutions exist that can boost economic growth while preserving nature, but they are often hidden in start-ups or research labs. They remain unknown to decision makers and are not implemented at industry level, so few people realize that everyone can use them and how profitable they have become. We need to embrace clean technologies and efficient solutions, because they are much more than ‘ecological,’ they are ‘logical’.”*

Dr. Bertrand Piccard, Initiator and Chairman of the Solar Impulse Foundation

A VOICE TO ENCOURAGE THE IMPLEMENTATION OF SOLUTIONS

An influential thought leader on progress and sustainability, Bertrand Piccard is now working to develop collaborations with governments, institutions and large companies to give them practical tools to reconcile ecology and economy. Therefore, he aims to prove that solving climate change – rather than an expensive problem – is a fantastic market opportunity.

A LABEL TO BRIDGE THE GAP BETWEEN ECONOMY AND ECOLOGY

One of the first labels for positive impact businesses bringing together protection of the environment and financial viability. The “Solar Impulse Efficient Solution” Label is attributed following an assessment performed by external independent experts. Solutions applying for the label must go through a neutral methodology based on verified standards. An award for clean and profitable solutions.

TOWARD A PORFOLIO OF 1000 LABELLED SOLUTIONS

To address environmental challenges while enabling economic growth, Bertrand Piccard has launched, through the Solar Impulse Foundation, the challenge of selecting #1000solutions that can protect the environment in a profitable way. His goal is to present them to decision-makers to fast-track their implementation.

BECOME A MEMBER OF THE WORLD ALLIANCE
Submit your solution right now to have a chance to be listed in the #1000solutions Portfolio.

▶ **SIGNUP.SOLARIMPULSE.COM**

NEED MORE INFORMATION?
Ask about our ecosystem of innovators, seekers and investors.

▶ **ALLIANCE@SOLARIMPULSE.COM**

EDITORIAL

UNLOCKING THE FULL POTENTIAL OF HYDROGEN IN EUROPE

Hydrogen is a highly abundant component of the universe and is currently enjoying unparalleled momentum in Europe and around the world. With its ambition to achieve climate neutrality by 2050, Europe needs to speed up its energy transition and reduce by at least 55% its greenhouse gas emissions over the coming decade.

The transition towards a low-carbon economy is both an imperative challenge and a great opportunity to build a better future for our society. Clean hydrogen, whether blue or green, can indeed play a critical role in the decarbonisation path.

Hydrogen can enable economic sectors, in particular power generation, industries, transport, and buildings to substantially reduce their carbon footprint. Today, hydrogen production has a high environmental footprint because it mostly comes from fossil fuels. According to the International Energy Agency, hydrogen is responsible for around 830 million tonnes of carbon dioxide per year.

The challenge is to scale up clean hydrogen produced from zero-emission electricity such as renewable and nuclear energy, and accelerate the deployment of hydrogen-based applications. Two other important challenges are to make clean hydrogen economically viable by lowering the costs of the electrolysis process and developing hydrogen transport infrastructure.

Europe is at a turning point to make the hydrogen economy a reality. With the publication of its Strategy for Hydrogen last summer, the EU laid out its vision to support the growth of clean hydrogen, outlined a number of key actions, and presented three strategic phases in the timeline up to 2050.

Hydrogen, which currently accounts for less than 2% of Europe's energy mix, is expected to represent around 14% by 2050. The roadmap aims at establishing a framework that will enable a functioning hydrogen market.

The launch of the Clean Hydrogen Alliance which gathers together major players from the whole value chain – from production to application – will facilitate the necessary investment to help the scaling up of hydrogen technologies across the continent.

Regarding the legislative process, the Council adopted its conclusion in December calling on the Commission to further elaborate and operationalise the EU Hydrogen Strategy while the European Parliament is expected to adopt its position in Spring. This may lead to intense – but interesting nonetheless – political debates.

In this edition of the European Files, we explore the potential for a hydrogen-powered future in Europe through the perspective of policymakers and businesses. Their contributions analyse the existing economic and political hurdles and recommend policy incentives that will enable the upscaling of clean hydrogen technologies and support the transition towards a low-carbon economy.

Editorial by
Laurent Ulmann & Cyrille Mai Thanh

Editor-in-Chief
LAURENT ULMANN

Management: The European Files / Les Dossiers Européens - 19 rue Lincoln, 1180 Brussels
www.europeanfiles.eu - ISSN 1636-6085 - **email:** ulmann@europeanfiles.eu
Publication Director and Editor-in-Chief: Laurent ULMANN
Layout & printing: Drifosett Printing - www.drifosett.com

TABLE OF CONTENTS

UNLOCKING THE FULL POTENTIAL OF HYDROGEN IN EUROPE

Renewable Hydrogen: A Key Driver for Europe's Energy Transition

KADRI **SIMSON**

European Commissioner for Energy

The European Green Deal and achieving carbon-neutrality by 2050 has been the main priority of the von der Leyen Commission since taking office at the end of 2019. Despite the challenges of the Covid-19 pandemic, 2020 was the year of laying down the path towards our 2050 target.

Perhaps the most significant step was the agreement by EU leaders that the EU should reduce greenhouse gas emissions 55% by 2030 (relative to 1990 levels) – as proposed by the Commission. This is a political commitment, which ties the EU into raising our ambitions for the coming decade. Our services in the Commission are now preparing a range of proposals for this summer, so that the EU can be "fit for 55%".

At the same time, the Commission provided a number of other key building blocks in 2020 aimed at achieving our medium and long-term goals. Within the remit of energy policy, these include strategies on **energy system integration, renovation, offshore renewable energy,** and **methane emissions.** In legislative terms, we also proposed a revision of the **rules for the trans-European networks for energy** and produced a detailed assessment of how Member States intend to meet their targets in the coming decade through their respective **national energy & climate plans** (NECPs).

While all of these initiatives combine to set us on the decarbonisation pathway, the most exciting element for many is the **Hydrogen Strategy**, published last July. Its aim – to kickstart investments to scale up the production and use of clean hydrogen and fulfil its potential as one of the key drivers in the green energy transition.

Although hydrogen is already used in the EU, it is for the moment primarily used as a feedstock and less in the energy sector– accounting for only 2% of Europe's present energy consumption – 96% of this hydrogen is produced with natural gas, emitting significant amounts of CO_2 in the process. This form of hydrogen is not sustainable for the long-term. But if we can scale up renewable hydrogen, there is every chance it can make a significant contribution to the clean energy transition and strengthen European industrial competitiveness at the same time.

To decarbonise our energy system, we need more energy efficiency, more renewables and more electrification. However, we also need more renewable fuels and gases. In many sectors of industry and transport, electrification has the potential to respond to the challenge. However, there will be areas, such as long-distance and maritime transport as well as aviation - or certain industrial processes (such as steel production) – where electrification is simply not an option as it is not available or not cost effective. This is where renewable fuels and gases are needed. And this is why renewable hydrogen can potentially hold the key to eliminate emissions in these hard-to-decarbonise sectors. Furthermore, hydrogen will be important to help balance a renewables-based electricity system by providing long-term storage and buffering of renewable energy.

I am frequently asked if I think Europe can emerge as a leader in a global shift towards clean hydrogen. I have no doubt that we can. Already today, the EU is leading in the development of electrolysers, a key technology needed to convert renewable electricity into hydrogen. At the same time, the EU has the right policy framework in place to accelerate the large amount of low-cost renewables needed to produce hydrogen. The EU is also the first region with the objective of climate neutrality, which gives our industry the market and investment certainty.

So where do we stand at present? Today, around 60 MW of electrolysers have been tested and demonstrated in the EU. By the end of 2024, we aim to have 6 GW of electrolysers – a hundred-fold increase, and 40 GW of electrolysers by 2030 with the aim to produce 10 million tonnes of renewable hydrogen. To achieve these objectives, we not only need to scale up individual plants, but to develop the associated hydrogen ecosystem and supply chains for storing, transport, and delivering hydrogen to the end-consumers. Investments will be needed to transform our industrial processes, to build larger electrolysers and to develop the hydrogen trucks, boats and planes of the future. This creates an enormous industrial opportunity for the EU.

Our Member States are already responding to this challenge. National strategies have been launched by France, Germany, Netherlands, Portugal and Spain, with draft strategies in preparation by Austria, Italy, Poland and others. Furthermore, 22 Member States have signed a collaboration agreement to jointly develop and support innovative cross-border hydrogen projects. A recent agreement signed by Portugal and the Netherlands to transport renewable hydrogen from Portugal to the Netherlands shows the commitment towards a common approach.

At the same time, clean hydrogen offers new opportunities to re-design our energy partnerships with our neighbouring countries and regions, and as a way to contribute to their clean energy transition. In particular, North Africa has great potential to supply cost-competitive renewable hydrogen to the EU if the renewable power generation in these countries accelerates. I am therefore pleased that the European Commission and Morocco are jointly facilitating a new collaborative platform on renewable hydrogen under the International Renewable Energy Agency.

The European Green Deal provides us with a holistic approach to tackle the climate challenge. We are applying the same principles to our hydrogen strategy. Hydrogen is part of our growth strategy, it fits within a holistic vision of an integrated energy system, it is based on a collaborative and joint approach among our Member States, and it provides an opportunity to shape the global energy transition.

For more information, see Commission webpage on hydrogen

THIERRY **BRETON**
European Commissioner for Internal Market

From Ambition to Action: Enabling **Europe** to Become a **Global Leader** in **Hydrogen Technologies**

We have the ambition to become the first climate-neutral continent by 2050 and reduce emission by at least 55% by 2030. This will not be possible without a deep decarbonisation of our industry, our mobility ecosystem and our energy system.

Renewable and low-carbon hydrogen can help us to decarbonise the most polluting industries like steel, chemicals and heavy transport e.g. trucks or aircrafts, where reducing carbon emissions is both urgent and hard to achieve. For instance, when conditions are right, clean hydrogen could help to reduce emissions in the steel sector by almost 95%.

Today, the amount of hydrogen used in the EU remains limited, and is largely produced from fossil fuels. The aim of the EU action is to deploy mature clean hydrogen across all of the most emitting sectors of our economy by the middle of this century, and to become the first fully fledged clean hydrogen market in the world. That is the main message sent by the Hydrogen Strategy for a climate neutral Europe, which the Commission published last year.

What is needed however is to create scale to bring down the costs, especially by building a competitive clean hydrogen value chain in Europe. This of course requires big investments for the scaling up the production of renewable and low-carbon hydrogen, boosting its applications in industry and mobility as well as in the necessary infrastructure.

Cumulative investments in renewable hydrogen in Europe could be up to €180-470 billion by 2030, and in the range of €3-18 billion for low-carbon fossil-based hydrogen. Combined with EU's leadership in renewables technologies, the emergence of a hydrogen value chain serving a multitude of industrial sectors and other end uses could employ up to 1 million people, directly and indirectly. Analysts estimate that clean hydrogen could meet 24% of world energy demand by 2050, with annual sales in the range of €630 billion. And as investment cycles in many of the concerned industries and in the energy sector are around 20-30 years, and as the interest in clean hydrogen is growing globally, we have no time to lose.

But most of all, we need to strengthen partnerships and collaboration among industry, EU, Member States and the relevant stakeholders.

Europe has leading players at each segment of the clean hydrogen value chain, but the challenges of scaling up production and boosting demand require a systemic approach along the whole value chain. That is why in July last year the Commission launched the European Clean Hydrogen Alliance, which brings together industry, national and local public authorities, civil society and other stakeholders. The Alliance has already attracted a lot of interest, with more than 1000 organisations - majority of them companies, joining since its launch. Together with the few thousand participants of the European Hydrogen Forum organised in November, this points to a very big interest from the hydrogen ecosystem. In my discussions with CEOs at the European Hydrogen Forum, leading EU companies confirmed solid commitment to objectives of the Alliance.

Industrial alliances are built to transform this type of commitment into real action. The European Clean Hydrogen Alliance will establish an investment agenda and support the scaling up of the hydrogen value chain across Europe. It will play a crucial role in facilitating and implementing the European Hydrogen Strategy. It is also a political signal of EU's commitment to invest in technologies enabling climate neutrality.

The work of the European Clean Hydrogen Alliance is entering a new phase. Following an open call for applications, we are now kicking-off the work of the six thematic roundtables responsible for the alliance's operational work. They are in charge of building a project pipeline and an investment agenda in their area, while ensuring coherent implementation along the clean hydrogen value chain. When relevant to their mission, they may also flag obstacles and bottlenecks for the upscaling of clean hydrogen, provide input to the work on regulations, standardisation, and research and innovation priorities.

At the same time, it is clear that public support is necessary for large-scale investments to kick-start the clean hydrogen value chain. The Commission has already identified clean hydrogen and renewables as a flagship for the recovery, due to their huge potential for energy transition, job creation and cross-border investment. We are encouraging Member States to do the necessary investments and reforms as part of their national Recovery and Resilience Plans.

We also hope to see concrete projects resulting from the manifesto on Important Projects of Common European Interest on hydrogen, prepared by the German Presidency and signed in December by 23 European countries, which makes clean hydrogen a truly European endeavour.

The EU has supported research and innovation on hydrogen for many years, giving it a head start on the development of clean hydrogen and establishing EU leadership for technologies such as electrolysers, hydrogen refuelling stations and large fuel cells.

By supporting the development of clean hydrogen, we have shown that we are serious about decarbonising our industry and attaining our climate neutrality ambitions. Now we need to consolidate this EU leadership to ensure this technology benefits our economy and society at large.

The New **Decarbonised Hydrogen Economy**: a **Growth Engine** in a **Post-Covid Europe**

BRUNO LE MAIRE

French Minister of Economy, Finance and Recovery

2020 has witnessed growing interest for the tiniest and lightest atom: hydrogen. Hydrogen technologies and uses have found their way in European Recovery Plans, and hydrogen strategies are at the heart of many Member States' decarbonation path.

Why is it the right time?

In the wake of the COVID-19 crisis, our top priority is to get back on our feet swiftly. Indubitably, bouncing back will require fortitude and innovation. It also requires that we invest, already now, in our future – and that we have a clear idea of the future we call for. We want to come out of the crisis stronger, cleaner and fairer.

Stronger

We need a more competitive economy. The Covid-19 crisis proved that we depend too heavily on imports in certain market segments. It can undermine our ability to address major societal issues by our own means, such as protecting the health of our citizens, disposing of the means to defend ourselves, or securing our ability to undertake the green transition. We should not rely on massive equipment imports to decarbonize our economy – unlike what we previously did with photovoltaic panels. I believe in breakthrough technologies as a leverage to deepen our economic sovereignty.

Cleaner

In Europe, we have made a commitment to tackle climate and environmental-related challenges. We have already started to modernize and transform the economy with the aim of reaching climate neutrality by 2050. We have agreed on a 55% GHG emissions reduction intermediary target for 2030. We now need to accelerate the pace on environmental issues. We should move swiftly to give momentum to our stimulus plans and foster new investments in clean technologies.

Fairer

The economic crisis is also an opportunity for us to rethink our economic model and the kind of society we call for. Beyond the question of sovereignty, relocation of industrial production is also a matter of preserving jobs in our regions. We have the expertise and the talents required in Europe to develop new technologies; we need to invest in them. Massive public intervention and support will provide the right impetus for businesses to move forward.

Why should we support hydrogen?

Decarbonised hydrogen technologies support all three goals. They offer the opportunity to create, on the European soil, an industrial ecosystem key to the continent's future economic sovereignty. They contribute to shape a competitive and fair economy: we expect the hydrogen sector will create 50 000 to 150 000 direct and indirect jobs in France over the next ten years. Decarbonised hydrogen technologies also give us tools to tackle the great challenge of the 21st century: the decarbonation of our economies.

In France, we have set for ourselves a clear, unifying goal: to launch a green hydrogen aircraft by 2035. I trust it can be reached. However, applications for hydrogen technologies are manifold. Hydrogen is an alternative to fossil fuels for vehicles (terrestrial, airborne, waterborne), and hydrogen technologies can be seen as complementary to the battery technology. Hydrogen can also be used as a feedstock for industries, such as refining, ammonia or steel making. Eventually, hydrogen could also serve as energy storage and facilitate the integration of renewable energy in our electricity mixes.

It is now up to public authorities to share the risks with researchers and industrialists in order to come up with new and innovative solutions. I am convinced that the EU has the potential to place itself at the forefront of the innovation race for the development of hydrogen technologies and its uses, but we need massive investments for that. In France, we have earmarked EUR 7 bn for the decarbonisation of hydrogen production and the design of a hydrogen industry. EUR 2 bn of them are to be invested in 2021 and 2022 already, in the frame of our stimulus plan "France Relance".

Why should we have a European approach?

This battle must be fought together with our European partners, in order to compete with the American and Chinese powers, which can rely on substantial domestic markets and a single leadership. The European Single Market is a powerful asset to establish a competitive economic area and attract necessary investments. But we need investments on a scale that no single Member States can match.

I was very proud to sign, on December 17th and along with 22 other Member States, the Manifesto on Hydrogen. We agreed to work on large-scale joint investment projects in order to support the development and deployment of hydrogen technologies and systems, and to grasp the possibility to shape together an Important Project of Common European Interest (IPCEI) that would support the rise of our industries in hydrogen technologies throughout the value chain. The IPCEI is a unique opportunity for Member States to coordinate their efforts to foster both economic investments and the green transition, and share the benefits of their cooperation.

Yet this is only the beginning of the hydrogen path. The IPCEI scheme must be complemented by an ambitious European industrial strategy, a long-term framework for supercharging the twin green and digital transition and reinforcing industrial value chains for technologies key to our strategic autonomy. I stand ready to implement it together with our European partners.

JOÃO PEDRO MATOS FERNANDES

Portuguese Minister of Environment & Climate Action

The Portuguese Hydrogen Strategy to **Decarbonise** its **Economy**: The Project to **Produce Green Hydrogen** by **Electrolysis**

Portugal was the first country in the world to assume the goal of being carbon neutral in 2050. Working towards that objective our last coal-fired power station will be closed this year. We believe 2021 will be a decisive one in driving the European economy towards recovery and growth, preparing for the future, namely through the two-fold – green and digital - transition and strengthening society's resilience. Within the Portuguese Presidency of the Council of the EU we look forward to conclude the negotiation of the European Climate Law with the European Parliament, enshrining climate neutrality and an ambitious emission reduction target for 2030 of at least 55% when compared to 1990.

Hydrogen will play a very important role in decarbonization. It will be key, particularly to transform the more "hard to abate" sectors. To achieve its full potential, it is very important to make progress, taking the necessary steps to make its price competitive and create a market, while maintaining investment in research and innovation, to develop the essential infrastructures and implement measures of certification of origin. Furthermore, following up on the excellent work done by the German Presidency, Portugal will strive to keep hydrogen as a central priority in the energy sector.

Portugal aims to start the green hydrogen production project on an industrial scale as soon as possible. We are in a good position to do so, considering our strategic advantages: a well-equipped deep-water harbour in Sines; a solar power price among the lowest in the world; public land available to install the hydrogen industrial complex and a modern natural gas supply network. We will combine these advantages with our ambitious decarbonization targets for 2030: a 55% reduction in greenhouse gas emissions and a 47% share of renewables in gross final energy consumption. During the next decade we aim to achieve 2 to 2,5 GW of installed capacity to produce hydrogen, to have between 10% to 15% of hydrogen injected into the natural gas grid and build between 50 to 100 hydrogen refuelling stations. These objectives amount to an investment of around 7 to 9 billion euros.

The hydrogen production in Portugal will reduce imports and energy dependency, strengthening ours and European Union's energy security. This will strengthen the position Portugal as an exporter of green energy while decarbonising the industry, transport and heating. It stimulates industry and gives new uses to the natural gas infrastructure that the country already has in place. This will be not only a major industrial project, but also an economic and social development project which will create or re-qualify existing jobs by calling for new skills and increase research and development – namely on electrolysis with waste and salt water. The green hydrogen production project is focused on leveraging solar energy, but also wind energy, on-shore and off-shore, as factors of competitiveness, industrial transformation and opportunity to increase exports.

Decentralising production is one of Portugal's priorities. With that in mind, the Portuguese green hydrogen production plans are not limited to the Sines region and there will be projects of different scale, scattered throughout the territory. Together with the new legislation on energy communities, decentralized hydrogen production is an opportunity to attract investment to the interior of the country, allowing each territory to make the best use of its endogenous resources and actively participate in the energy transition, showing - as we have always said - that decarbonization, while challenging, is above all an opportunity.

The environmental ambition of the EU Green Deal will not be accomplished if Europe acts isolated. Climate change is global and is not limited by national borders. All EU actions and policies will have to contribute to the achievement of the objectives. The challenges are complex and interconnected.

We believe that a country from southern Europe like Portugal can have an active role and push forward the broad use of hydrogen, particularly green hydrogen, becoming a key element in accomplishing Europe's decarbonization goals. As an ambitious and innovative country with a robust track-record in renewables, we bring forward our commitment and our current state of play in the hydrogen field and contribute to the global market.

TERESA RIBERA

Vice-President Government of Spain and Minister for the Ecological Transition and the Demographic Challenge

How **Renewable Hydrogen** Will Help **Descarbonise** the **European Economy** The Case for Spain

Energy efficiency and renewable-based electrification are long since the cornerstone of global action towards decarbonisation. While the Intergovernmental Panel on Climate Change has made remarkably clear the need to focus on reducing greenhouse gas emissions, a number of institutions have filled in the details regarding which technologies can support on this endeavour. For example – the International Renewable Energy Agency has estimated that renewable energy and energy efficiency solutions together offer over 90% of the mitigation measures needed to reduce energy-related emissions.

Completing this picture, hydrogen has been widely acknowledged as a key energy carrier to decarbonise those sectors of the economy where electrification is not feasible or cost-effective. Examples of these sectors are parts of the energy-intensive industry, long-haul high load transport, maritime shipping or aviation. Its potential to storing energy and contributing to balancing out our power system is also extraordinary. Hydrogen can certainly play a pivotal role in helping the world – and the EU – achieve climate neutrality by 2050, only if we make sure hydrogen is developed in line with this objective.

The European Commission published in July 2020 the excellent EU Hydrogen Strategy, which made a giant step in moving towards achieving EU climate and energy objectives. This Strategy set the development of renewable hydrogen – produced through electrolysis from renewable sources – as the unquestionable priority for the EU, recognising it is the most compatible option with the EU's climate neutrality and zero pollution goal in the long term and the most coherent with an integrated energy system.

If renewable hydrogen is the best technology available for the 2050-horizon, it seems important we concentrate our financial and regulatory resources on renewable hydrogen, swiftly and decisively, from the very start. We must avoid investing in non-renewable technologies that risk becoming stranded assets in the medium-term. We cannot afford squandering our resources on technologies that will not be with us in thirty years.

The international competition on renewable hydrogen is expected to be fierce, at a time key international actors such as China, South Korea and Japan are solidly committing to climate neutrality and the U.S. Biden administration has made a strong pledge for the energy transition. These countries are in the works of releasing ambitious national hydrogen strategies, in which they show their clear determination to become leaders on cutting-edge technologies such as electrolysers or fuel-cell components. If the EU intends to become a global frontrunner in this strategic, clean industrial ecosystem, which will be essential for our future climate-neutral energy

system, every minute counts. There is no time for transition solutions.

Fully harnessing the potential for renewable hydrogen production within the EU, while building a strong, competitive EU value chain, must be our priority. For one reason – the EU has the capacity to succeed in it. According to the International Energy Agency, only between 2020 and 2025, the increase in renewables-based generation in Europe is expected to be more than nine times the rise in electricity demand. Also importantly, strategic autonomy and energy self-sufficiency are valuable assets the EU is in a position to guarantee for the future if we make the right decisions now.

R&D&i is going to be an important pillar across the whole renewable hydrogen value chain, most particularly for reducing costs and making renewable hydrogen a cheap, viable alternative to fossil-based hydrogen. To that end, an Important Project of Common European Interest (IPCEI) on renewable hydrogen can be crucial to facilitate channelling the necessary public funds to swiftly achieving technology maturity for renewable hydrogen production, while strengthening cross-border cooperation and creating a genuine EU value chain.

The vision of Spain is to develop the industrial ecosystem of renewable hydrogen by focusing first on replacing existing fossil-based hydrogen production – which amounts to 500,000 tonnes per year in Spain – by renewable hydrogen production. Refining, fertilisers and other chemical products are good candidates for such a thing. Simultaneously, high-temperature industrial processes in steel or construction-material manufacturing have a significant potential to abate emissions by shifting in the short-term to renewable hydrogen. Likewise, we see valuable opportunities in the mobility sector, for example in maritime shipping, aviation or hard-to-electrify railways.

In a first stage, Spain is devising the promotion of renewable hydrogen clusters, which can bring closer producers and consumers while creating a synergies-fuelled ecosystem to kick-start the market. Building renewable hydrogen production capacity back-to-back to existing hydrogen demand will prevent unnecessary transmission and distribution infrastructure, reducing investment costs and carbon footprint. In a later stage, we will promote a more distributed production by using electrolysers to facilitate the integration of increasing shares of renewable electricity, following the guidance provided by the EU Energy System Integration Strategy and, namely, the principle of energy efficiency first. Before designing any new infrastructure or repurposing existing gas infrastructure for dedicated renewable hydrogen, we should ensure the existence of sustainable and reliable demand. Notwithstanding, we should plan no new additional investments in natural gas infrastructure, as they risk locking us into fossil fuels for decades, diverting us from climate neutrality. The geography of hydrogen is likely to be significantly different from existing natural gas corridors.

Following this vision, Spain has recently approved a National Hydrogen Roadmap, reinforcing Spain's commitment to renewable hydrogen. The Roadmap foresees an installed capacity of at least 4GW electrolysers by 2030 – 10% of what expected by the European Commission throughout the UE by that year – for which 8.9 billion EURO are expected to be mobilised, while foreseeing an intermediate milestone of 300-600 MW by 2024. Spain's rich renewable resources and solid value chains will be the warrants of this development. Indeed, together with our Portuguese friends, we have the potential to build a strong Iberian hub of renewable hydrogen in the medium- and long-term, while first prioritising domestic production and demand, expanding renewable hydrogen clusters and minimizing carbon footprint and transport costs.

The post-COVID19 recovery is an exceptional opportunity. Let us harness it as a catalyser to inject the impetus renewable hydrogen needs to develop its full potential and significant benefits.

FATIH BIROL

Executive Director of the International Energy Agency

Global cooperation is essential for realising hydrogen's huge potential

Hydrogen has for too long been ignored by the energy sector, despite the important role it can play in addressing our environmental challenges like climate change and air pollution – and in enhancing energy security. Momentum behind it continues to grow, but IEA analysis shows there is still a huge amount of work to be done for it to reach a scale that would make a key difference to efforts to reach international energy and climate goals.

Much has happened since the IEA released our landmark report on hydrogen at the G20 Energy Ministers Meeting in Japan in June 2019. Over the past two years, around 80 megawatts (MW) of electrolysers, which produce hydrogen from electricity, were installed worldwide, boosting global capacity to around 250 MW. The largest electrolyser plant to date was opened last year in Fukushima, Japan. And two large projects to produce hydrogen from natural gas with carbon capture became operational in 2020. They will capture 1.5 million tonnes of CO_2 per year. In 2019, 12 500 fuel cell vehicles were sold, double the amount of 2018.

Governments around the world are stepping up their efforts. Since early 2019, 12 countries and the European Commission have set out ambitious hydrogen strategies or roadmaps. And at least another nine are due to be released very soon.

These encouraging trends show the energy world's high expectations for hydrogen. But the progress gives us no cause for complacency – much more has to be done. The ambition of the strategies that governments are setting out is impressive. The challenge now is to design and implement the policies, regulations and investment plans that will turn those ambitions into reality. The IEA is ready to play a significant role by providing its data and policy expertise to support governments in this critical phase.

Hydrogen technologies are not the only ones we need to reach our energy and climate goals. We will need a wide range of clean energy technologies – from renewables, nuclear power and energy efficiency to batteries, carbon capture and bioenergy. But hydrogen is a critical part of any ambitious clean energy transition strategy.

The use of hydrogen will need to expand across many parts of the global energy sector – from road transport to shipping and aviation, from iron and steel production to the power sector. In fact, if the world is to reach net-zero emissions as outlined in the IEA's Sustainable Development Scenario, hydrogen could account for as much as 13% of total final energy consumption.And practically all hydrogen production by then would need to be low carbon, either through the use of fossil fuels with carbon capture, utilisation and storage – or through the use of electrolysers. Around 3 300 gigawatts of electrolysers would be needed. In practical terms, this requires bringing the equivalent of today's largest electrolyser into operation every hour for the next few decades.

This is why the IEA is deepening and expanding its work on hydrogen to support its continued development. This includes closely collaborating with the Japanese government on the Hydrogen Energy Ministerial Meeting this year. The IEA is proud to be able to contribute its expertise and convening power to the event, since international cooperation will be essential for successfully tapping into hydrogen's huge clean energy potential

Hydrogen is a big opportunity for many countries. The IEA is committed to help governments and industries in making their very own choices for this important technology opportunity. As we pointed in our 2019 report, the coming decade will be critical for hydrogen's long-term success.

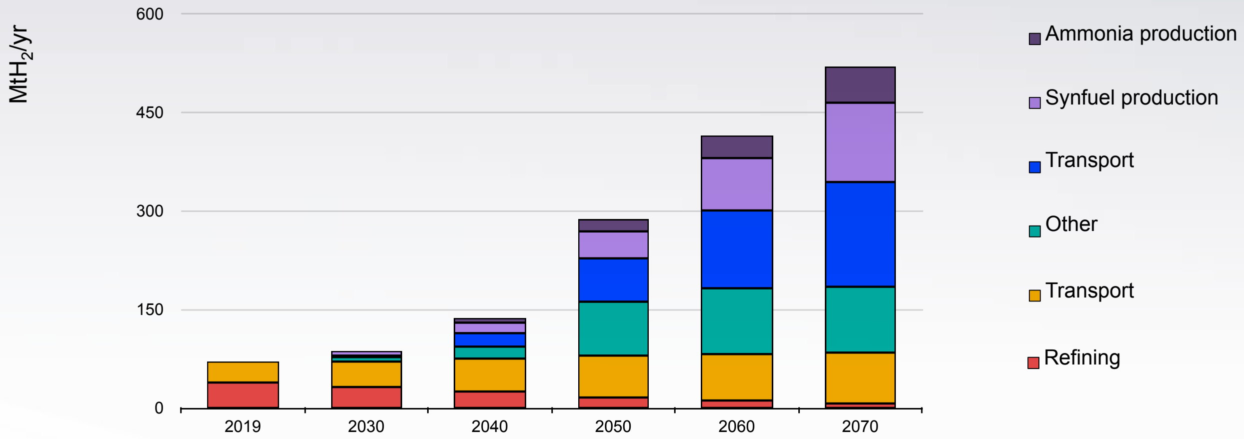
To help the world keep track of progress on this front, the IEA will start publishing a new Global Hydrogen Review this year. This report will serve as hydrogen's North Star, assessing the impact of all government and industry plans. It will examine how actual on-the-ground progress compares with stated ambitions from around the world, and help decision-makers to fine-tune their strategies to drive real progress in investment.

And I am very pleased that Noé van Hulst, the former Hydrogen Envoy of the Netherlands and now the Chair of the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), has agreed to act as a special adviser to the IEA on hydrogen-related matters and ensure that we work with all hydrogen stakeholders to advance the cause.

The time for hydrogen may have finally come, and countries around the world have to be ready to seize the opportunity. The IEA is ready to do all it can to support this.

Hydrogen – a key pillar for reaching energy & climate goals

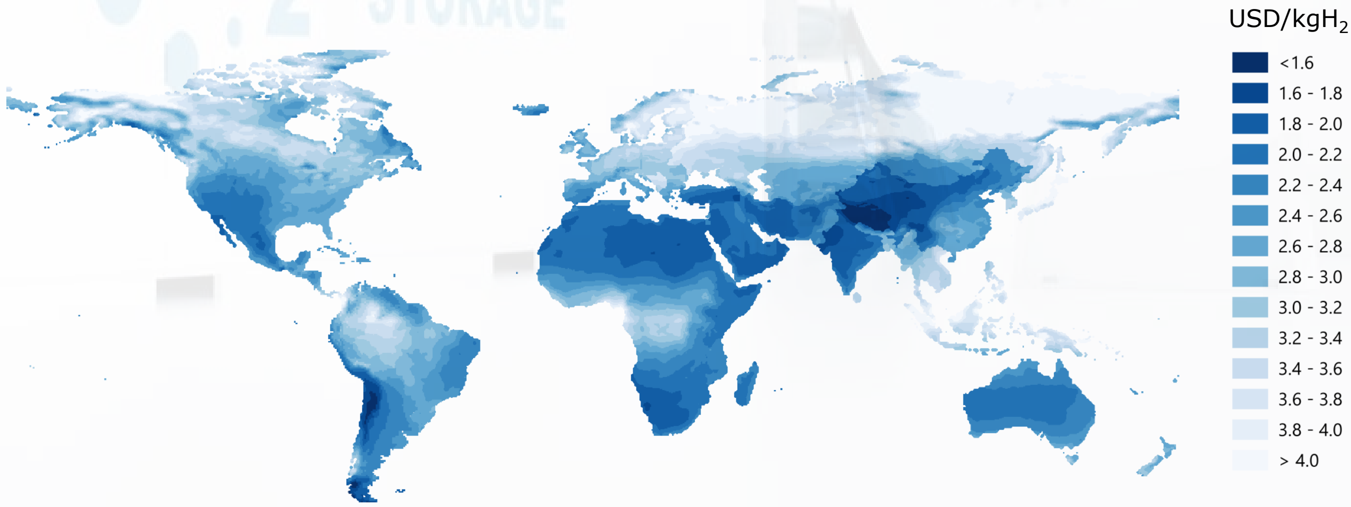
Global hydrogen use by sector in the Sustainable Development Scenario, 2019-2070



Global hydrogen use grows sevenfold by 2070 compared to today in the Sustainable Development Scenario, with demand growth almost completely met by low-carbon hydrogen.

Renewables hydrogen costs are set to decline

Long-term hydrogen production costs from solar & wind systems



The declining costs of solar PV and wind could make them a low-cost source for hydrogen production in regions with favourable resource conditions.

Building an investment case for hydrogen

AMBROISE **FAYOLLE**

Vice President of the European Investment Bank

Low-carbon hydrogen could be the missing piece needed finally to wean our energy systems off fossil fuels. Like oil and gas, low-carbon hydrogen can be stored and used when needed. Low-carbon hydrogen can also be used in hard-to-abate industries like steel and ammonia production, and it can decarbonise long-haul transport vehicles like buses, trucks, ferries that are difficult to electrify.

Getting low-carbon hydrogen usage to the level of oil or gas requires building large-scale production, storage and transport networks – investments expected to range from €200 to €500 billion by 2030. Low-carbon hydrogen also needs to be competitive with the fossil fuels currently used in industry and transport, as well as with natural gas, which creates hydrogen using a steam methane process. Whereas hydrogen electrolyser and fuel cell technologies hold big potential for innovation, economies of scale and expanded production will be crucial to bringing down prices for low-carbon hydrogen – as will continued low prices for electricity from renewable energy. In most cases, a higher carbon price on fossil fuels will also be needed to ensure low-carbon hydrogen's competitiveness. In addition, the regulation governing hydrogen transport and storage may need some adaptation to incentivise investment in the needed infrastructure.

So far, the European Investment Bank (EIB) has focused on financing research and development (R&D) in hydrogen transformation and application technologies, as well as public transport schemes deploying hydrogen buses and rolling stock, and supply or refuelling infrastructure. In the future, we also wish to support projects that expand the supply and use of hydrogen at larger scale, and we hope that we will be able to do that with the right policy and regulatory framework in place at the EU and Member State levels.

Hydrogen's moment

While low-carbon hydrogen's potential has been talked about for over 20 years now, the ticking clock of climate change – and a need for new energy sources – has renewed the focus. To keep the rise in temperature below 1.5 degrees Celsius, the European Union (EU) has pledged to cut its carbon emissions by at least 55% by 2030, compared to 1990 levels, and aims to become climate neutral by mid-century. In this context, the implementation of the European Green Deal that the European Commission has put forward at the end of 2019 will be crucial. While existing renewable energy can get us part of the way, hydrogen will be important for the decarbonisation of high emitting and hard to abate industrial sectors (for example, steel) which cannot be electrified, as well as for transport where batteries are suboptimal or not suitable (such as long-distance freight, marine or air).

To some extent, hydrogen produced from natural gas is already used in industries such as steel and ammonia production, but the production processes entail significant carbon emissions. Renewable energy, such as wind and solar power, however, can be tapped to produce green hydrogen. The falling prices of renewable energy are making the economic case for hydrogen more clear.

Seeing low-carbon hydrogen's potential, **the EU has made low-carbon hydrogen a core part of the European Green Deal and of Europe's efforts to secure its energy future**.

As a result, **political will is coalescing around hydrogen**. In July 2020, the EU announced an ambitious Hydrogen Strategy that calls for:

- Scaling up supply and demand for green hydrogen;

Ambroise Fayolle, EIB Vice-President and Pierre-Etienne Franc, Hydrogen Council Co-Secretary, sign advisory agreement to address climate change with increased investment in hydrogen
©Cyrille Lachèvre/EIB

- Supporting the development of new markets and infrastructure;
- Establishing Europe as a leader in the hydrogen industry, a creator of highly skilled jobs.

In this context, we welcome the European Commission's recent proposal to update the Trans-European Networks for Energy (TEN-E) regulation, to include battery and green hydrogen energy storage.

The enthusiasm for clean hydrogen extends to the national level, where EU members such as Germany, France, Portugal and the Netherlands have crafted their own hydrogen strategies. Germany has even promised to back hydrogen development with a public budget of €9 billion.

Providing a catalyst

In the last eight years, the EIB has invested €2 billion euros in hydrogen projects – plowing money into electrolysers, catalysts, fuel cells, electric trains, hydrogen bus fleets, refueling infrastructure and industrial applications. Today, we have **approximately €1 billion of hydrogen-related projects in our pipeline**, and we are looking for more innovators to finance. At the same time, our new energy lending policy focuses on decarbonisation and the potential of low-carbon gases like hydrogen. We have also forged partnerships with the Hydrogen Council, a group of leading energy, transport, industry and investment companies, and France Hydrogène, the French association for hydrogen and fuel cell development, to identify promising projects and innovation.

We have the technical experience, through our Advisory Services, in helping innovators and governments put together projects in a way that can attract financing. We guide them in sorting through the various financial tools – debt products, guarantees or equity instruments – that can reduce investor risks, particularly for new technologies or new industries trying to scale up. Our support goes beyond financial tools, however, to include market research and constructing new business models.

An example is our support for the HyDeal initiative. It involves a number of industrial players – including gas transmission systems operators, electrolyser manufacturers and solar photovoltaic developers – that are coming together to build a large-scale, integrated hydrogen ecosystem designed to deliver low-cost green hydrogen for industrial clients. The hydrogen produced will come from solar-powered electrolysis and will be transported via pipelines to a number of storage and delivery hubs.

A public push

Building the low-carbon hydrogen ecosystem up to the point that it could contribute to replacing fossil fuels would require enormous investments in renewable energy such as wind and solar or substantial new capacity for carbon capture and storage. The EIB has experience in these kinds of projects.

There is also need and scope for further technological progress in hydrogen conversion technologies – from low-carbon electricity to hydrogen (electrolysers) and to electricity (fuel cells). This is an area, where the Bank has already accompanied multiple companies – small and large – in their R&D and innovation activities.

In addition, investment in hydrogen transport and storage and re-fuelling (for transport) infrastructure is needed. Investment and finance can be mobilised for projects based on business models that promise an adequate risk-return ratio. Hydrogen fuel cell technology may be a good alternative to batteries for buses, trains, ships and potentially planes.

Knowing this, we have funded a number of hydrogen projects in transport, such as hydrogen buses in Riga and hydrogen refuelling stations for buses in Denmark. The H2 Corridor project in France, which received a €40 million loan from the EIB, is building the production, transport and distribution infrastructure needed for a hydrogen-powered transport corridor in the Occitanie region in France.

We need to act together

Active coordination, among the EU institutions, national governments and industry, is essential if the hydrogen dream is to become reality. **Europe's transitioning of its energy systems from high-emitting fossil fuels to low-carbon hydrogen will require massive investment and monumental coordination.**

Launching initiatives to support EU member countries' national strategies and to develop new financing mechanisms could help. At the same time, however, we need to build hydrogen production, storage and distribution links across EU member states. Those cross-border projects will require specific coordination and an alignment of public resources.

In November 2020, following on the good experience with the **European Battery Alliance**, the European Commission launched the **European Clean Hydrogen Alliance**, which brings together the industry, public authorities and civil society to identify a pipeline of hydrogen investments. Hydrogen projects are being included in the list of Important Projects of Common European Interest (IPCEI), which allows them to receive public support.

The EIB, which cooperates with the European Battery Alliance, is looking forward to doing the same with the hydrogen industry. Higher-risk financing instruments, developed together with the European Commission, have proved helpful in addressing projects in this sector, which entail significant technical and market risk. In addition, EIB advisory services can play a key role to help not-yet mature projects to develop.

The Bank remains committed to continue its support for investments in clean hydrogen – in line with the indications of the EU Taxonomy – which could range from R&D investments to demonstration projects, as well as the building of the necessary infrastructure.

Deploying **Clean Hydrogen Energy** for a **climate-neutral Future**

JENS GEIER

MEP (S&D, Germany), Rapporteur on the Hydrogen Strategy, Member of the ITRE Committee, European Parliament

The European Union has endorsed the Paris Agreement and has committed with the European Green Deal to achieve climate neutrality by 2050 through a just transition. This transition implies the decarbonisation of the entire economy, including hard-to-decarbonise sectors. This transition towards a clean energy system also needs to ensure security of supply and affordability of energy. As hydrogen produced through electrolysis with electricity from renewable energy sources is a clean alternative to fossil fuels and can be used for various purposes, including feedstock for industrial processes, fuel cells and energy storage, it can make a valuable contribution to this transition. However, hydrogen represents only a small part of the European energy mix and 95% of our hydrogen production is currently based on fossil fuels[1]. Furthermore, clean hydrogen is not yet competitive. Due to the currently limited availability of low-carbon and clean hydrogen, its use should be concentrated on sectors that operate close to competitiveness of hydrogen or that currently cannot be decarbonised by other means. Examples are the steel and chemical industry and aviation and maritime transport.

Thus, the EU needs to develop a sustainable hydrogen economy that aims at making clean hydrogen competitive as soon as possible. For this, a hydrogen strategy that covers the whole hydrogen value chain, includes demand and supply sectors and is coordinated with national efforts, is necessary. The European Commission has made a first step in this direction by adopting "A hydrogen strategy for a climate-neutral Europe" in July 2020.

However, hydrogen is not the silver bullet solution to decarbonisation. Instead, direct electrification should be considered the preferable option for decarbonisation. In addition, the EU needs to base its hydrogen economy on clean hydrogen, as only clean hydrogen is sustainable in the long term. To ramp up clean hydrogen production and establish the hydrogen economy fast enough to achieve our climate goals, low-carbon hydrogen can play a transitional role, as clean hydrogen is not yet sufficiently abundant and competitive. However, the European Commission should continuously assess for how long, for which purposes and how much low-carbon hydrogen is needed. I am furthermore convinced that it is important that fossil-based hydrogen is phased out as soon as possible.

Hydrogen Classification and Standards

In order to create an ecosystem for investments, a single European classification for the different types of hydrogen is needed. I support the Commission's proposed classification based on the carbon content of hydrogen and stepping away from the commonly used colour-based approach. In addition, we need to be able to clearly identify clean hydrogen. For this purpose, I suggest the development of standards and a European certification and labelling system based on an independent, science based review of the lifecycle emissions of hydrogen production. As clean hydrogen production is based on renewable electricity, we also need guarantees of origin for hydrogen and renewable electricity. These elements are important for hydrogen consumers to be able to invest consciously in clean hydrogen options.

Ramping up Hydrogen Production

To achieve the ambitious goals set in the Commission proposal for a Hydrogen strategy, to scale up the production of clean hydrogen and to establish a functioning and predictable clean hydrogen market that attracts investments, a comprehensive regulatory framework for hydrogen needs to be put in place. The EU gas market regulatory framework could serve as a blueprint, due to the common features of hydrogen and gas, together with the Clean Energy Package, due to its holistic approach to reviewing the functioning of the energy market.

To ramp up clean hydrogen production and to prevent diverting renewable energy from other use cases to hydrogen production, the EU also needs to create sufficient additional renewable energy production. This goes hand in hand with providing the necessary infrastructure for renewable energy, including transporting renewable energy to hydrogen production sites. The Commission and Member States should ensure that the missing infrastructure is provided as soon as possible. In addition, as renewable electricity is responsible for a significant part of clean hydrogen production costs, it is important to reduce costs by abolishing taxes and levies on renewable electricity in order to achieve competitiveness.

Hydrogen Infrastructure

The EU should avoid a chicken and egg problem between hydrogen infrastructure, production facilities and demand. We need to develop all elements from the start. The EU should incentivise infrastructure development, e.g. through the revision of the TEN-E regulation. I support the Commission's approach to start planning the medium range and backbone transmission infrastructure from the start to develop a fully-fledged internal hydrogen market as soon as possible.

As cost-efficiency is always important, the existing gas infrastructure could be retrofitted for pure hydrogen use, which could reduce

1 European Commission: Hydrogen generation in Europe: Overview of key costs and benefits, July 2020, https://op.europa.eu/en/publication-detail/-/publication/7e4afa7d-d077-11ea-adf7-01aa75ed71a1/language-en

investment costs and levelise the costs of transmission. Hence, this possibility should be assessed on a European and national level.

Hydrogen Demand

The hydrogen demand side is a crucial aspect for developing a clean hydrogen market and can contribute to decarbonisation. Therefore, clean hydrogen needs to become a more attractive business case for hard-to-abate sectors than investments into fossil-based solutions. Only then, the EU would be able to prevent carbon lock-ins and to achieve decarbonisation in time.

In order to have a better oversight of the clean and low-carbon hydrogen needed, I suggest sector roadmaps that lay out the development of hydrogen demand and investment and research needs for the different demand sectors. These roadmaps should be drafted on a European level in close cooperation between stakeholders and European institutions.

Due to the current lack of competitiveness of clean hydrogen, we should also consider putting in place targeted demand-side policies such as quotas for the use of clean hydrogen in the focus sectors. Innovative measures such as carbon contracts for difference should also be taken into account. The Commission needs to detail, however, how such measures could be financed and implemented.

Research, Development, Innovation and Financing

Furthermore, development and innovation along the whole value chain of clean hydrogen remains of paramount importance. We need demonstration projects of industrial scale to be able to implement hydrogen solutions in demand sectors. Here, the European institutions have to ensure the full involvement of SMEs: Some can deliver innovative solutions, while the bulk of them may have limited resources to implement clean hydrogen solutions for their own decarbonisation.

In order to meet the high investment needs to establish a clean hydrogen economy, European programmes can play an important role. Especially, NextGenerationEU, Horizon Europe, the Connecting Europe Facility, InvestEU and the ETS Innovation Fund can help financing clean hydrogen projects and attract additional public and private investments The European Parliament shall continue to push to provide these programmes with sufficient financial resources in the annual budget circle.

The Role of Hydrogen in an Integrated Energy System

Furthermore, I underline the importance of an integrated energy system to promote renewable energy. The gas, electricity and hydrogen grids should be coordinated. Here, hydrogen can play a key role as energy storage to balance intermittent renewable energy supply and demand. This solution is not competitive yet and the EU needs further investments for this purpose. Therefore, I welcome the alignment of the hydrogen and the energy system integration strategies. I am now waiting for the Commission's concrete legislative proposals and revisions of relevant existing legislation to set the regulatory framework for a competitive and clean hydrogen market to see if all the aforementioned priorities will be reflected. In the meantime, I am excited to continue the negotiations for the European Parliament's own initiative report on the European hydrogen strategy as Rapporteur. I believe that it can be a valuable input for the legislation to come.

Hydrogen - Making Europe a leader in each segment of this strategic value chain

DIDIER HOLLEAUX
Executive Vice President ENGIE

Europe is striving to become the first carbon-neutral continent by 2050 and as a key milestone on this path, the European Commission proposes to raise the greenhouse gas (GHG) reduction target for 2030 to at least 55%.

ENGIE supports this highly ambitious objective which requires a strong acceleration of decarbonization and activation of all levers. In particular, energy efficiency and a substantial and rapid increase of all types of renewable energies production is required. Electrification will surely play a key role but will not be sufficient. Development of renewable electricity will have to be complemented by renewable and low-carbon gases and liquid fuels as well as renewable (district) heating and cooling solutions. Moreover, efficient planning and utilization of new and existing infrastructures both for electrons and molecules is a fundamental pillar of a more integrated energy system, indispensable to achieve decarbonization objectives in the most cost-efficient way while ensuring security of supply. Renewable and low carbon hydrogen will play a key role to decarbonize the energy system.

The role of hydrogen in an integrated, increasingly decarbonized energy system

Hydrogen is a very versatile energy carrier, which can be used in fuel cell vehicles (such as fuel cell trains, trucks and busses), heating installations (e.g. fuel cell micro CHPs), in hydrogen-ready gas turbines for electricity production or as a basis for e-fuels. It is also an indispensable feedstock in numerous chemical and industrial processes, e.g. in the production of ammonia, methanol or in refineries. Hydrogen is a promising feedstock to produce steel.

It is however crucial that **hydrogen is produced from renewable or decarbonized sources in order to make a real contribution to GHG reduction**.

In this regard**,** ENGIE is convinced that during transition both renewable and non-renewable low-carbon hydrogen are needed to achieve Europe's ambitious climate targets**. However, hydrogen from renewable sources should be the dominant long-term solution due to its specific benefits.**

In fact, hydrogen helps to better integrate renewable power; converting wind and solar electricity into hydrogen allows these variable energy sources to be stored and/or transported in a cost-efficient way, if needed over long distances, before reconverting back into power or using the hydrogen directly in end-use sectors. Hydrogen produced from renewable power, i.e. inexhaustible sources, also has a better environmental footprint than other options. The development of territorial energy hubs offering renewable hydrogen and combining several uses (industry, mobility, other final uses), would foster the creation of local ecosystems. Moreover, renewable hydrogen has the potential to become a European strategic value chain capable to generate significant economic growth, jobs and competitiveness, not least due to the deep technological knowledge present in Europe and the leading role of European companies for instance in electrolysis manufacturing and renewable development. We strongly believe hydrogen can be part of an EU industrial renaissance, that both European public and private stakeholders aim at making happen.

At ENGIE, **we are working on both sides; we are investing massively in renewable energies and we have kept that direction in spite of the sanitary and economic conditions we have faced**, by adding 3 GW of wind, solar in our portfolio over the last year. Furthermore we will almost double the share of renewables in our power generation mix (31 GW which makes up 30% today) to 58% by 2030. And at the same time, **we are investing in R&I and industrial pilot projects, in order to demonstrate the huge potential of renewable hydrogen**. Of course, renewable hydrogen is currently more costly to produce than non-renewable hydrogen. However, its costs will decrease sharply in the future with a competitiveness convergence with other technologies when the carbon price is included. Such a convergence is expected in the early 2030's. Therefore, it needs to be developed right now, with the support of various mechanisms, to ensure its deployment at scale.

ENGIE is active in hydrogen production, transport, storage and uses, comprising almost the whole hydrogen value chain

ENGIE already has a full portfolio of large-scale European projects covering the whole spectrum of the upcoming hydrogen economy in Europe and other regions. Few examples: **Masshylia,** led in cooperation with Total near Marseille, aims to supply renewable hydrogen, produced locally by dedicated large scale solar farms, to the Total Biorefinery. The **HyGreen Provence project** developed with the Durance-Luberon-Verdon region (DLVA) and Air Liquide, comprises green H2 production, a dedicated H2 pipe & large scale underground storage. ENGIE is also involved in, respectively, the development of a disruptive hydrogen liquefaction technology for heavy and long distance mobility (**ELHySE project with ArianeGroup**), the deployment of green H2 refueling stations in France (**RHyZomes project**), the **HyNetherland project** in cooperation with Gasunie, the production of methanol with captured CO_2 (**North-C-Methanol project**), or E-methane production (combination of green H2 and captured CO_2

like **Methycentre project**). Let's mention too the **H2 SINES project in Portugal**, where ENGIE join forces with key national players EDP, Galp and REN, to develop a renewable hydrogen integrated value chain starting with a 100 MW electrolysis capacity to supply Galp's refinery and blend into REN's Natural Gas network and scaling up to 1 GW for export to Northern Europe. And the list is not exhaustive.

Additionally, **infrastructure companies are getting ready for the scaled use of hydrogen and other renewable gases**. Indeed, by 2030, renewable hydrogen production capacity only is expected to reach 40 GW, the ambition stated in the European Hydrogen Strategy. Given the hydrogen production potential in different countries, hydrogen will need to be transported across the EU. To that end, **the European Backbone Study** authored by eleven gas infrastructure companies provides a possible map of approximately 6,800 km of H2 pipelines by 2030, consisting mainly of "repurposed" existing natural gas pipelines (estimated to be twice less expensive than new ones). In France, by the same token, GRDF and GRTgaz also invest in R&D and equipment to adapt their grid for the blending of methane and hydrogen, if and when it is necessary before a 100% H2 network is developed. Interconnections between Member states are considered as well; GRTgaz, in cooperation with CREOS, is developing the first H2 interconnection between France, Germany and Luxembourg by retrofitting existing gas pipes (**MosaHYc project**). And all production means are analyzed: Elengy is assessing the decarbonized hydrogen production through pyrolysis and use of solid carbon, and the management of the CO_2 value chain in the LNG terminals. On its side, Storengy works on dedicated H2 storage, based on the large potential to create new salt caverns and to convert existing natural gas caverns. It has just begun a 3 years project (**Hypster**) which will test a pilot cavern for H2 with the financial support of the Fuel Cell & Hydrogen Joint Undertaking.

Eems Haven Power plant (CCGT; 5 units, the land next to the last unit is designated for the 100 MW hydrogen plant).

Levers to enable the emergence of a Hydrogen market

As any "not yet mature" technology, Hydrogen – especially the renewable one – needs support. **ENGIE welcomes the positive messages passed by the European Commission in its hydrogen strategy issued in July 2020**. We are fully involved in the Clean Hydrogen Alliance launched by Commissioner Breton, with the support of Hydrogen Europe.

In addition to the direct investments ENGIE is already making, **unleashing the huge potential of a hydrogen economy requires**:

1. **Setting the appropriate regulatory framework in the "Fit-for-55%" package expected by June 2021 to cover renewable hydrogen, and the complementary "gas" package**. These are unique opportunities to create the right conditions for the rapid growth of renewable and low carbon hydrogen. Those levers should enable a level playing field between all types of hydrogen, to ensure the development of both renewable and low-carbon hydrogen. This starts with a clear terminology and certification schemes, for both of them, On this basis, market tools such as Guarantees of Origin can be developed, as well as market-based support mechanisms and underlying third-parties access to H2 infrastructures;

2. **Providing public financial support, at national, transnational and European levels**. National plans are announced by a growing number of Member States, sending a strong signal to private stakeholders. The use of the IPCEI frame in the hydrogen sector, which makes countries work together and unleashes public funding, is very welcome, as well as the priority given to hydrogen in the Recovery and Resilience Plans. These crucial commitments by Member States will be complemented by European instruments: Horizon Europe, the Innovation and Modernisation Funds, will help a lot in financing demonstration projects. We expect from the public authorities a stable and long-term support, especially for renewable hydrogen.

As a conclusion, **ENGIE is a strong believer in the future of hydrogen, and the role that the European Union shall play in that sector**. We are committed, together with industrial partners and policy makers, to make the EU the champion of the highly promising hydrogen economy.

Directing **Public** and **Private Investments** Towards **Hydrogen Production**

ANGELIKA **NIEBLER**

MEP (EPP Group), Shadow rapporteur on the Hydrogen Strategy, Member of the ITRE Committee

The vision for renewable hydrogen

The Green Deal sets ambitious targets for the reduction of emissions. European industries work hard to achieve climate neutrality by 2050 and renewable and low-carbon hydrogen will play an important role on the way towards this goal. Especially for energy-intensive sectors, such as the chemical industry, cement, steel or heavy vehicle transport hydrogen is a real option for reducing carbon emissions. Further, hydrogen can serve as an energy carrier to transport renewable energy to production sites or other distant demand centres. Additionally, blending renewable hydrogen with natural gas decreases the carbon content, while allowing renewable energy producers to access the gas market.

The Challenge

Currently hydrogen from renewable sources is available only at a small scale. It accounts for just around five percent of the world's hydrogen production and its price is far from competitive. Low-carbon and renewable hydrogen will only contribute to the reduction of emissions all over Europe, if we arrange for ramping up the production of both, low-carbon and renewable hydrogen and, thus creating a market which provides at the end renewable hydrogen at a competitive price. According to a recent analysis of the European Commission, the share of hydrogen in Europe's energy mix is expected to increase from currently less than 2% to 13 or 14% by 2050. Thus, the necessary installation capacity for hydrogen production from renewable energy is set to be 40 GW of electrolysers within the EU and another 40 GW in neighbouring countries by 2030, compared to a capacity of currently only 1 GW. Having these figures in mind, it is obvious that hydrogen from renewable sources alone will not help to quickly decarbonise industrial production, but carbon capture and storage (CCS) technologies need to play a significant role to significantly cut emissions in the short and medium term.

Where do we need to invest - and how much?

The European Commission estimates that cumulative investments for renewable hydrogen could be up to 470 billion Euro until 2050, taking into account the costs for a necessary scale up of solar and wind energy. Investments into the retrofitting of existing plants to produce low-carbon hydrogen from natural gas using CCS technologies, might be up to 18 billion Euro. From now on to 2030, investments in electrolyser capacity could range between 24 and 42 billion Euro. And there will be further costs for infrastructure to store, transport and distribute renewable and low-carbon hydrogen. As regards transport, existing gas infrastructure should be made hydrogen-ready which also requires investments.

The strategic dimension of building up a hydrogen market - Why we need a roadmap

As set out, creating a hydrogen market demands huge investments and a medium and long term planning. Thus, we have to think in milestones and go from low-carbon hydrogen to renewable hydrogen. To achieve carbon neutrality by 2050, we need a clear roadmap setting out the necessary steps to be taken and the respective investments required in order to build up a competitive hydrogen economy.

Necessary Investments

1. Public Investments

Public and private investment is needed for ramping-up a hydrogen economy. To this end, it is essential that hydrogen is covered in the scope of existing financial EU instruments like the ETS Innovation Fund, dedicated to the funding of innovative low-carbon technologies. The Innovation Fund focus on CCS and Carbon Capture and Utilisation technologies and makes it therefore the perfect instrument for ramping-up the low-carbon hydrogen market, while it could also contribute to achieving market maturity for renewable hydrogen technologies. The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) will also play an important role in research and development on renewable and low-carbon hydrogen. Its renewal under Horizon Europe was very important but it needs an increased budget to ensure sufficient funding for hydrogen R&D. In cooperation with the FCH JU, the European Clean Hydrogen Alliance must provide an investment agenda and a project pipeline, coordinated between industry, national authorities and civil society, as soon as possible. Hydrogen could also be considered in the general objectives of the Partnership for Research and Innovation in the Mediterranean Area (PRIMA), given the importance of the Mediterranean area in the scale-up of renewable energy sources. Investments into gas infrastructure should also be supported under the framework of the Important Projects of Common European Interest.

2. Private Investments

Apart from public investments, it will be crucial to also activate private funding. This means we need to create incentives for investments. To do so, it might be necessary to evaluate demand-side policies but we need to avoid the creation of artificial needs and undue market distortions, wherever possible and should preferably stick to market based solutions. Regulatory incentives, such as the possibility to account for hydrogen or synthetic fuels towards renewable targets or emission reduction thresholds in specific sectors, could help to increase demand. Carbon Contracts for Difference could also be considered for a transitional period.

3. Taxonomy

Taxonomy plays an important role in directing future private investments. Thus, applying taxonomy rules, it is of utmost importance that private investment in low carbon infrastructure and projects is equally supported as investments in renewable hydrogen projects. Only by a taxonomy framework that allows for both investments, we can rapidly move towards a functioning hydrogen market.

Summary

Competitors on the global level, like China, are already stepping up to compete with Europe for leadership in hydrogen technology. But Europe is also well prepared to compete globally if we arrange for the right political setting: The successful implementation of Europe's hydrogen strategy has the potential to show that the Green Deal can be a driver of economic success and a promoter of European leadership in an emerging global market.

JEAN-BERNARD LÉVY

Chairman and CEO of EDF

Low-carbon electrolytic hydrogen: a win-win for climate and energy system integration

In these times of uncertainty, where one emergency chases another, a necessity remains: CO_2 emissions must be drastically reduced. The energy sector is at the crossroads of climate mitigation, economic recovery and technological innovation. In this perspective, low carbon hydrogen produced by electrolysis is a needed complement of direct electrification and is essential to decarbonise key segments of transport and industry.

Indeed hydrogen could play a major role in achieving carbon neutrality of the continent by 2050. Since it is expensive and not easy to produce in a way that does not emit CO_2, it should be primarily used in sectors where no other solutions are available, such as hard-to-abate industrial and transport sectors.

Hydrogen is widely regarded as a cutting-edge technology and the EU leads the way. 50 to 60% of the ecosystem of hydrogen start-ups are based in Europe[1]. Not only has the European Commission presented an ambitious European Hydrogen Strategy (in July 2020) but many Member States, such as France, Germany, Spain and the Netherlands, aim at integrating hydrogen into their energy future.

However, less than 0.1% of the hydrogen produced in Europe today comes from renewable or low-carbon electricity. At odds with the enhanced EU climate targets[2], 95% of this hydrogen is of fossil origin and emits 10Kg of CO_2 per Kg of hydrogen produced. In France, the manufacture of *fossil fuel-based hydrogen* is responsible for the emission of 11.5 Mt of CO_2, i.e. 3% of national emissions[3]. It is high time to replace it by low carbon hydrogen. In line with our 'raison d'être' in support of a CO_2-neutral future, EDF is developing a new ally to electrification: low-carbon hydrogen produced by electrolysis.

As soon as electricity emits less than 200 gCO_2/kWh, electrolysis reduces emissions compared to fossil hydrogen. Nevertheless, electricity-based H_2 is currently 2.5 times more expensive than fossil hydrogen. Closing this price gap will require financial support in the first years on both the production side and on the demand side. It is challenging, but we believe that the EU, with its strong industrial basis, has what it takes to build a thriving hydrogen industry by creating joint investment projects throughout the value chain. Europe is already a leading electrolyser producer with 25–30% of the global market share. EDF wants to support further growth in this area and that is the reason why the group invested in McPhy, a leading electrolyser manufacturer aiming at deploying a giga factory in the EU. In addition, the cost of electrolysis will decrease dramatically and, at the end of the day, we won't need dedicated funds anymore if we plan a phase-out of all fossil fuels and have a direct substitution of clean H_2 in place of fossil H_2.

I am truly convinced that it is possible to bring industrial partners around the table to identify barriers and solutions, to kick off projects in the field of hydrogen, with an

1 Material economics (2020), Mainstreaming green hydrogen in Europe, commissioned by Breakthrough Energy

2 At least 55% less greenhouse gas emissions by 2030, compared to 1990.

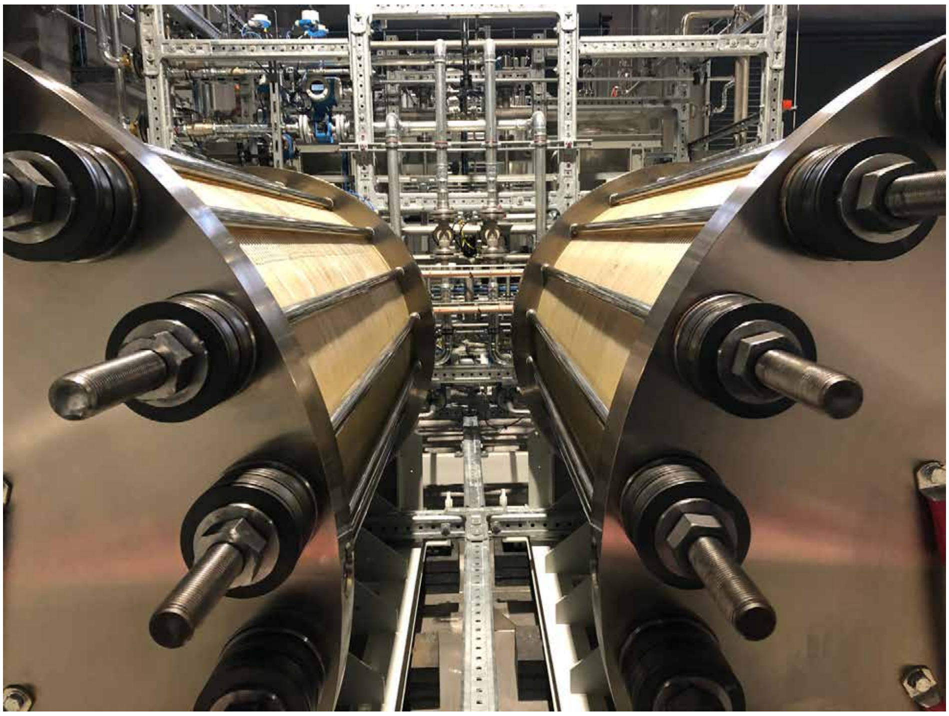
3 French Ministry of Ecological and Solidarity Transition – Plan de déploiement de l'hydrogène pour la transition énergétique https://www.actu-environnement.com/media/pdf/news-31396-plan-hydrogene-ministere-transition-energetique.pdf

The EDF EIFER publicly funded H2Bus project in Offenburg (Germany) open discussion with policy makers. This is the reason why EDF actively participates in the industrial committee of the European Hydrogen Council and in the new European Clean Hydrogen Alliance which is currently being launched by the European Commission. With my fellow co-chairs of the round table on hydrogen production, we aim at identifying the bottlenecks which slow down projects with a view to contributing to a robust EU policy framework. .

With a sound yet flexible regulatory framework and sufficient financial support to kick start this nascent industry, hydrogen growth, technology innovation and ample employment opportunities can be unleashed. This can contribute to the EU post-Covid recovery by locating major parts of the supply chain in Europe rather than betting extensively on imports. What is at stake here is the development of large amounts of low carbon hydrogen. It is indeed crucial that CO_2 emissions guide policy making and upcoming support measures. CO_2 emissions across the production life cycle must give clarity and transparency to both investors and consumers.

To swiftly deliver significant volumes in a cost-effective way, we also see a key role for electrolysers set up close to the consumption areas and connected to low carbon power grids as this allows the swift deployment of projects and a high number of production hours while reducing transport costs. Imports can be part of the picture but when walking away from fossil fuels the EU should seize the opportunity of reinforcing its energy sovereignty and resilience. To enable this grid connected production of hydrogen, it is critical that the EU policy frameworks enables traceability and transparency, for instance the system of guarantees of origin could be strengthened/improved to enable the certification of both renewable and low-carbon hydrogen. For this purpose, the EU funded Certif'HY project is a GO system readily scalable.

As the first producer of renewables in Europe, EDF supports the key role of green hydrogen produced with renewable electricity which is at the core of the EU Hydrogen Strategy. Betting on the massive deployment of electrolysis projects is a unique opportunity to find synergies, flexibility and to enhance energy system integration. I am personally convinced that low-carbon and renewable electrolytic hydrogen is a win-win for decarbonisation. Not only does it contribute to fight against climate change, but it can also boost economic recovery while putting the European industry at the forefront of a major technological deployment.



MORTEN **HELVEG PETERSEN**

MEP (Renew Europe – Denmark), Vice-Chair ITRE Committee

The **switch** from **natural gas** to **green hydrogen**, and its importance for **climate change** promises

The fuel of the future will be green renewable hydrogen - but for that to be a reality there is a long but exciting road ahead. We are taking the first steeps now, with the Hydrogen Strategy, but we are going to step up the work in the coming years both in Parliament, the Commission and the member states.

In Brussels, some talk highly of natural gas as a transition fuel that can power the green transition in the coming years. However, the is no long-term future in natural gas but only the risk of a lock-in. The ETS system will increase the cost of natural gas, while the prices of electricity and thereby the power of green hydrogen is expected to fall intensely. That is why we need to make the transition to green hydrogen as smooth as possible, because there is no doubt that we need a complete renewable fuel to reach climate neutrality in 2050.

Instead, we should take a long-term perspective and secure the funds needed for investments in the infrastructure and technology required to create the green hydrogen of the future. We need to support large scaled electrolysis project, so we can ramp up the production form MW to GW of energy. But we also need to look at how we produce the electricity required for the hydrogen production.

The is no doubt that the most efficient energy source is pure electricity and we must prioritize to electrify the union - powering it with renewable energy sources. But there will be sectors that cannot be electrified where we need an alternative – this is where hydrogen comes into the picture. Fueling parts of the heavy industry together with heavy transport, airplanes and ships with green hydrogen will create a huge demand. For transport the weight of batteries will probably make it impossible or inefficient to make them run on electricity - here hydrogen, either in pure or concerted form, will be much needed.

Further hydrogen has the potential to increase the overall effectiveness of the whole electricity system by using the excess supply in the grid and avoiding that the power production is curtailed. Here hydrogen production can be intensified at night or in the holidays, when electricity demand is lower, and it is cheaper - thereby using the excess supply. This means that we need also need to look at the regulation of the power grids, such that the production of hydrogen will never be regulated or taxed in such a way that it will put a damper on the production of it.

However, in the long run the need for green hydrogen and thereby the electricity to power it, will be at such a level, that we need dedicated production facilities to power the electrolysis process. This means that we have to build solar power facilities, offshore wind farms and other renewable energy sources that directly can power an electrolysis facility and thereby be dedicated to hydrogen.

This is why both the Commissions' Sector Integration Strategy and Offshore Strategy are of such an importance. Just to take one angle, the offshore potential is enormous – wind, wave and tide energy that can be created at sea and converted to hydrogen either at old oil platforms or separate energy islands before sent to shore. Hereby we can convert massive amounts of renewable energy directly to green hydrogen, that can be used to fuel the mentioned sectors which cannot be electrified.

Another important step is to look at the infrastructure. There is no doubt that a Europe running on green hydrogen, to power heavy transport and heavy industry, will need large investments in the infrastructure for transporting hydrogen. An obvious solution is to use existing gas infrastructure and pipes – repurposing them form transporting gas to hydrogen. However, one major problem is that we do not know the future demand and use of hydrogen.

Many gas pipes are built in areas that are being electrified and does not necessary run by areas with large renewable energy production. Further we cannot be sure that the capacity necessary for the hydrogen demand will meet the gas capacity which the pipes are built for. This means that the potential for using existing gas pipes are unknown. It is therefore essential, that we start by assessing the demand for hydrogen and where it is needed. Further we need to figure out where the hydrogen will be produced and start building the production facilities before we create the infrastructure. Otherwise we risk throwing huge amounts of money after infrastructure project we won't need in the future - instead of spending it on developing the renewable energy required for producing the huge amounts of green hydrogen that is necessary for the climate goals.

So, there is no doubt the next big project is green hydrogen when we have met our electrification limits. We just need to figure out how we get there - starting with developing the renewable energy needed, ramping up the electrolysis facilities and figuring out precisely what infrastructure we need to make hydrogen accessible where it is required.

KRISTOFFER BÖTTZAUW

Director General of the Danish Energy Agency

A **Danish perspective** on a **clever deployment** of **Hydrogen**

As we welcomed 2021, the first wind turbines was in place in what will be the largest offshore wind farm in Denmark. The 600 MW offshore wind farm at Kriegers Flak will generate enough electricity to supply 600.000 Danish households. But Kriegers Flak will not be the largest for long. The first steps have already been taken to establish even bigger offshore wind farms in Danish waters, and *while* almost half of the electricity in Denmark is generated by wind energy today, projections show that in 2027, all electricity in Denmark will be based on renewables, with about 75% wind energy.

We need wind energy to fulfill our climate targets in the long run. And to do so, Denmark have decided to use the wind energy to produce green hydrogen and to focus on the so-called Power-to-X technologies in the hard-to-abate sectors.

Two energy islands will serve as energy hubs and produce e-fuels

A broad majority of political parties in Denmark have recently set a target of 70% reduction of CO_2 in 2030 compared to the 1990 levels, and one of the first decisions made, was to expand offshore wind energy in Denmark even further. This will be done by, among other things, establishing two energy islands. The energy islands will be serving as hubs for electricity generation from the surrounding wind farms by collecting and distributing the electricity between countries connected by an electricity grid. The intention is to connect the energy islands to neighboring countries, step-by-step, along with increased energy demand.

The energy islands combined will have 5 GW of wind energy, potentially up to 12 GW and not only will the energy islands generate electricity, eventually they will produce e-fuels based on green electricity. The e-fuel will serve to enable a green transition of sectors such as heavy transport, which is difficult to electrify, and change the fuels our trucks, ships and airplanes run on.

Next step: a clever introduction of green hydrogen in the energy system

Denmark has come a long way with phasing out fossil fuels in the electricity production. In fact, the transition of electricity production away from fossil fuels is almost completed. The next challenge in the green transition is to reduce emissions in transport, in agriculture, in industry and in individual heating. However, hydrogen and e-fuels are energy intensive to produce, and thus currently rather expensive. That means that they should be used in sectors with otherwise hard-to-abate emissions such as heavy transport.

In a Danish context, green hydrogen is not only regarded as a fuel component, hydrogen is also regarded as a way to balance the electricity production and the electricity consumption. In fact, production of green hydrogen enables a higher share of renewables in the system. In other words, renewable energy and green hydrogen beautifully complement each other. As we see it, conditions in Denmark are great for hydrogen production. First Danish waters provide for ample wind resources and wind technologies are available at prices that are much more attractive than just a few years ago. Furthermore, the widespread Danish central heating system allows for synergy effects with excess heat being used in the conversion processes, e.g. from electricity to hydrogen. Denmark therefore has the right conditions to become future exporters of hydrogen and other e-fuels.

Tender on hydrogen and related technologies is underway

This said, however, the introduction of hydrogen and e-fuels into the energy system represents a number of challenges. One of the challenges is to stimulate the production and the demand at the same time, for instance in shipping and other means of transport. The Danish government is working on a strategy for hydrogen-fuels, which will address some of the core challenges. As was the case with wind energy in the early days of that technology, production of hydrogen needs a helping hand to get started and bring the technologies to full scale. Therefore, one of the very first +100 MW tenders globally on hydrogen and related technologies is underway. The tender is financed by the Netherlands in exchange for statistical transfer of renewable energy in the Danish energy system. The agreement is an example of how hydrogen is a shared priority in both Danish and Dutch energy politics. With a number of Danish companies having expertise in hydrogen and related technologies, and with a myriad of projects already thriving, we are looking forward to this tender with great enthusiasm.

Denmark has come a long way with phasing out fossil fuels, deploying renewable energy at scale in the electricity sector, and has taken the first steps to electrify what can be electrified in transport, heating and in the industry. The next steps in the green transition may well be production of green hydrogen to be used in hard-to-abate sectors. We expect to have challenges, but with dedication and with the right amount of technology development, hopes are high for a new adventure.

The **International Dimensions** of the **European Hydrogen Strategy**

HILDEGARD **BENTELE**

MEP (EPP Group), Member of the ITRE Committee

It is at the same time a chance and a burden for industry to adapt their processes to the ambitious climate goals of the EU and to reduce greenhouse gas emissions. One way could be to replace fossil fuels and feedstock in hard-to-decarbonise sectors with clean hydrogen. Hydrogen is for a variety of actors the Holy Grail to reach the ambitious climate goals of the EU and the European Commission and EU Member States support the idea to establish a "hydrogen economy" to boost demand and to reach economies of scale.

Until now, the production of clean hydrogen is not yet competitive in comparison to fossil-based hydrogen. Besides the need to speed up and enhance renewable energy production in Europe, it will be necessary to tap the potential of renewable energy worldwide, first and foremost in regions where due to their geography renewable energy and subsequently clean hydrogen can be produced more cost-efficiently.

The European Hydrogen Strategy gives us the chance to pave the way for these international co-operations. As a prerequisite, to establish a worldwide market for hydrogen, we have to set and promote standards to establish a rules-based market that contributes to a secure and competitive supply of hydrogen for the EU market.

The interest in clean hydrogen is growing globally and the European Union should be ambitious to become a world leader in not only the production of clean hydrogen and the use of clean hydrogen, but also to pay attention to keep its current good position as technology. Competition is strong: countries like China, Japan and South Korea are pursuing ambitious plans for hydrogen and fuel cell technologies and have already established national plans for the development of markets and an industry. While EU countries issue only about 16% of the total patents concerning hydrogen, the three Asian countries alone account for more than 55% of all worldwide patents regarding fuel cells and over 65% of all hydrogen-related patents. Consequently, the EU has to take fast action to establish a conducive framework which allows for the full development of its strong international brands and by that secure future-proof jobs.

At the same time, hydrogen provides Europe with the chance to re-design its energy partnerships and to promote actively new opportunities for cooperation based on the production of clean hydrogen with both neighbouring countries and regions, but also on an international level. The German government – in the context of its national hydrogen strategy - is one of the front-runners in entering new hydrogen partnerships, for example with Marocco, Chile or Australia. Co-operation with North Africa, with its solar energy resources and its average of 3.600 hours of sunshine yearly, the windy Sahara desert and hydropower offers opportunities which should be strategically seized at the European level in terms of a "Common European external energy policy". Studies and projects, for example by the German development aid implementing agency, are showing that one option might be to establish an "intermediary European buyer" to grant purchase commitments and by that spur extension of renewable energy production and establish long-term delivery relationships. In addition, North Africa and Europa are already connected by several existing natural gas pipelines being the most cost-effectively and environmental-friendly way to transport hydrogen. The same is true for Ukraine that has good wind resources together with a large potential for biomass and is already connected to the European natural gas grid. Repurposing for hydrogen could become "the" new task for gas suppliers. The characteristic of hydrogen as an energy carriers and storage allows for optimal usage of renewable energy worldwide – Let's build up a global hydrogen economy!

Natural Gas and Hydrogen: Bridging the Regulatory Gap

DR JAMES WATSON
Secretary General Eurogas

Natural gas currently represents a significant pillar for our energy system. In 2018, important coal-to-gas switching took place in the power sector and, by 2019, natural gas accounted for 23% of total EU primary energy consumption. Natural Gas accounts for more than 20% of electricity generation, and more than 40% of it is being consumed in buildings**.**

Today, the European Commission is committed to delivering a long-term vision on climate neutrality by 2050, with a target of at least 55% reduction in greenhouse gas emissions by 2030. This will hinge upon a host of new initiatives such as the renewable energy directive and energy efficiency directive, expected during the second quarter of 2021, so as to address system integration and the hydrogen strategy. Further legislation due in the fourth quarter will provide an opportunity for the gas sector to demonstrate its commitment to fighting climate change, as will the new market rules, by focusing on decarbonising gas.

This new climate ambition is a driving force for change and Eurogas, which represents more than 50 companies and industry groups from 24 countries in the European gas wholesale, retail and distribution sectors, stands committed in supporting the transition. Hence, we undertook a study with DNV GL – an independent risk management and quality assurance consultancy – to determine how the EU could deliver on its climate ambitions. The study assesses a pathway to a carbon-neutral future, comparing it to the European Commission's 1.5TECH scenario, outlined in the 2050 long-term decarbonisation strategy. What we see is that we could achieve the EU's climate goals at significantly lower costs than European Commission estimates, as long as we develop the hydrogen economy in the 2020s.

Natural gas has a key part to play in reducing EU emissions, and has been since 1990. By 2030, in parts of Europe, using natural gas will displace coal and oil thereby improving air quality and reducing carbon emissions contributing to increased ambition for GHG reduction. More quick wins could be achieved by replacing oil with LNG in maritime transport, or using gas as a transportation fuel which would require CO_2-emission measurement to occur via the well-to-wheel approach rather than the tailpipe one.

Despite this, however, natural gas will have to ultimately decarbonise itself in order to help deliver on a bona fide carbon-neutral economy, and several options to achieve this are being produced today such as biomethane and hydrogen (both blue and green). Many of our members are developing both blue and green hydrogen projects and biomethane, which contribute to Europe's leading role on clean gas technologies, providing jobs and securing economic growth.

Kickstarting the hydrogen economy needs to take place as soon as possible therefore, with a homogenous regulatory framework to back it including: a binding EU-level target for renewable and decarbonised gas consistent with the existing targets; a harmonised framework for Guarantees of Origin to ensure transparency and tradability; fostering the blending of hydrogen and methane so as to drive market uptake and ensure infrastructure interoperability.

If we do not build now, we will miss out on the chance of achieving carbon neutrality in any cost-effective way. Many EU countries recognise that hydrogen will be part of the future energy mix. There are projects in Germany, France, The Netherlands, Belgium, Spain, Portugal, to name just a few. Eurogas will be working on making sure hydrogen is deployed at scale. There is 33 bcm/year of grey hydrogen produced in Europe and, if we were to work that into blue hydrogen quickly, it could already be a big win.

In this respect, and according to all credible studies from the European Commission to International Energy Agency, the Intergovernmental Panel on Climate Change and our own, Carbon Capture and Storage is a necessity if we are to reach carbon neutrality by 2050. The chemicals industry, for example, considers natural gas with CCS and later Carbon Capture and Utilization to be a promising pathway to transition their operations towards climate neutrality. While the large-scale realisation of CCS has been met with challenges in the EU, a positive, stable regulatory environment would enable the sector to play its part fully on the path to carbon neutrality.

Renewable hydrogen will be key to achieving the EU's 2030 climate ambitions and climate neutrality by 2050. This will be driven by the massive build out of intermittent renewables and the difficulty to store electricity will result in the need for seasonal storage through hydrogen production, which in turn will help renewable developers to realise profits from their parks.

Ultimately, the bridge lies in a cohesive, single policy framework. This is needed to enable the development of new value chains for renewable and decarbonised gases. All options must be considered. In parallel, clear technical rules will facilitate hydrogen's integration. Over time, this will allow the steady growth in final demand for pure hydrogen, in sync with the development of infrastructure, ensuring the transition to the clean energy economy.

Towards greater hydrogen production capacity in Europe

FRANÇOIS-RÉGIS MOUTON de LOSTALOT-LASSALLE

International Association of Oil & Gas Producers, Regional Director Europe

OLAV AAMLID SYVERSEN

Vice President Political and Public Affairs – Global Head of EU Affairs / Country Manager Belgium Equinor Energy Belgium NV

As the EU works to implement the historical stimulus and recovery plan agreed last year, European leaders rightfully want to make sure success in delivering not just for today, but for a stronger, more resilient Europe in the future.

In the early days of the pandemic in 2020, many feared the freshly announced Green Deal would be stillborn, sacrificed on the altar of economic recovery at all costs. But bold choices were made: to look at the EU's 2050 climate neutrality objective not as a constraint to the recovery, but as an opportunity and driver for a more prosperous and sustainable Union.

Molecules are back in the game

The recovery has now become an unequivocal commitment to the twin transitions: decarbonising our energy system and expand Europe's digital backbone. At the same time, through analysis presented by the European Commission, the understanding of what it takes has evolved. Most policymakers now realize that an 'all-electric' mantra will not materialise due to technological and cost limitations. Molecules will continue to play an essential role in the transition and can do so without compromising on climate ambitions and hydrogen is likely to be central to such a future.

The European Commission's Hydrogen Strategy offers us a glimpse of a possible direction of travel envisaged for the EU energy system, setting out ambitions and a legislative agenda for the years ahead.

Driven by the commendable willingness to succeed for the long term, it seems however that the Commission has put most of its eggs in one basket. With a strategy that seeks to design policy support and channel finance to specific, chosen technologies – in this case electrolysers using renewable electricity – doors are shut for options that can deliver low-carbon hydrogen in the near term and even negative-carbon hydrogen in the long term.

The strategy thus seems somewhat incomplete. In fact, to rely solely on molecules of renewable-based hydrogen would require more electricity generation than if the entire economy was to be 'simply' directly electrified. As one senior German government official recently remarked, "it took us 15 years to realise we couldn't electrify everything, let's not wait another 15 to realise we'll need more than just renewable hydrogen".

An inclusive approach to open up options

Truth is, the challenge to produce and deliver meaningful amounts of sustainable hydrogen to drive the decarbonisation of the European economy is not simply one of technology choices. It is also one of safeguarding and evolving a competitive internal energy market that delivers affordable energy options for consumers.

Indeed, a *technology-inclusive* regulatory framework, incentivizing GHG emission reductions, that works for producers and consumers alike, will be essential for European global competitiveness, economic prosperity and environmental resilience.

Rather than a *technology-narrow* strategy based on overly optimistic assumptions as a starting point, EU Member States are best served by a strategy leading them to deploy a mix of sustainable hydrogen manufacturing technologies. This will better reflect their industrial and technological strengths and allow their industries to thrive in a competitive internal market for hydrogen and contribute to its deployment.

To help understand Europe's hydrogen potential and inform future policy choices, IOGP and its Partners will in March this year publish the '*Hydrogen for Europe*' study commissioned to Norwegian and French research centres SINTEF and IFPEN, with Deloitte as project manager. The study will highlight the technological and financial implications of various pathways, and inform policy makers about the types of projects likely required to scale up a hydrogen market and industrial hydrogen value chains in Europe.

Decarbonizing Heating

All the while the policy framework is still debated, industrial actors are already pursuing a wide range of hydrogen production projects across Europe. In the UK, around the city of Leeds, industrial actors have partnered in a regional and multi-sector effort, the "H21 Project", to showcase how 3.7 million homes and 40,000 businesses, currently heated by natural gas, could become emission-free by 2034.

The pillar of this effort is combining 12.15 GW of natural gas-based hydrogen production facilities with CCS and make smart use of existing gas pipelines and some new build to transport hydrogen and CO_2. In six further phases, it is envisaged to convert, by 2050, 12 million more homes across the rest of the UK alongside other sectors to hydrogen sourced from multiple technologies and lowering GHG emissions with 0.25 $GtCO_2$ equivalent per year.

Cancelling industrial emissions

Based on this vision, several at-scale decarbonisation projects promising to kick start decarbonisation of industry and power, are now being pursued in this region of the UK[1]. One such example is the "H2H Saltend" project[2] (Fig. 1) with at its core a natural gas-based hydrogen project at Saltend Chemicals

1 https://www.drax.com/wp-content/uploads/2019/11/Capture-for-Growth-Zero-Carbon-Humber-V4.9-Digital.pdf

2 https://www.zerocarbonhumber.co.uk/wp-content/uploads/2020/07/equinor-H2H-saltend-brochure-2020.pdf

Park near the city of Hull. The planned 600 MW autothermal reformer plant to convert natural gas to hydrogen and fitted with CCS would be the largest of its kind in the world. From first production, H2H Saltend will reduce industrial CO_2emissions by nearly 900,000 tonnes per year.

In a second step, hydrogen and CO_2 pipeline infrastructure will be extended further to other industrial sites in the Humber region, enabling them in turn to fuel switch to hydrogen or capture their emissions. These sites include Drax Power station[3], SSE Thermal's Keadby site, Uniper's Killingholme site and British Steel at Scunthorpe.

Through smart use of a variety of technologies and network design the region could come to host a large-scale sustainable hydrogen demonstrator by the mid-2020s; integrating carbon negative power from bioenergy carbon capture and storage (BECCS) and demonstrate the role of hydrogen in cleaning steel production.

In the process, not only will the region's 55.000 workplaces in manufacturing continue to thrive, but a significant contribution will also be made to create an estimated 43,000 new job opportunities that a switch to hydrogen in energy-intensive industrial sectors across the UK could bring. **Combined, the regional projects now pursued in the North of England/Humber region would allow for the decarbonisation of nearly 50% of the UK's industrial emissions!**

Clean Steel

Similar industrial scale project of manufacturing of sustainable hydrogen is ongoing in the EU. In the border region of the Netherlands and Germany, the "H2morrow" project partners are maturing a suitable concept for the generation and transport of natural gas-based hydrogen combined with CCS to the largest German steelworks in Duisburg.

The concept involves transport of natural gas from Norway via the existing transport network to an autothermal reforming plant (ATR) fitted with CCS on the German or Dutch North Sea coast. The ATR plant would have a hydrogen reforming capacity of up to 800,000 Nm³/h (2.7 GW), of which 600,000 Nm³/h of hydrogen (2.1 GW) for Thyssenkrupp Steel Europe and 200,000 Nm³/h to be provided to third parties.

The CO_2 captured at the ATR plant is planned to be transported, either by ships or pipelines, to safe CO_2 storage at sites such as the Northern Lights[4] project in Norway or other storage options, e.g. the Porthos project[5] offshore of Rotterdam.

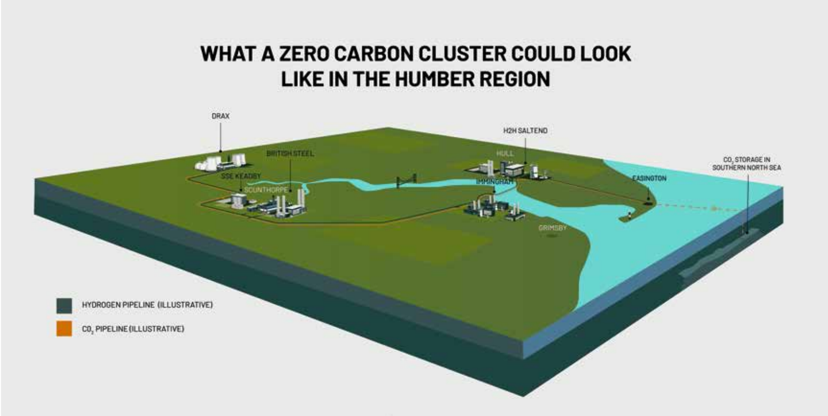


Fig.1: Smart decarbonisation of industrial clusters – H2H Saltend, UK

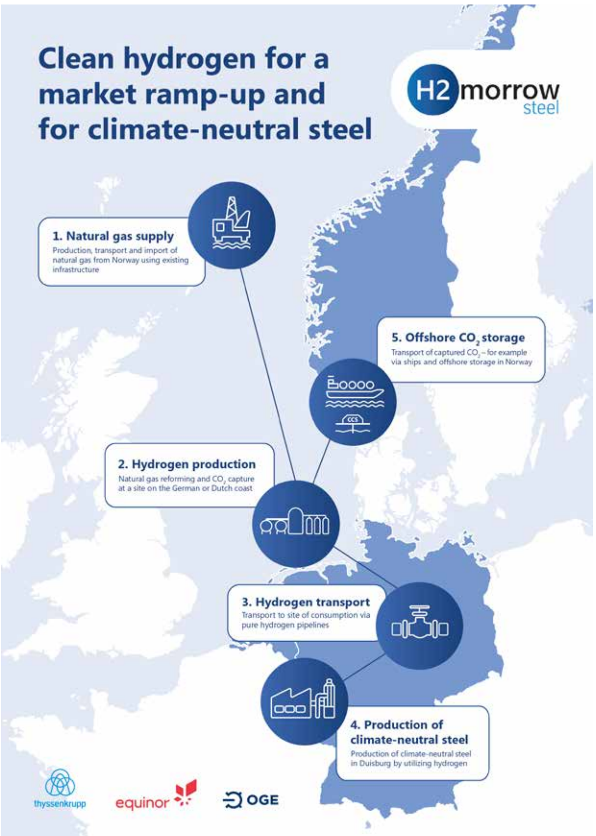


Fig. 2: Partnering for clean steel, H2omorrow

The "H2morrow" steel project would allow for 7 million metric tonnes of climate neutral steel per year. **Moreover, it would singularly enable up to 11 million tons of CO_2 savings annually corresponding to close to 20% of German steel industry's total CO_2 emissions and more than 5% of total German industrial emissions!**

Synergy is how we win

These projects, alongside the large size natural gas and CCS-based "H-vision" project[6] and Europe's largest renewables-only hydrogen production project, the "NorthH$_2$" project, both planned in the Netherlands, are testimony to the prowess and ingenuity of European industry in creating symbiotic hydrogen-based decarbonisation clusters across sectors, technologies and borders, while preserving and creating industrial jobs.

European leaders must encourage the deployment of many more such projects by encouraging collaboration and partnering – which also mitigate risks related to infrastructure investments – rather than pushing technologies by ideology or decree. Not only will they deliver substantial emission reductions, they will also secure Europe's economic resilience and growth.

A Europe that successfully leads large scale industrial decarbonisation will inspire global partners and accelerate emission reductions beyond its own borders. Implementing the Hydrogen Strategy through *technology inclusive* rather than *narrow* legislation is an important first step in that regard.

3 https://www.drax.com/energy-policy/capturing-carbon-at-drax-delivering-jobs-clean-growth-and-levelling-up-the-humber/

4 https://northernlightsccs.com/en/about

5 https://www.porthosco2.nl/en/

6 https://www.h-vision.nl/en

CHRISTIAN **EHLER**
MEP, EPP ITRE Coordinator

Why **Europe Needs Targets** for **Hydrogen Energy** Infrastructure Rollout

As part of the European Green Deal, the Commission adopted on 8 July 2020 a new dedicated strategy on hydrogen in Europe, in parallel with the strategy on energy system integration. It will bring together different strands of action, from research and innovation over production and infrastructure to the international dimension. Hydrogen is an essential element in the energy transition and can account for 24% of final energy demand and 5.4m jobs by 2050, says a study by the FCH JU from 2019. The so-called renewable hydrogen (also called green hydrogen) is expected to play a key role in the decarbonisation of sectors where other alternatives might not be feasible or be more expensive. This includes heavy-duty and long-range transport and energy-intensive industrial processes.

First, the EU Hydrogen Strategy will give a boost to clean hydrogen production in Europe. The production of clean hydrogen needs to be increased by creating a sustainable industrial value chain. We should boost the demand for clean hydrogen coming from industrial applications and mobility technologies. Clean hydrogen needs a supportive framework, well-functioning markets, and clear rules, as well as dedicated infrastructure and a logistical network. To target support at the cleanest available technologies, the Commission must work to introduce a comprehensive terminology and certification, to define renewable and other forms of hydrogen. It must be based on lifecycle carbon emissions, anchored in existing climate and energy legislation, and in line with the EU taxonomy for sustainable investments.

Secondly, promoting research and innovation in clean hydrogen technologies is crucial. If there are 2030/2050 targets on CO_2 reduction, they must be reflected in Horizon Europe and the related Joint Undertakings. There is also a need to set targets to create the necessary energy infrastructure as well as to provide an appropriate capacity building to have hydrogen available sufficiently as an important bridge technology to decarbonise energy-intensive energy sectors. The European Clean Hydrogen Alliance will help build up a robust pipeline of investments. Together with Important Projects of Common European Interest (IPCEIs) we have important means to enhance investment in clean, decarbonised, and low carbon hydrogen. The Alliance must be encouraged to come up with an investment agenda and a project pipeline, in cooperation with the Fuel Cells and Hydrogen Joint Undertaking that can ensure the implementation of the hydrogen goals set by the Commission as soon as possible. I welcome the renewal of the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) under Horizon Europe. The Commission should use it as a competence centre for clean and low carbon hydrogen and make use of the experiences gained in the Joint Undertakings, especially on Hydrogen fuel cells, and to incentivise further research into these technologies. I would suggest to include the deployment of hydrogen in the general objectives of PRIMA in line with the priorities of Horizon Europe in order to strengthen research and innovation capacities and to develop knowledge and common innovative solutions across the PRIMA region.

Thirdly, the transition to a net-zero greenhouse gas economy requires a clean energy transition that ensures sustainability, technology neutrality, security of supply, and affordability of energy and competitiveness of energy prices. The development of hydrogen systems might be addressed differently by Member States, considering differences in the topology of their existing gas infrastructure, their capacity to develop different ways of hydrogen production technologies, different potential for innovation and a varying demand for hydrogen by different industries in each member state. The building of a competitive hydrogen market that contributes in a time and cost-efficient manner to the Union's climate-neutrality objective for 2050 requires well developed transmission infrastructure to distribute efficiently hydrogen efficiently from production sites to consumption areas across the Union which may be achieved based on repurposing of existing gas grids and building dedicated hydrogen transmission infrastructure.

Fourthly, the Commission must streamline its approach on hydrogen with the industrial strategy and make it part of a coherent industrial policy. We should call on the Commission to provide a technology-neutral emissions threshold standard for hydrogen and a regulatory framework that ensures guarantees of origin, tradability across member states and is consistent with the ETS as early as possible in 2021. We need to stress that one core criteria for the standards, certification and labelling systems should be the CO_2 footprint rather than the production method to respect technology neutrality.

Finally, there is a timely need for hydrogen production, storage and transport, and distribution infrastructure and the parallel development of demand and supply. Despite the concentration on industrial clusters in the first phase, the progressive reconversion of distribution grids and the planning of infrastructure for transmission over longer distances and its regulation should already be undertaken. The synergy benefits of integrating hydrogen production and infrastructure with other parts of flexible, multi-energy systems, such as waste heat recovery for district heating grids. Interoperability with the gas system and interconnection of hydrogen infrastructure within the EU must be assured.

Hydrogen valleys driving growth and jobs

BART BIEBUYCK

Executive director of the Fuel Cells and Hydrogen Joint Undertaking (FCH JU)

Hydrogen Valleys have recently become a global phenomenon, with integrated, complex projects emerging across the world in a drive to accelerate the development of the hydrogen-driven economy.

In her SOTEU[1] address of 16 September 2020, European Commission President von der Leyen pointed to the role of Next Generation EU to help deliver hydrogen valleys "to bring life to rural areas". More recently, in a speech to the Hydrogen Council, she mentioned their role in creating a "true European clean hydrogen market" as they will allow Europe to produce hydrogen where it is most economical and build the infrastructure needed to distribute it, while creating growth and jobs. Indeed, this is exactly what Hydrogen Valleys and Hydrogen Islands are: "Places where clean hydrogen creates growth and jobs in full respect of the environment"[2].

It does not come as surprise then that more than 1000 participants from across the world gathered on 19 January for the online launch of the Hydrogen Valley Platform (H2V.eu). This platform was developed by the FCH JU, on behalf of the European Commission, under the umbrella of Mission Innovation "Renewable and Clean Hydrogen" Innovation Challenge.

The platform presents and connects the existing regional clusters, with 32 hydrogen valleys from 18 countries already featured on the platform.

The FCH JU coined the concept of "hydrogen valley" as a way to designate a geographical area – a city, a region, an island or an industrial cluster - where several hydrogen applications come together into an integrated hydrogen ecosystem that consumes a significant amount of hydrogen, improving the economics behind the project. It covers the entire hydrogen value chain: production, storage, distribution and final use. As such, "hydrogen valleys" offer a pathway for scaling up and making this technology a viable solution.

This comes as the result of a sustained process, which started in 2017 with our Regions and Cities Initiative, and continues with the Project Development Assistance through which we are supporting 11 local authorities from across the European Union to develop their concepts for regional hydrogen projects into detailed work plans. Hydrogen valleys are also the topic of a Smart Specialisation Platform[3] for industrial modernisation - which aims to support EU regions committed to generate a pipeline of industrial investment projects following a bottom-up approach.

The H2V platform is undoubtedly an important initiative to take the hydrogen valley concept to the next level – and see how is represented at a global level. It is a very useful tool for project developers and not only. Policy makers, local and regional authorities and many others can benefit from its findings.

The platform will increases the visibility of Hydrogen Valleys in the industry, among policy makers and funding entities and boost the uptake of the hydrogen economy. It is a great example to show how international collaboration on hydrogen can boost the hydrogen economy, and we are happy to see so many countries involved and on the track for developing such projects.

So far, the global analysis of hydrogen valleys we undertook for the launch of the platform shows clear signs of a maturing market, but also highlights that the developers face common challenges, especially concerning business cases and regulation.

In line with the EU Hydrogen Strategy, the FCH JU has supported and will continue to support the development of hydrogen valleys in Europe both in the mainland and in the islands. Last year, we awarded 10 million EUR for the project Green Hysland, which aims to create a 'green hydrogen ecosystem' in the Balearic Islands.

Green Hysland will generate, distribute and use at least 300 tonnes of renewable hydrogen locally per year, produced from solar energy on the island of Mallorca. Mallorca is ideally positioned to develop the first hydrogen hub in Southern Europe, while becoming Europe's first example of an integrated island economy based on green hydrogen. The project will also include the development of business models for replicating the project to other EU islands and beyond. As the project progresses, it will develop local expertise and new employment opportunities in the sustainable energy sector on the Balearic island, which will come as a breath of fresh air to the hard-hit economy of Mallorca.

Other previous initiatives supported by the FCH JU are the projects Heavenn (in 2019) and BigHit (2018). HEAVENN is a large-scale demo project brings together production, distribution, storage and local end-use of hydrogen into a fully-integrated and functioning hydrogen valley in the Northern Netherlands, with a total initial investment of 88 M EUR. At a smaller scale, BIG HIT created a hydrogen territory in the Orkney Islands in Scotland, benefiting communities and businesses who want to use more locally generated renewable energy.

I strongly believe that hydrogen valleys will play an integral part in building further momentum in the market and driving economic recovery and growth. I would like to invite all those interested to have a look at the platform and to get involved.

1 State of the Union Speech, 16 September 2020

2 Speech by President von der Leyen to the Hydrogen Council, 19 January 2021

3 https://s3platform.jrc.ec.europa.eu/hydrogen-valleys

The scaling up of **hydrogen**, a **European** task

NIELS FUGLSANG

MEP (S&D group), Member of the ITRE committee

2021 marks the 30th anniversary of the launching of the first offshore wind park "Vindeby". The wind park consisted of 11 turbines that altogether had a capacity of 5 MW. Today, one single offshore turbine can have a capacity of more than 8 MW. The world's largest wind park in operation, the Hornsea 1, can power 1 million homes and as a next step, whole energy islands are under development.

Today, wind energy successfully brings us clean and affordable energy on a large scale. We are now laying the foundation for another vision. A vision where we will create not only green electrification in huge amounts, but also huge amounts of green fuels for heavy transportation, freight and industry. However, we do not have another 30 years this time.

The need to scale up green energy technologies is of utmost urgency if we are to reach our climate goals. Everything that we have achieved in the wind industry has to be achieved with in every sector simultaneously at a speed never seen before. According to the International Energy Agency, 45 percent of carbon dioxide reductions in 2050 has to come from technologies that is not even commercialised on a smaller scale at this moment.

Clean hydrogen is a major pillar in this transformation. A known technology with little impact today, yet with a huge potential. So how can we overcome its main challenges and move forward?

Public-private partnerships are essential

Hydrogen has to be scaled up at an enormous speed. This will require investments from both public and private actors. Governments have to keep the risk of investments low, whereas private actors must find the most promising projects and invest heavily in them. The EU should be ready to support Member States and make sure that state aid rules effectively supports the needed subsidiaries to clean hydrogen. Partnerships across the value chain also have to be established. The real climate effect will not be reached until clean hydrogen is effectively utilised in transportation, freight and industry. No buyer, no producers, and vice versa. As such, governments hold an important role in stimulating the demand side as well.

Scaling up hydrogen takes a shared effort

In the 1980's, Danish wind turbine fabricants used the Danish market as a laboratory while increased export required a rapid scaling up and fast accommodation to mass production. Scaling up of clean hydrogen requires both technological development and a large market to stimulate growth. The prospects of a huge European hydrogen market is therefore a necessity for local developers to strive for speedy innovation and increased production.

A shared market requires shared infrastructure. The revision of the trans-European energy networks (TEN-E) regulation is an important step to make sure that the EU actively supports clean hydrogen such as electrolysis powered by renewable energy like wind or solar. The support of hydrogen storage facilities will be an essential part in order to take advantage of the enormous wind power resources in Europe and at the same time make Europe less energy dependent. Hence, due to the commitment to become carbon neutral by 2050, we need a massive increase of storage capacity to guarantee the security of energy supply. At the same time, the storage perspective of hydrogen is a major driver in the business case as advanced storage is necessary to utilise excess wind power for the hours where production exceeds consumption.

Let us take the clean way from the beginning

The revision of the TEN-E also highlights another important issue: European funds should only be available for projects that are 100 percent carbon free. We do not have the time for transitional experiments that keep fossil fuels artificially alive. The purpose is to decarbonise the sector, create a green economy and eventually eliminate carbon dioxide from our energy consumption. Therefore, we must put all our effort into clean hydrogen products if we are serious about scaling up the technology.

Keep public support

Hydrogen could eventually bring cleaner air to our cities and a healthier planet when replacing oil and gasoline in heavy freight vehicles or ships. This will benefit us all. However, many local societies still do not applaud the necessary infrastructure projects. This is understandable: The prospect of having large construction sites and energy plants next door is not something that most people wish for. But most of their worries can be accommodated, for instance through early public participation, by enabling local communities to engage, to participate financially or to compensate nearby communities, while we ensure close cooperation between sectors. I believe that if we choose the right approach and explain our purposes, we can achieve the practical implementation of our hydrogen vision.

The **future** of **Hydrogen** under the **Green Deal ambitions**

MARIA **SPYRAKI**

MEP (EPP – ND Greece) Member of ITRE Committee, European Parliament

Hydrogen is a central element of the EU plans in meeting the net-zero emissions target by mid-century. It is not the "silver bullet" for the decarbonisation of our energy mix, but it is the energy carrier that we have to invest more heavily. Hydrogen can be used as a feedstock, a fuel or an energy carrier and storage, and has many possible applications across industry, transport, power and buildings sectors" as the Commission underline on its relevant Communication.

However, before we welcome the new hydrogen decade, we have to become very well prepared on the following fundamental aspects, which will finally affect the success of the strategy.

1. Do we have the capacity to produce the quantity of green hydrogen we need in the EU as soon as possible?

According to the Strategy "in the first phase, from 2020 up to 2024, the strategic objective is to install at least 6 GW of renewable hydrogen electrolysers in the EU and the production of up to 1 million tonnes of renewable hydrogen", and "in a second phase, from 2025 to 2030, hydrogen needs to become an intrinsic part of an integrated energy system with a strategic objective to install at least 40 GW of renewable hydrogen electrolysers by 2030 and the production of up to 10 million tonnes of renewable hydrogen in the EU."

Are we ready to proceed so fast in order to address the 2024 target? Shall we invest intensively by all means on technology innovation and green hydrogen production by transforming former coal regions into hydrogen valleys and incentivize and facilitate our industry to transform itself into green energy consumer? The milestone of 2024 is tomorrow. We have also to be prepared for green hydrogen massive import, particularly from Africa, which means additional investments in infrastructure.

2. Are we prepared to work with a realistic approach based on complementarity and transitional technology?

The Council conclusions on December 11th on hydrogen underline that emphasis should be given to hydrogen from renewable sources and that additional renewable energy demand from hydrogen will have to be taken into account in the future deployment of clean power generation capacity. It also acknowledges however, that the role that low-carbon hydrogen will have in an initial phase to ramp up production in parallel with blue hydrogen made from natural gas with carbon capture technology.

Since at the same date the European Council adapts the conclusions on climate law, it is now time for speed action. "The European Council acknowledges the need to ensure interconnections, energy security for all Member States, energy at a price that is affordable for households and companies, and to respect the right of the Member States to decide on their energy mix and to choose the most appropriate technologies to achieve collectively the 2030 climate target, including transitional technologies such as gas".

The translation of this decision depends on the political will of the governments in the Member States. However, the update of legislation in batteries, focusing on a whole life-circle approach, the renovation wave of buildings, the sustainable transports and a number of additional EU initiatives consisting the parameters of the European Green Deal, constitute a road map in order to transform not only our economy, but also our life model. In order to achieve this transformation, we need to use all the available instruments complementary and to take into account that big changes are successful since having people on board.

3. Are we ready to Repurpose our infrastructure before building new ones? Important European Projects of Common Interest are needed.

Our first priority is to include hydrogen as a key part in our energy mix and therefore, we have to provide adequate infrastructure. Investing now in low-carbon gas infrastructure will help to avoid a lock-in effect into fossil assets that otherwise will become stranded as Europe moves towards net-zero emissions.

In order to reach the target of at least 55% decarbonisation by 2030, more upfront investments are needed to lower the overall cost during the lifetime of these investments. Before we start building new infrastructure we have to repurpose the existing gas infrastructure into hydrogen-proper as fast as we can.

Earlier this year, a group of eleven European gas infrastructure companies presented plans to create a dedicated "hydrogen backbone" to connect future hydrogen supply and demand centres across Europe. According to those plans, 75% of the network will consist of retrofitted natural gas pipelines, which are gradually expected to become redundant as volumes of natural gas decrease in the future.

4. How can we secure and provide affordable energy for our citizens without leaving anyone behind?

Under the new ambitions of the Green Deal, we proceed to the revision of the TEN-E regulation.

The objective of the future TEN-E is to support the implementation of the European Green Deal through the decarbonisation of energy, transport, industry and buildings, by fostering the deployment of innovative technologies and infrastructure, while keeping the energy transition socially sustainable.

However, we have to be realistic and to bridge the gap between our ambition of not relaying on fossil fuels, in general, and at the same time to provide affordable energy in the market, for our citizens and the industry. In addition, we have to take into account the stability of the system and the security of supply.

Hydrogen : Time to scale up !

MATTHIEU GIARD

Executive Vice-President
Member of the Executive Committee
AIR LIQUIDE

The development of low-carbon hydrogen is key for the decarbonization of our society.

Hydrogen is a central pillar of the energy transformation required to limit global warming to 2°C. To achieve this scenario, the world will need to decrease energy-related CO_2 emissions by 60% by 2050[1]. Hydrogen can play a major role in this transition. In 18 applications in the sectors of transportation, heating and feedstock for the industry, hydrogen could become the low-carbon solution the most competitive in 2030[2].

In the context of the Covid crisis, many countries have released recovery plans rightfully putting hydrogen at the center of the economic recovery. In 2020, several Member States such as Germany, France, Portugal and Spain published their hydrogen strategies in order to develop the sector by allocating each several billions to it. Most recently, the French government created the National Hydrogen Council (co-chaired by two CEOs, Patrick Koller from Faurecia and **Benoît Potier** from Air Liquide), to structure the relation between the industry and the government in the hydrogen sector. On its side, the European Union has set, in its ambitious hydrogen strategy presented in July, a production target of up to 10 million tonnes of renewable hydrogen in the EU by 2030, for which large investments are needed. These will be discussed in the European Alliance for Clean Hydrogen.

Air Liquide has been supporting for a long time of Hydrogen and has therefore warmly welcomed all these initiatives. We think that **now is the time to scale-up and accelerate.**

As a world leader in gases, technologies and services for Industry and Health, Air Liquide is present in 80 countries with approximately 67,000 employees and serves more than 3.7 million customers and patients. With more than **50 years of experience in the entire hydrogen value chain from production to storage, transportation and end-uses**, it is our ambition to play a world leading role in hydrogen solutions, as well as in processes and technologies necessary to decarbonize industries and energy use. In order to open up a new chapter, we have recently **adapted our internal organization to steer the way** in the hydrogen world.

Air Liquide is committed to further develop hydrogen markets in Asia, the Middle East, the US and Europe, in industry to **decarbonize, steelmaking processes, electronics, chemistry, refineries** as well as the **mobility** market. Also in the **space** sector Air liquide has been preparing, testing, and optimizing the installation and connections of cryogenic lines for launch pads since the 1980s, including liquid hydrogen for the Ariane rocket.

Air Liquide is convinced that it is necessary to develop global industrialisation programs to finance series and deployment at scale or a support program focusing on key value chains. According to the FCHJU, the projected deployment of hydrogen would create an estimated EUR 820 billion industry for the fuel and associated equipment for EU companies by 2050. At the same time, the EU hydrogen industry could provide employment for about 5.4 million highly skilled workers[3].

One of our main targets is to gradually **decarbonize the production of hydrogen**. For mobility applications as an exemple, are committed to achieve 100% low-carbon or renewable hydrogen supplied by 2030.

To achieve this objective, it is necessary to combine amongst other biogas reforming, the (access and) use of renewable energies, through water electrolysis as well as the use of technologies for the capture and storage of carbon emitted during the process of producing hydrogen from natural gas.

Over the last years, our Group has accelerated its investments in clean hydrogen. A few recent announcements:

- together with the Port of Rotterdam Authority, launch of a jointly created initiative, which aims at enabling **1,000 hydrogen-powered zero-emission trucks**

With a charging time of less than 5 minutes and a range in excess of 500 km, hydrogen-powered cars are an efficient alternative in the fight against CO_2 emissions in the transportation sector.

1 IEA Report "Energy Technology Perspective" (2017)

2 Study "Path to hydrogen competitiveness", from the Hydrogen Council (2020)

3 Report "Hydrogen Roadmap Europe', FCHJU (2019).

on the roads connecting the Netherlands, Belgium, and western Germany by 2025 ;

- 40% stake acquisition in the capital of the French company H2V Normandy, which aims to build a **large-scale electrolyzer complex of up to 200 MW** for the production of renewable and low-carbon hydrogen in France ;
- **inauguration** (in January 2021), of **the world's largest electrolyser** - 20 MW PEM unit - based on renewable electricity in Becancour, Canada ;
- a **Franco-German cooperation with Siemens** Energy to lay the ground for mass manufacturing of electrolyzers that will produce green hydrogen.

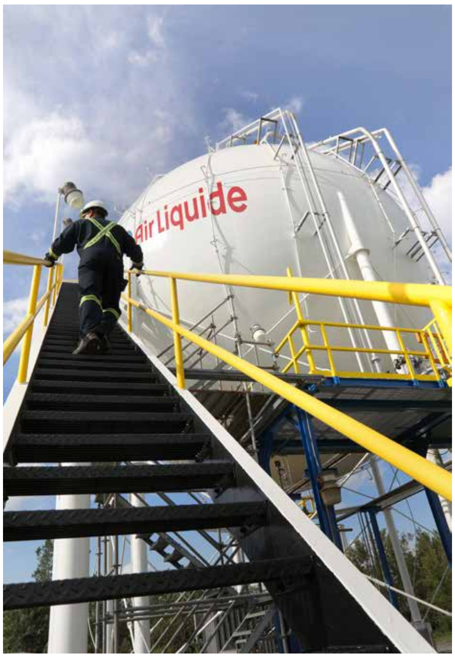
It is crucial to keep in mind that the success of hydrogen requires a systemic approach, from upstream decarbonisation pathways to downstream user segments. The EU will have the opportunity to set a favourable landscape for the development of hydrogen this year, notably through the 'Fit to 55' package and the review of the gas package.

Putting in place the right instruments and dedicated legal frameworks will allow hydrogen to become the second leg of the energy transition alongside renewable electricity by replacing coal, oil and gas across different markets of the economy.

1. In order to be successful in the transition towards green hydrogen, it is necessary to foster low carbon hydrogen as well, in particular through **to support the development of CCS projects** as in the Netherlands or Norway and address regulatory obstacles. We already manage a Carbon Capture unit in Port-Jerome in France, convinced that all renewable and low-carbon hydrogen production means should be considered and largely deployed to reduce costs and optimise carbon emission reductions. It is therefore paramount to secure a **level playing field** between users and producers for **access to renewable energy and CO_2 storage**.
2. Also, **a Guarantee of Origins system dedicated to hydrogen** and relying on what the CertifHy European project has developed, would help attesting the evolution towards carbon neutral hydrogen production and giving an appropriate market value.
3. Concerning usages, we could **distinguish between the main applications of hydrogen in order to tailor the policy framework** and trigger markets uptake. Some of these markets might need a step-stone approach for regulation, however, H2 for industrial application and their associated infrastructure could remain driven by the existing and functional market.
4. On the other hand, **mobility applications should be at first and highly supported** considering the impact on air quality and therefore public health, the maturity of the technologies and their spillover effects on the other segments. Each country needs to foster the scaling-up of distribution infrastructures in the transportation sector to prepare the users' shift towards zero emission mobility. The **Alternative Fuel Infrastructure Directive** revision should enable the development of hydrogen infrastructure in all EU countries with ambitious deployment targets.
5. In order to address the production cost gap of clean hydrogen with conventional hydrogen, setting a **carbon contracts for difference (CCfD)** scheme in which the EU could pay the difference between a strike price and CO_2 market price in the ETS program would be a solution that Air Liquide supports.

Along with the right legal framework, the EU has to continue to financially support large scale projects of hydrogen production and uses to facilitate the large scale deployment and uptake of clean hydrogen to help **decarbonize downstream uses**. It is necessary that the various existing **funding instruments** (CEF, Horizon 2020, the ETS-Innovation Fund, etc.) **are designed and combined to finance the whole hydrogen value chain**. The on-going setting of the EU Taxonomy must make it possible to direct funding towards renewable hydrogen and low-carbon projects in line with the Certifhy approach.

We believe that, with these policy and financial support measures, our European continent holds unique conditions which can facilitate clean hydrogen markets growth in the coming years. It is **time for the sector to scale-up and for companies to play their role on the international scene**. Air Liquide is ready to lead the way with its strong industrial know-how and expertise in this field.



On 26th January 2021, Air Liquide inaugurated the world's largest electrolyser - 20 MW PEM unit - based on renewable electricity in Becancour, Canada.

Port-Jerôme (in Normandy, France) is one of the few sites in Europe capable of producing certified low-carbon hydrogen. The Cryocap™ technology can capture up to 100,000 metric tons of CO_2 a year.

Changing the ground for a **competitive hydrogen ecosystem** in **Europe**

JORGO CHATZIMARKAKIS

Secretary General of Hydrogen Europe

The decision of the European Council at its December summit to fully support the EU Hydrogen Strategy marks another highlight in the historical year 2020 for the energy transition and for hydrogen. The Council elaborates in its conclusions on steps to be taken towards creating a hydrogen market for Europe and hence to help the European Union to meet its commitment regarding carbon neutrality in 2050. With this the Council gives a clear political guidance to implement the EU Hydrogen Strategy and by asking the Commission to further elaborate and operationalise the objectives thereof notably in terms of the upscale of electrolysers and other hydrogen technologies. Additionally, the Council asks the Commission to support a dedicated hydrogen grid development in the upcoming revision of the TEN-E regulation whilst supporting the creation of hydrogen clusters across the EU.

Concretely the European Union now heads for the scale up of electrolyser technology up to 6 GW in 2024 and subsequently 40 GW in 2030. This corresponds to one million tons of renewably produced hydrogen in four years and 10 million tons in 10 years. This strategy comes along with earmarked funding by the member states which has already surpassed the 40 billion threshold summing up the different hydrogen strategies of European Member States. At the same time the financial framework Next Generation EU foresees clear instruments to enhance a faster deployment of the strategy. This is backed by the minus 55 percent target to reduce CO_2 emissions until 2030 compared to the reference year 1990.

Energy Commissioner Kadri Simson presented a few days after this historical decision by the European Council the new TEN-E regulation on the infrastructure for energy to be supported with European instruments. The proposal encompasses two new categories for the production and distribution of hydrogen. This legislative proposal represents a first steppingstone towards the realisation of the European Union's ambition to develop a hydrogen economy and firmly position the EU as a global frontrunner on hydrogen. All future infrastructure investments must be fit-for-purpose and fully aligned with the objectives of the European Green Deal. The deployment of clean hydrogen at large scale is contingent on the availability of an appropriate infrastructure to transport hydrogen from its point of production to demand centres locally, regionally and internationally

Finally, member states launched this same week a process to allow more state aid flexibility with regards to hydrogen projects called "Important Projects of Common European Interest" (IPCEI). EU Energy Ministers signed a Manifesto under the leadership of the EU Presidency and in presence of EU-Commissioners Vestager and Breton as well as EIB President Hoyer. In their declaration they "recognise the importance of promoting cross-border collaboration and of working on large-scale joint investment projects in order to support the development and deployment of hydrogen technologies and systems, particularly in hard-to-abate sectors where hydrogen and its derivatives are either the only available or the most cost-efficient decarbonisation solution, and of fostering a liquid, sustainable and contestable European hydrogen market in the near future as well as supporting export industries." The joint projects shall include sectors along the whole hydrogen value chain and the corresponding project pipeline needs

to be finalised until March 2021 in order to be put into a legal framework allowing member states to fund these projects up to hundred percent under certain circumstances.

The door to let Hydrogen technologies contribute to a massive and immediate decarbonisation of different sectors is wide open now. The course has been set in order to kickstart the deployment of these technologies by large demonstrators and pilot projects until 2024. As of 2025 the EU needs to be ready to adopt elements of market incentivisation for the use of clean hydrogen and the rollout of a dedicated infrastructure in order to become the principal global marketplace for clean hydrogen. This includes the idea of decarbonising the current big customers of hydrogen namely industrial clusters using hydrogen as a feedstock already today.

In this context the import of renewably produced or decarbonised hydrogen from destinations that can cheaply produce hydrogen will lead to the establishment of hydrogen hubs, especially via ports like Rotterdam, Antwerp or Hamburg. Connecting the hubs and the clusters via dedicated hydrogen pipelines will be the first step to build up a dedicated hydrogen infrastructure and backbone all over Europe. Importing hydrogen will be one of the major elements of the European strategy as this creates resilience and establishes new value chains between the EU and its neighbours. Setting the right course is a start but by far not enough. If we are to be successful, the next 4 to 5 years will be characterised by relaxing state aid rules and making use of the financial instruments available in the post pandemic era. In order to frame the conditions for the infrastructure and the hydrogen markets of the future we might look into the adoption of an overarching legal umbrella guiding all the different initiatives and activities in the field of clean hydrogen. That's why we should enter into a debate about a "Clean Hydrogen Act" which allows us to overcome the current situation of a scattered landscape with regards to hydrogen relevant legislation. The Clean Hydrogen Act would streamline the activities in order to fulfil the ambition of both, the European Commission and the European Council to make Europe the leading marketplace for clean hydrogen in the world.

Full speed ahead: **Developing European Infrastructure** for **Hydrogen**

TORBEN BRABO

Chief Executive Officer, Energinet Gas TSO and President of Gas - Infrastructure Europe (GIE)

The next vital stage of the energy transition in the EU has begun. The 2030 goal has been defined and the direction toward a fully decarbonised Europe for 2050 is set. The Commission has come forward with ambitious strategies on system integration and hydrogen. Now action is needed. Being in the gas sector we feel the change and welcome it.

The European gas infrastructure companies have the competences and experience that will help the EU to reach the climate targets. We are developing new value chains; using new technologies and digital tools; changing the markets – fitting them to the future needs. Transition on all levels.

Developing hydrogen infrastructure

Green electrons and molecules will together be the main components in the energy system. Sun and wind will provide the primary renewable source for hydrogen. But transport from the often remote production sites to the main consumption centers requires cost effective transmission over long distances. This is the key competence for the gas infrastructure operators. The recent European Hydrogen Backbone study shows how the future backbone of hydrogen transmission can develop across Europe in order to facilitate a green energy system.

In parallel, smaller and decentral hydrogen projects are being developed across Europe in clusters. The smaller projects have less financial risk, can be developed faster; can be closer to the end-users and rely on local wind and sun. Many of these projects need storage facilities. Some projects need the flexibility to balance demand and supply, while other projects aim at selling the hydrogen for peak power. It is expected that these cluster projects will grow and be connected into hubs; which again could be interlinked by transmission systems.

Size matters. Electricity consumption is around 2500 TWh in the EU, while molecules and liquids (gasses and oil) provided approx. 4500 and 6000 TWh of the primary EU energy demand. The decarbonization of existing electricity production is step 1, but the grander step 2, must secure molecules and liquids being partly replaced by direct electrification, or indirect electrification via hydrogen. This is a real volume challenge.

Balancing the energy system and linking to supplier countries

On top of this – the intermittent renewable electricity production and hydrogen production – need flexible balancing options, as well as a possibility for storing large energy/hydrogen volumes over seasons. And electrification in new sectors further increases the seasonal variations in demand. Again, gas storages can easily take the flexibility role in hydrogen. Other types of flexibility and storage will naturally also play a role. Gas Infrastructure Europe (GIE) is currently preparing a report on the role of storages in the European Hydrogen Backbone.

Hydrogen will also be produced outside the EU: Abundant sun and wind in Northern Africa. Possibilities for blue hydrogen from Norway or Russia must be included in the EU scenarios. These energy sources might provide cheap hydrogen and could help facilitate the development of new hydrogen infrastructure. Existing (LNG) terminals and pipelines will have a role to play here.

Projects are being developed across Europe

Hydrogen projects increase exponentially supporting the climate goals. The Clean Hydrogen Alliance with its roundtables and matchmaking of project promoters with investors will be key instruments in realizing additional projects. A balance between new infrastructure projects and repurposing of existing assets will be key for a cost-efficient transition. Huge time- and cost-savings arises from using the existing assets. While in other cases, new transmission and storage infrastructure is needed.

Beyond hydrogen is step 3 in full decarbonization. Full decarbonization of molecules, liquids and solids (natural gas, oil and coal) will need other types of building blocks to serve as feedstock into all processes. Carbon dioxide need to be captured and stored or utilized in production of synthetic fuels in combination with renewable hydrogen. Access to and transport of CO_2 need infrastructure. Gas/molecule transmission and storage is also here ready to play new roles.

The development of hydrogen in the energy mix will happen along multiple pathways. Some EU Member States already use hydrogen and can quickly go for large scale clusters and backbone. Other countries have abundant renewable resources, which needs to be further developed in order to support the hydrogen economy. A third group of countries can include blending of hydrogen into the methane gas systems.

Need for clear regulation

There is a continued need for gas infrastructure in the European energy system. The sector is undergoing a huge transformation. But speed is currently affected by uncertainty and ambiguity from the (missing) regulatory framework. Roles and responsibilities on hydrogen should be defined; Clarity on regulated services and requirements should be decided; Need for joint network planning – gas, electricity and hydrogen; Network development plans (TYNDP) for these joint projects at the ENTSO's; Markets to sector couple (electricity to hydrogen, being stored and transported, and used); Clear value chains – remuneration along the value chains; Securing pilots and Sandboxes; Guarantees of Origin across sectors and borders and time; Push for renewable energy targets.

The need for speed, the immense complexity and uncertainty shouldn't hinder progress. A dynamic regulatory approach is important for the energy transition: Allowing for short term developments to happen, providing the certainty needed, without picking the winners and with the possibility for developing the regulatory setup. It's exciting times and the gas sector will continue to contribute towards reaching our climate goals.

Get set – GO!

KRISTIAN RUBY
Secretary General of Eurelectric

Towards a Continent Powered by Clean Electricity: Leading the Charge on Hydrogen

The tide is turning in the energy sector. The transition to decarbonised sources of energy to power our mobility, heating and cooling, as well as industries is in full swing. If only few years ago this transformation was considered almost utopian, it is now quickly becoming a reality. But an acceleration of this process and strong partnerships across different sectors of the economy are urgently needed to win the race against climate change, and bring the greenhouse gas emissions to zero.

The European electricity sector is speeding up on decarbonisation. In 2019, renewable energies and nuclear covered 59 % of the mix. In 2020 their share rose to 63%. The wider penetration of renewables coupled with a progressive phase out of coal capacities have led to a 29% decrease of power sector's CO_2 emissions during the third phase of the Emissions Trading System.

This trend is set to continue. As much as 80% of EU's electricity could be fossil-free by the end of the decade, putting the power industry in prime position to support other sectors in their decarbonisation efforts via direct and indirect electrification.

Electricity – the fuel of choice for the zero-emissions economy

Today, approximately 70% of greenhouse gas emissions in Europe come from energy use across economic sectors. This being caused by their heavy reliance on pollution fossil fuels. As the power sector decarbonises its generation, the electrification of transport segments, industries, heating and cooling will put Europe's carbon-reduction targets within reach.

The potential is huge: 63 % of the energy use in transport and in buildings, and 50% of that used by industries, can be electrified.

The road transport sector is already moving in this direction. A landmark one million electric vehicles were sold in 2020. Despite the economic hardship caused by the COVID-19 pandemic, every 10th new passenger car bought by Europeans was either a pure electric or a plug-in hybrid.

The growing demand for EVs shows a positive trend spurred by the introduction of EU and national targets for CO_2 emissions reductions, support schemes for buyers, diversity of models, as well as an increased awareness around the reliability of these vehicles. But an extra push is needed to get 40 million EVs on Europe's road by 2030.

The maritime transport, which still relies on highly polluting fossil fuels, is another segment that urgently needs a credible decarbonisation pathway. In several countries, electric ferries and boats are being introduced for short distances, thanks to numerous innovations that have made batteries cheaper and better. Moreover, clean electricity is starting to replace the use of on-board oil-powered generators, while the vessels are docked. This process, known as shore-to-ship or cold ironing, is contributing to the reduction of emissions from one of the most energy intensive port activities.

Indirect electrification – a carbon neutral and cost efficient solution

While electricity is by far the most efficient decarbonisation vector, hydrogen is emerging as an alternative for those sectors, such as heavy industry or long-haul transportation, which cannot directly run on clean electricity.

But the production of hydrogen needs to be carefully observed, and clean methods should always be prioritised. With over 95% of Europe's hydrogen produced using fossil fuels, this industry's CO_2 emissions levels are worryingly high. In 2017, the hydrogen production equalled the emissions stemming from the entire German economy.

Opting for clean hydrogen, extracted from water through electrolysers powered by the abundant renewable-based electricity or nuclear power would cut this industry's emissions. This clean hydrogen, could become a decarbonised source for the production of novel maritime fuels, such as ammonia, or be used as feedstock for other industrial processes.

50% of the total energy used by industrial processes can be directly electrified. Electric arc furnaces are progressively replacing the fossil-fuelled furnaces for the production of steel. What's more, pilot projects that explore the use of green hydrogen instead of carbon-based feedstock in the steel industry are already showing promising signs.

The price of clean hydrogen is one stumbling block for scaling up its industrial use. Re-thinking the taxes and levies applied to electricity could bring down the cost of production, thus making it competitive with fossil fuels. A clear reliable system for classifying different types of gases based on their production process will also be a critical tool to establish trust and transparency for customers.

The next frontier: stepping up the sector integration

Europe can make the best use of its clean power supply to efficiently decarbonise transport, heating and cooling, as well as a number of industrial application, by fostering strong synergies between these sectors. A more integrated way of working would result in a more efficient and sustainable system; in optimised energy infrastructures able to integrate increased amounts of variable renewables and support the flexibility needs; and in decarbonising the electrified energy demand.

NICOLÁS **GONZÁLEZ CASARES**

MEP (S&D, Spain), Member of the ITRE Committee, European Parliament

Hydrogen Strategies and The Importance of Solving the **Dual CO_2** And Methane **Performance Challenge**

From the European Union's (EU) inception, energy policy has been at the heart of the political activity addressing our greatest challenges. Given that climate change and energy are two sides of the same coin, the need to achieve a carbon-neutral economy is one of the most significant challenges of our time. The European Green Deal is our answer to this challenge, and it will lead us to climate neutrality by 2050 at the latest. It offers us an opportunity to maximize the benefits of quality of life, health, resilience, and competitiveness.

We are currently discussing how to achieve the Green Deal's ambitious goals in the most equitable and cost-effective way. Several strategies and plans included in the deal have been presented over the last months, such as Energy System Integration, Hydrogen, Renovation Wave, and the Methane strategy. These strategies will help to reform the policies and regulations related to energy and the transition to a climate neutral economy. The work to develop the EU Green Deal has not slowed despite the unexpected COVID-19 pandemic. On the contrary, it has accelerated. The European Green Deal should guide our steps towards recovery.

As a shadow rapporteur of the Energy Sector Integration report, I believe that it is essential to take into account the synergies between energy carriers, infrastructures, and sectors to address the necessary acceleration of Union decarbonization, implementation of renewable energies, and improvement of energy efficiency to the levels required by the goal of reducing emissions by 2030, and to achieve climate neutrality by 2050.

Energy efficiency, together with electrification through renewable and sustainable energy sources, is the basis of the future energy system. However, as renewable electricity is unlikely to cover all energy demand in the next decades, additional energy carriers will of course be required. Therefore, clean gas has an important role to play and also a significant place in our discussions.

In the different impact assessments and reports we can see that there is significant potential for renewable gases, and most notably renewable hydrogen, to decarbonize those sectors where cutting emissions is otherwise difficult. The gas sector, amongst other

sustainable energy carriers, should engage in decarbonization, replacing as much as natural gas as possible with clean gases like renewable hydrogen, biogas, and synthetic fuels.

For the decarbonisation of our economy in general, and of the gas sector in particular, we must look beyond CO_2 emissions. Methane is the second most important greenhouse gas (GHG) —19% are energy-related — as the recent European strategy for the reduction of methane emissions highlights. The reduction of methane emissions is imperative to both decarbonize the gas sector and integrate the power and gas sectors.

The European hydrogen strategy proposes the use of natural gas combined with CCS to produce blue hydrogen. In addition to the doubts regarding its economic viability, even more so considering its compatibility with the EU-ETS, we will need to carefully consider any related GHG emissions, including methane, and how to eliminate them. If we do not take into account all the process's emissions or leaks, we will be cheating on the transition. If natural gas is to have a role as a bridge in the transition, those emissions have to change without delay. Likewise, to avoid problems with the promotion of decarbonised gases, possible leaks must be clarified and accounted for.

Nowadays, renewable gases are mainly biogases. According to the EU's long-term decarbonization strategy, the EU's consumption of biogas (and biomethane) is projected to increase by around four times today's consumption. The methane strategy also proposes to promote the production of sustainable biogas to avoid methane emissions from waste. This is a win-win solution, which can also generate additional revenue streams for farmers and provide opportunities for development and investment in rural areas. However, it is essential for biogas developments to comply with strict sustainability criteria, to avoid the opposite effect. Measures to support biogas production must be carefully assessed to avoid perverse incentives that could lead to an overall increase in emissions.

We know that biogas will not be enough to meet the necessity of the EU's decarbonized gas demand. Synthetic fuels, mainly renewable hydrogen, have a vast potential, not only as a clean carrier but also as an industrial opportunity. An energy carrier such as clean hydrogen will be necessary to decarbonize the sectors where direct electrification is not possible. It will also will allow to strengthen the power system as it is a suitable solution for storage and balancing the system. For this, it is essential to begin by clarifying the different types of hydrogen, as well as establishing standards that explain its characteristics and origin. The upcoming legislative reforms, such as the Renewable Energy Directive, should integrate this type of measures.

Without demand, we will not be able to lower the costs of clean hydrogen. However, not all solutions are compatible with climate-neutrality. We must prevent the promotion of demand from having perverse effects such as increased grey hydrogen. The ultimate goal must be clean and sustainable gases. Therefore, the Commission's objective to increase the capacity of electrolysers go in the right direction. It is necessary to prioritize gases produced with renewable energy (green gases) to be consistent with our climate-neutrality objective. Industrial clusters are an excellent starting point for action while possible long-distance infrastructures are being planned.

Our resources are limited. We cannot afford to invest in technologies or infrastructure that will be unnecessary in 30 years. It is essential to avoid any further lock-in from fossil fuel infrastructures and sunk investments, particularly any new fossil gas infrastructure. To that end, the taxonomy regulation and the revision of the TEN-E will help to improve our energy infrastructure and interconnections - especially power interconnectors - and to put the funds, tools and strategies in place as we embark on the path to climate-neutrality.

Finally, with the Next Generation EU instrument, we have an opportunity to invest in the technologies and processes of the future, be competitive, and improve people's lives. It is essential to promote projects that allow us to meet our climate commitments, avoiding temptations to bet on outdated models. The transition towards climate neutrality will benefit from a safe and stable regulation that leaves no one behind.

Hydrogen's role to **decarbonise** the **European gas grid**

JAN INGWERSEN

General Director of ENTSOG

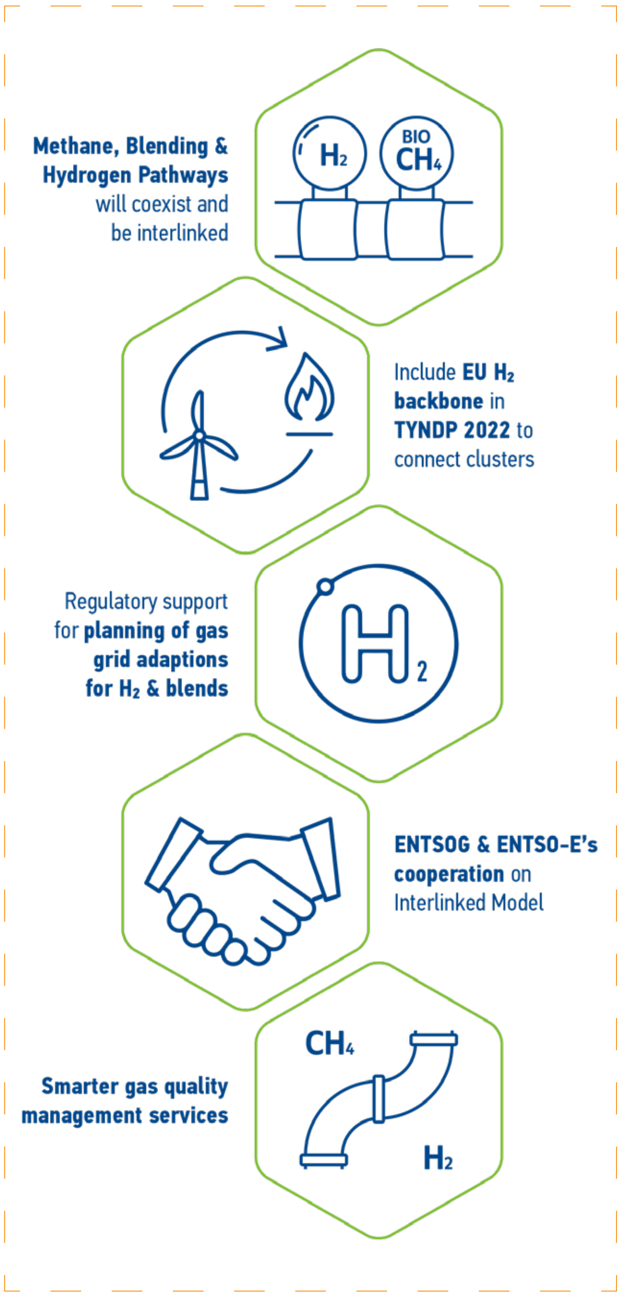
Gas TSOs will have an important role to play in supporting the upscale of the hydrogen economy – in creating the open access to grids, connecting the supply and demand dots, and by sharing European gas Transmission System Operators' (TSOs) experience in markets organisation. The challenge today is not that the individual technologies are not proven and ready, but that they need to be scaled-up in order to offer cost-effective climate benefits.

ENTSOG (European Network of Transmission System Operators for Gas) recognises the changing infrastructure needs for transporting increasing volumes of renewable, decarbonised and low-carbon gases, such as hydrogen and biomethane. Robust, timely and effective adaptation to meet the needs of the changing landscape of the European energy market allows for the cost-efficient and cost-effective decarbonisation of Europe's gas grids. It will facilitate the meeting of the EU Green Deal commitments and address the post COVID-19 recovery plan for a green economy. Existing gas infrastructures will be an important accelerator for this.

Building the EU's future gas network should start already now if we reasonably expect it to be completed for 2050. The EU already has a well-established and trusted planning process for network development, based on the TYNDP process, which should be used for the future development of the grid. TYNDP 2022 could identify the initial 'no-regrets' backbone of retrofitted or repurposed gas infrastructure and prepare for its gradual expansion. Updated CBA methodology evaluation criteria could include digitalisation of measuring and data handling, and energy storage and flexibility from all technologies. The upcoming TEN-E revision should account for the new hydrogen market and deliver this first stage 'no regrets' backbone.

In ENTSwOG's '2050 Roadmap for Gas Grids' – published in December 2019 – the European gas TSOs makes practical recommendations on how to effectively combine well-functioning, liquid gas markets and established security of gas supply, with the commitment to reach decarbonisation goals. In light of the European Commission's Energy System Integration and Hydrogen Strategies, ENTSOG proposed the 2050 Roadmap Action Plan. The Action Plan indicates how a hybrid, dual gas quality system with biomethane and hydrogen molecules could coexist and form the early stages of the hydrogen economy. The hydrogen market could be composed of several clusters (until more mature markets exist), relying on a cross border, dedicated, interconnected hydrogen infrastructure or in a blend with natural gas.

Gas TSOs fully support the European Commission's plan to place the EU Hydrogen Strategy at the core of the green recovery, together with the Energy System Integration Communication, and



ENTSOG 2050 Roadmap Action Plan: Delivering Europe's Future Energy Networks the revision of TEN-E Regulation. ENTSOG has joined the European Clean Hydrogen Alliance, and co manages its Round Table on Transmission and Distribution. In the engagement for the European Clean Hydrogen Alliance, ENTSOG will openly and transparently work for:

- Allowing for effective impetus and scale, for all types of hydrogen
- An inclusive definition for renewable, decarbonised and low carbon hydrogen
- A Guarantees of Origin and Certificates System, being effectively connected to the EU ETS, as another carbon abatement solution
- A full value chain approach and synergies with Energy System Integration, including consideration on how to deal with taxation regimes that currently impede market integration of Power-to-Gas (P2G).
- Regional specificities in the EU, in relation to hydrogen clusters and hydrogen backbone networks
- Adopting similar regulatory principles for hydrogen transport as applied to gas, to benefit of all market participants.
- European Commission's clarification on how gas TSOs can have an active role in supporting the development of a European hydrogen market.

ENTSOG have launched an Advisory Panel for the Future of Gas Grids with the purpose to ensure transparency and coordination between the entire value chain – to transition to a hydrogen economy, support gas TSOs and stakeholders in identifying practical challenges and solutions for gas grids on retrofitting/repurposing of existing gas infrastructure, and development of a EU Hydrogen backbone. The panel will also analyse the role of blending and work on an EU-wide approach for CO_2 infrastructure. The panel will discuss how to convert and adapt the existing system to future needs, focusing on infrastructure, technical, regulatory and organisational aspects of such a transition. The main deliverable of this Advisory Panel will be to produce a Recommendation Report annually, and potentially to issue specific recommendations as needed.

Since its foundation in 2009, ENTSOG, along with its Members, Observers and Associated Partners have helped to build a competitive and secure European gas market. In the next decade, ENTSOG will continue to contribute to the decarbonisation process. The gas system is in transition towards net-zero 2050 with existing infrastructure which can already support decarbonisation but also the scale-up of clean gases, as necessary. An adaptation of the energy infrastructure is required to develop significant production capacities of renewable and decarbonised gas, and to adapt the demand to new gases like hydrogen. The transmission infrastructure can be used as a backbone to integrate clean gases and support an efficient energy market. European gas TSOs are ready and willing to make this happen in a timely, sustainable and cost-efficient manner.

Photo courtesy of terranets bw GmbH

ELSI KATAINEN

MEP (Renew Europe, Finland), Member of the TRAN Committee, European Parliament

Hydrogen as One of the Solutions for the Decarbonisation of Transport

Hydrogen is a versatile raw material and a promising solution for our efforts to build a greener and low-carbon economy. With sufficient investments and right policy-making, clean hydrogen can play important part in the future energy system and the fuel mix for transport.

EU's target of climate neutrality will revolutionize future energy production, industrial processes, housing and transport. This means that the use of electricity will multiply and be based on renewable solutions such as hydrogen produced from solar and wind power.

Our transport sector runs still mainly on fossil fuels. Currently transport accounts for a quarter of EU's total greenhouse gas emissions. Unlike energy, manufacturing and agriculture, the transport sector has not managed to reduce its emissions from the 1990 levels. The change is yet to come.

With the new European Sustainable and Smart Mobility Strategy, presented by the European Commission last year, the Union is driving for 90 a percent emissions cut in the sector by 2050. The goal is extremely ambitious. The Decarbonisation of the transport sector will be challenging with each mode of transport having its own needs and particularities.

For example, electrification shows a promising path to reduce emissions in passenger vehicles and light goods vehicles used for relatively short distances. However, a long recharging time and heavy batteries create challenges for heavier vehicles over longer distances. This is why we need several solutions.

Hydrogen, on the other hand, can be refuelled quickly without heavy battery packs. It can serve as a practical solution for long-distance transportation on heavy trucks, cargo ships and aeroplanes. At its best, a hydrogen vehicle could store large amounts of hydrogen, refuel fast and emit only water vapour.

However, there are still a number of technical and economic obstacles to the hydrogen economy. Today, hydrogen produced in EU comes mainly from fossil fuels and the volumes are limited. Utilisation of clean hydrogen in the EU calls for massive investments in refueling stations, distribution and production facilities, in which the EU and national recovery programmes should play a key role in line with the Green Deal targets. The already available hydrogen fuelled vehicles in local transport, such as city buses will be key in extending the application of hydrogen to other modes of transport.

In addition, further investments in research and innovation across the entire hydrogen value chain are needed, with the EU's *Horizon Europe* research programme playing a leading role.

The work to put this all into action has already started. In 2020, the European Commission introduced a Hydrogen strategy with the aim to extend the use of hydrogen and to reduce CO_2 emissions from hydrogen production with advanced technology and renewable energy.

Member States should show leadership too. My home country of Finland participates among many other EU-countries in the IPCEI (Important Project of Common European Interest) as part of EU´s hydrogen strategy targeting a faster shift into the hydrogen economy. The aim is to accelerate the industry's transition to the production and use of clean hydrogen and the development of new uses for hydrogen. This will help Finland to achieve its goal of a carbon-neutrality by 2035.

In the transition towards low-carbon transport, it is vital to keep different options on the table. Building EV-charging infrastructure or developing sustainable biofuels do not have to compete with hydrogen, but rather seen as mutually supportive means to achieve the common goal.

Many energy sources and solutions are needed to decarbonise the European transport sector. This means deploying already available sources such as sustainable biofuels and electrification and to support and anticipate future solutions such a hydrogen. EU policies should focus on setting common targets and creating a good and predictable investment environment that rewards industry and actors for reducing emissions.

Hydrogen must be harnessed efficiently and at a competitive price. The transition to competitive hydrogen economy requires political will, financial support and incentivising legislation that supports new technologies and innovations. The global race is ongoing for the best and most commercially viable way to produce sustainable hydrogen. EU should be an enabler and leader in this competition.

JAN-CHRISTOPH OETJEN

MEP (Renew Europe Group), Vice Chair of TRAN Committee

Green Hydrogen - The dream of energy transition or just a fade? What does it take to meet the high expectations of a European hydrogen market?

As Vice Chair of the European Parliament's Transport & Tourism Committee, mobility means to me lived freedom; a value that always needs to be maintained. By 2050, the European Union wants to be climate neutral, which means a European economy with net-zero gas emissions. This objective is at the heart of the Green Deal and in line with the EU's commitment to global climate action under the Paris Agreement. Hydrogen has a promising future herein and is a key building block towards this objective. Within my mandate as Member of the European Parliament I strongly support the push for green hydrogen as an integral part of Europe's future emission-free mobility and for its vital role in the EU's energy mix.

In Europe and around the world, public attention for hydrogen has been growing significantly. One driver has been the European Commission's hydrogen strategy for a climate-neutral Europe, released in July 2020. This roadmap foresees hydrogen as an intrinsic part of an integrated EU energy system with a strategic objective to install at least 40 GW of renewable hydrogen electrolysers by 2030 and to produce up to 10 million tonnes of renewable hydrogen in the EU by the same year. Moreover, almost all Member States included hydrogen in their national policy frameworks for alternative fuels infrastructure, with some states already adopting their own hydrogen strategies. To me, it is obvious: hydrogen technology is *en vogue*.

The advantages of hydrogen lie in its diversity. It can be used as feedstock, as storage or energy carrier and as fuel. Within the transition of electricity production to renewable energy sources and reduction of GHG emissions, hydrogen is a potential added value across multiple industries and sectors. The roadmap of the Commission's Hydrogen Strategy aims to increase the share of hydrogen in the European Union's energy mix from 2% today to 13-14% by 2050.

In its Smart & Sustainable Mobility Strategy, published in December 2020, the Commission set milestones for a green, sustainable and resilient transport system: By 2050 nearly all cars, vans, buses as well as new heavy-duty vehicles will be zero-emission. By 2035, a zero-emission aircraft is expected to be market-ready. In my view, these ambitious goals must be achieved with the help of hydrogen technology and hydrogen drives. I am convinced that mobility applications are the first and most important large-scale industries in which hydrogen can be applied. Electric vehicles with hydrogen and fuel cell drives are already available on the market and due to the Alternative Fuels Infrastructure Directive, the European network of hydrogen filling stations is growing steadily. Revising this directive can now make hydrogen a mandatory fuel for all transport modes. The EU should work on points of synergy between the Trans-European Transport Network (TEN-T) and the Trans-European Energy Network (TEN-E), to achieve this process. Such a change would require a large availability and coverage of refuelling options, not least because of the specificities of infrastructure for heavy-duty vehicles. To provide for this, the European Union urgently needs to adopt a regulatory framework and common technical standards, which enable interoperability. A denser network of filling stations would allow for a broader application of hydrogen fuel cell mobility, and the combustion of (green) hydrogen in conventional internal combustion engines. As alternative or in addition to this, adding green hydrogen to conventional fuel production could already achieve a significant reduction in CO_2, a method comparable to adding biofuels.

The European Commission estimates that an investment of only 65 billion euro will be needed for transport, distribution, storage and refuelling stations. Additional money is needed for electrolysers, retrofit "fossil" hydrogen production sites and capacity expansion. One crucial pillar of financing is the InvestEU program, the capacity of which has been duplicated by the Recovery and Resilience Facility. It supports the leveraging of private investment in order to expand the hydrogen economy. SMEs also play a significant role in the Union's energy and transport value chains. For me it is therefore of utmost importance that they have equal access to these hydrogen support tools.

Besides that, Research and Development is significant in making hydrogen cost-competitive with conventional fuels while at the same time minimizing the environmental impacts of its production. Public funding such as through the Innovation Fund and InvestEU shall finance large demonstrators. Moreover, research fields like more efficient electrolysers, hydrogen from algae solar water splitting and pyrolysis, as well as infrastructure solutions for large-scale hydrogen distribution, storage and delivery shall be advanced.

It is clear that green hydrogen energy will become a significant pillar of the EU's future energy system, and that it will enable us to reach our ambitious climate-targets. Its vast potential and varietal use for the transport, industry and the housing sector, will pave the way for decarbonisation. But to ensure that it does not just remain a dream, boosting demand and supply on a competitive interoperable European hydrogen market, must be created. For all of this to work, the European regulatory framework must consolidate its economic, industrial and energy policy. My role is to ensure that Europe sees the big picture and that our politics do not focus on one single technology, but instead ensure that future legislation is open to any form of technology and future innovations.

AXEL KREIN

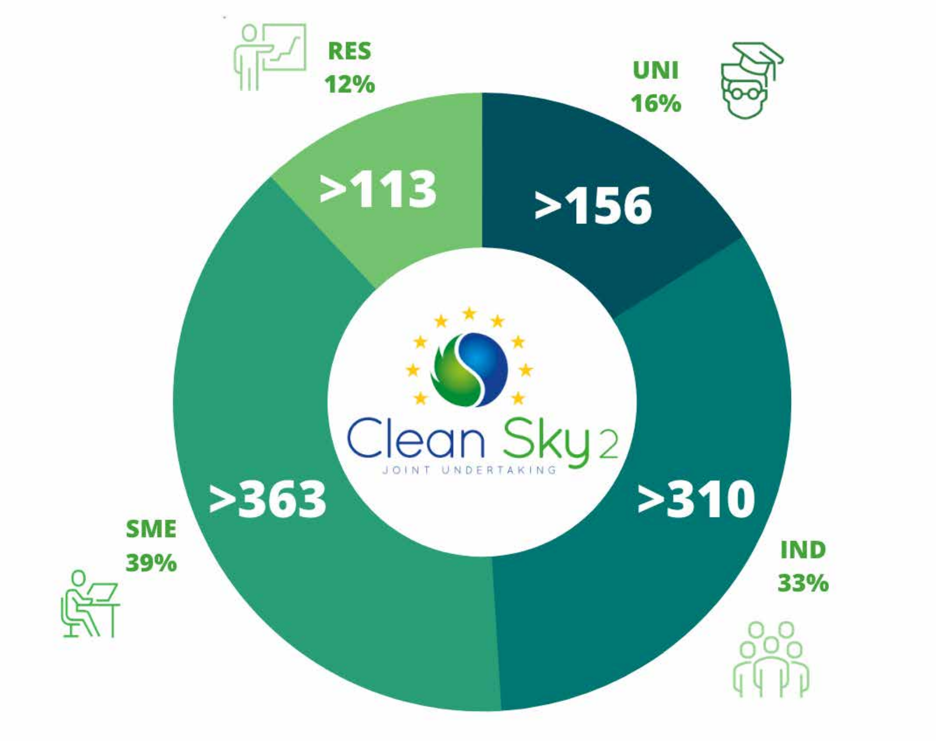
Executive Director - Clean Sky 2 Joint Undertaking

Hydrogen: Promising Zero-Carbon Technologies for Future Aircraft

The Clean Sky 2 Joint Undertaking's ambition is to enable step change in aviation's environmental and climate impact, and lay the ground work for the EU aviation sector to reach climate neutrality by 2050 in line with the European Green Deal's objective. In order to achieve this, an ambitious agenda is in progress to deliver technologies across the aircraft's overall architecture, its aerodynamics, structural design, propulsion and on-board systems. Clean Sky has built a remarkable eco-system across the full breadth of the EU involving over 900 participating organisations, including a significant participation of European SMEs and universities, as well as research organisations and industry.

As is often noted, there is no single 'silver bullet' to transform aviation into a low- or zero-carbon sector. We need to work all angles on the aircraft. Analysis performed in the early stages of preparing the next decade of research and innovation (e.g. in the EU under the Horizon Europe framework) has shown that technological advances in the next decade can help reduce aviation's energy intensity by around one third to one half. This is an essential step towards a low-carbon and ultimately climate-neutral system as the single biggest contribution is always 'using less' and driving for energy efficiency. The final push is certain to also need a re-think and reconsideration of the energy sources on board the aircraft, i.e. the transition away from fossil fuels towards low- or zero-emissions energy sources.

However, the aviation sector is, beyond any doubt, one of the most difficult sectors to decarbonise. It is energy-intensive, characterised by capital-intense equipment with extremely long life cycles, and is obviously safety critical. And crucially when comparing to sectors 'on the ground', aircraft weight/mass constraints preclude many potential low-emissions technologies that simply 'won't fly' given the need for very high energy mass-density. Current battery technology is one example where, despite big advances in power density, the state-of-the-art is still several factors below what would be needed for major adoption in large commercial airliners.



Hydrogen is an alternative energy source which could significantly reduce aviation's climate impact. It eliminates carbon dioxide (CO_2) emissions in flight and when it is produced carbon-free (i.e. through renewable energy sources) it creates a true zero-carbon solution to flying.

The climate impact of aviation, as measured by the global warming potential of its emissions, is not just a matter of CO_2. Aircraft impact the climate through non-CO_2 emissions as well, i.e. nitrogen oxides (NOx), soot, and water vapour, which create contrails and cirrus clouds. However, of all emissions species, it is undoubtedly CO_2 that has the longest 'latency' in the atmosphere and its effect can be present over several decades. Taking into account the relative contributions of all emissions and the uncertainties of these effects, the latest estimates show that hydrogen combustion could reduce climate impact in flight by 50 to 75 percent, and fuel-cell propulsion by 75 to 90 percent.

The Clean Sky 2 Joint Undertaking, in collaboration with the FCH 2 Joint Undertaking, recently assessed the full potential of hydrogen (H_2) propulsion to reduce aviation's climate impact through a study performed by McKinsey & Co. under a tender awarded in 2019 and concluded last year (https://www.cleansky.eu/publication/hydrogen-powered-aviation).

The study concluded that hydrogen propulsion has the potential to be a major part of the future propulsion technology mix with the potential to make climate-neutral aviation by 2050 a reality. However, as a highly disruptive innovation, it will require significant research and development, investments, and accompanying regulation. It is a high risk but high reward technology solution for a game-changing impact!

Indeed, several technological challenges still need to be overcome: enhancing the overall efficiency of hydrogen storage on-board with lighter tanks and fuel cell systems, liquid hydrogen (LH_2) distribution within the aircraft, turbines capable of burning hydrogen with low-NOx emissions, and the development of fast, safe, reliable and efficient refuelling technologies with flow rates comparable to kerosene so that aircraft turnaround times at airports remain competitive.

Assuming these technical challenges can be overcome, hydrogen-based propulsion can be a significant enabler in the quest for 'climate-neutral aviation' by 2050. But the challenges and the intrinsic qualities of hydrogen versus liquid fuels such as kerosene, in particular the energy density in volumetric terms, mean that it is likely to be best suited for commuter, regional, short-range, and medium-range aircraft.

For commuter and small regional aircraft, fuel cell-powered propulsion emerges as the most energy-efficient, climate-friendly, and promising option. For short-range aircraft, a hybrid propulsion approach (H_2 combustion and fuel cell) could be best suited, or simply H_2 combustion in advanced aero-engines.

In terms of fleet share and flight ranges, almost 80 percent of emissions come from flights up to 7,000 kilometres and cover 95 percent of the total number of flights. Flights spanning less than 3,000 kilometres and independent from the aircraft size account for more than 50 percent of today's total aviation CO_2 emissions. The main focus of decarbonising aviation should be on short-range aircraft flying less than 3,000 kilometres, as well as on medium-range aircraft up to 7,000 kilometres.

While hydrogen is technically feasible for evolutionary (tube-and-wing) aircraft operating flights above 10,000 kilometre range, it is likely to remain less suitable from an economic perspective. As a consequence, although hydrogen could power short-range aircraft with an entry into service as early as 2035, low- (net) carbon liquid fuels are likely to be the more cost-effective decarbonisation solution for the long-range market segment for a considerable time. But even in the case of synthetic liquid fuels such as 'Power-to-Liquid' kerosene, hydrogen will be required as one of the basic constituents for synfuel production.

Feasibility and economic analyses show hydrogen can be a major part of aviation's future technology mix. If hydrogen-powered aircraft are deployed in segments where they are the most cost-efficient means of decarbonisation, they could account for 40 percent of all aircraft by 2050, with this share further increasing after 2050.

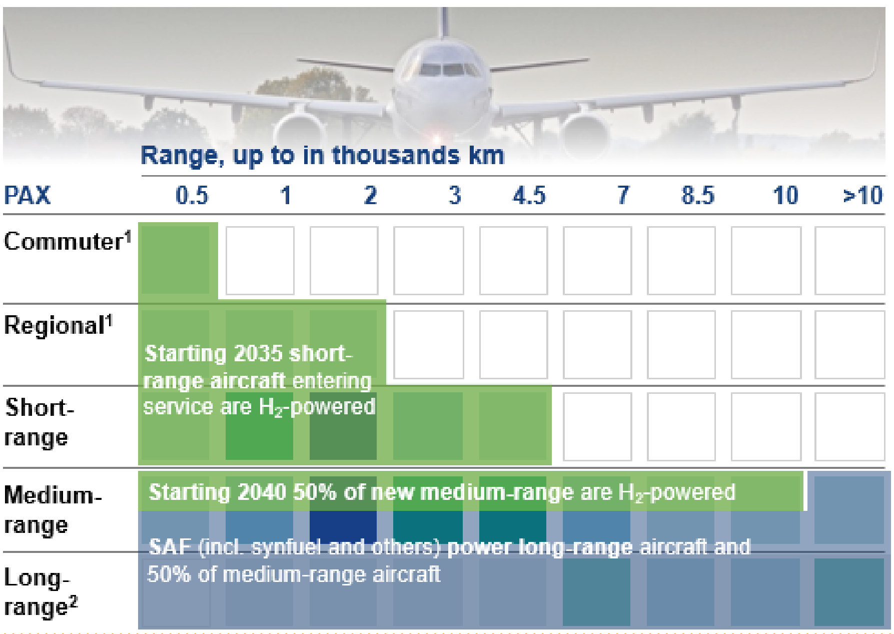
To make this a reality, bold steps need to be taken urgently to initiate a path towards decarbonisation of the air transport sector through hydrogen. The industry needs to change trajectory today, as the development phase and certification of new aircraft prior to their commercialisation can take more than 10 years, and substantial fleet replacement another 10-20 years. To transition to a new propulsion technology, a sector roadmap to reduce climate impact, a step-up in Research & Innovation (R&I) activity and funding, and a long-term policy framework will be required.

The sector roadmap needs to set the ambition level, align standards, derive safety measures, coordinate infrastructure build-up, overcome market failures and encourage first movers. An appropriate mid-term target could be the Entry-into-Service of a hydrogen-powered short-range aircraft before 2035, for which a first prototype would be required by 2028.

In line with this ambition, the key stakeholders of the European aeronautical sector have proposed the hydrogen roadmap as one of the three main R&I streams of the Strategic Research and Innovation Agenda for the next European Partnership on Clean Aviation (https://www.clean-aviation.eu/files/Clean_Aviation_SRIA_16072020.pdf).

In summary, hydrogen propulsion has significant potential to reduce the climate impact of aviation, thus contributing significantly to achieve the Green Deal's objective of Europe's climate neutrality by 2050. New technologies must be deployed across the board and R&I must be urgently accelerated before we can transition the aviation sector and the industry into a more efficient and decarbonised future.

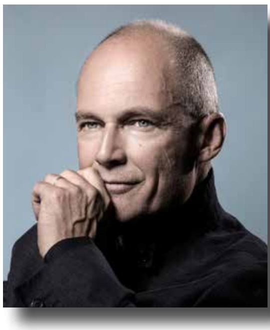
For more information about Clean Sky's innovative technologies currently under development, visit our online stand at https://cleansky.virtualfair.be



Potential impact by 2050

- **~40% aircraft** of fleet powered by H_2
- **1.8 Gtons of CO_2 abated** achieving net zero target
- **0.8 Gtons** additional reduction of non-CO_2 emissions[3]

Hydrogen – the Great Unifier?


©AFP_01

BERTRAND PICCARD

President of the Solar Impulse Foundation

For several months now, the pro- and anti-hydrogen lobbies have been waging a merciless battle in the media. It's a miraculous solution for some, an enormous hoax cooked up by the oil giants for others. In this debate, the losers are the general public, unable to form an opinion, and humanity at large, desperately in need of a substitute for fossil fuels.

Hydrogen is not something you can be "pro" or "anti". It's an element. Hydrogen atoms can do some things, but not others. In the many battles that oppose detractors and supporters of hydrogen, probably the biggest one is in the mobility sector. Rather than opposing each other, we must understand the potential and the limitations of this technology.

Since hydrogen doesn't exist on Earth in its basic state, it has to be **manufactured** from other elements. This process consumes energy, whereas oil can be found ready-made in nature. Today almost all hydrogen is so-called "grey" hydrogen, because it is produced from methane, a process that's inexpensive but generates CO_2.

Hopes are focused on **electrolysis**, which uses an electric current to break down water into hydrogen and oxygen. If the electricity comes from a renewable source, the hydrogen that's generated is clean. This method is still more expensive than reforming methane, but economies of scale and the falling cost of renewable electricity should make hydrogen produced this way competitive within ten years. Even today, in Switzerland, clean hydrogen, if untaxed, works out at the same price as taxed diesel when a barrel of oil costs $60.

But can enough renewable electricity be produced for all the "green" hydrogen we'll need? We can solve this problem if capacity continues to increase - the EU wants to multiply the capacity of its electrolysers by 40 by 2030. And especially if the incredible waste of energy in all sectors is reduced. **Energy efficiency** must go hand in hand with the electrification of society. The key factor that enabled Solar Impulse to fly 43,000 km around the Earth on solar power was that energy efficiency was at the heart of our approach.

The great advantage of hydrogen is that it can **store** renewable forms of energy, thereby solving the problem of their intermittency. Hydrogen is produced when there is surplus electricity; this power can then be released later, whenever we need it. The yield hasn't yet been optimised, but any amount is better than just wasting that renewable energy.

There's general agreement on the usefulness of hydrogen in **industry**, in combination with nitrogen for the production of fertilizers and in blast furnaces to produce steel; but the debate gets bogged down when it comes to **mobility**.

There are two applications here: hydrogen can be transformed into electricity by a fuel cell and so power an electric motor, or it can be used as fuel in a combustion engine. Each option has advantages and disadvantages.

A fuel cell emits only water vapor - so no CO_2 or NOx (nitrogen oxide). Its efficiency (the ratio between energy restored and energy supplied) peaks at 45 to 60%, which is much more than the 25 to 30% of a gasoline engine

The combustion engine is viewed as the culprit for pollution, whereas in fact it is the fuel used that creates this pollution. Today such engines burn gasoline or diesel, and this emits CO_2 and NOx: But they could very well burn hydrogen, with zero CO_2. Since the power capacity of hydrogen is three times that of gasoline, an internal combustion engine optimized for hydrogen would be 45 to 50 percent efficient at its optimum RPM, almost double what can be achieved with gasoline.

While consensus is emerging on the need to replace gasoline and diesel engines, opinions differ on whether to use batteries or hydrogen. For some, the battery and its "almost 100%" efficiency is much more suitable than the fuel cell, which is half as efficient. We might therefore imagine using light battery-powered vehicles for short journeys, and heavy hydrogen-powered vehicles for long distances, where large batteries would be too polluting to build and too heavy to transport. This could bring advantages in terms of range and refuelling speed, and it would also apply to the maritime and aviation sectors.

As for the **distribution network**, the "chicken and egg" dilemma can be solved by building the entire "henhouse" at a stroke, without waiting for subsidies. In Switzerland, private partnerships have brought all involved sectors together, with Hyundai supplying 1,000 trucks, the Migros and Coop supermarkets putting them into service, and the Avia, Agrola and Tamoil service stations supplying them with hydrogen. As this is produced with hydroelectricity, the same price per kilometer as for diesel is guaranteed. A similar kind of system has also been put in place in Paris by Air Liquide, a hydrogen supplier, and the Hype taxi company.

All this proves that, whereas batteries frighten the oil industry, hydrogen would allow it to diversify more easily, by retaining part of its infrastructure and ensuring the survival of millions of jobs - a fundamental advantage.

**In collaboration with Antonio Delfino, Head of Physics and Chemistry Department, Michelin Research and Technology, Switzerland*

Green Hydrogen for a carbon neutral transport sector

ISMAIL ERTUG

MEP (S&D, Germany),
Member of TRAN & ITRE Committees,
European Parliament

Green hydrogen is indispensable for a decarbonised economy. With the EU converging to a minimum reduction of its GHG-emissions of 55 % – and possibly more – compared to 1990 by 2030, hydrogen will play a major role in the decarbonisation of various sectors. Especially in the transport sector, green hydrogen will be pivotal in making our mobility carbon neutral by 2050.

To begin with, I would like to point out that hydrogen, in the long-term, can only be a viable substitute for fossil fuels if it is solely produced by using renewable electricity. For this, we may use renewable electricity, such as windfarms, that is genuinely build up for producing green or clean hydrogen and does not decrease the overall renewable share, or once we have a system wide surplus in our European energy system we may use it to transform the excess electricity into green hydrogen. In any case, from today's perspective, we will additionally need hydrogen imported from countries where renewable energies, especially solar energy, are produced in an easy and cost efficient way.

Hydrogen is being used directly, i.e. in fuel cells, but it will also be the basis for many e-fuels that can be used in ordinary internal combustion engines – and, for several transport modes, this option will be the only realistic one in the medium term.

In road transport, hydrogen is still one of the most promising solutions to achieve zero emissions in the heavy-duty vehicles segment; this is especially true for long-haul transport. According to numbers from the industry, we can estimate around 5,000 - 10,000 fuel cell powered trucks on European roads by 2025. By 2030, this number could climb up to 100,000. A crucial element to support this uptake of zero-emission trucks is infrastructure, which means that we need hydrogen-refuelling stations as well as so called mega chargers for battery electric trucks. The upcoming revision of the 'Alternative Fuels Infrastructure Directive' is a key element in this regard. Back in 2013, the European Commission intended to have binding targets for public charging points for cars. The Council watered down this proposal. We are still suffering from the consequences of this shortsightedness, because it has seriously hampered the uptake of zero-emissions vehicles all over Europe. In addition, it might have made the transformation more difficult and costly. Hence, it is of crucial importance that we do not make the same mistake for heavy-duty vehicles. We need binding European-wide targets for an alternative fuel infrastructure, particularly along the core TEN-T network.

Regarding aviation, hydrogen has a twofold significance. For example, Airbus has announced its intention to develop a hydrogen-powered plane by 2035, and the Commission has shown great support for this initiative in its 'Sustainable and Smart Mobility Strategy', which was published only a couple of weeks ago. At the same time, hydrogen is the basis for synthetic kerosene. Notwithstanding the possibilities a hydrogen-powered plane might have – in the near future, internal combustion engines will still mostly power planes, since directly electrified planes do not seem to be a viable commercial option in the next decades. Furthermore, planes are on average 11 years old and it is common that they remain in service for 24, 25 or even 30 years. This means that the planes put into service today will still be traveling the skies in 2050 which, in turn, is the year when Europe has pledged to be the first carbon neutral continent in the world. The 'ReFuelEU Aviation initiative' the Commission has promised to put forward this year is therefore key to achieve a carbon-neutral aviation sector as soon as possible, and hydrogen is the hinge to achieve this.

Finally, hydrogen is also the most viable option to decarbonise the shipping industry. We still see a lot of potential to make current combustion engines work more efficiently, or use other means to increase energy efficiency for the transport of goods on the water. In the mid- to long-term future however, hydrogen should be used in fuel cells. For longer trips, we will need it as a basis for ammonia. Ammonia has a higher energy density and is thus very well suited to propel the fuel cells of future container ships. In this regard, the Commission will present a proposal for its 'FuelEU Maritime initiative' soon.

The future of mobility needs vast amounts of clean-hydrogen. Kick-starting the European hydrogen industry will thus be one of the most important projects in the current legislative turn. Together with the successful ramp up of the European battery-cell production, this could be a crucial change in Europe's industrial policy approach: from a lengthy period of deindustrialisation towards reindustrialisation.

When **hydrogen partners** with **electrons: clean heating** for all

MAXIMILIAN **VIESSMANN**

Co-CEO Viessmann Group and CEO Viessmann Climate Solutions

"We want everyone in Europe to have a home they can light, heat, or cool without breaking the bank or breaking the planet," said Frans Timmermans when presenting the Renovation Wave in October 2020[1].

As CEO of a 104 year old company in climate solutions, I am convinced that this dream is feasible. We can make it. And we will - with a mix of decarbonised electricity and decarbonised heating fuels, including hydrogen. Electrons and molecules together are the winning tandem. Success depends on our ability to get both people on board and to optimize the whole energy system; a narrow focus on sectors or heating technologies in isolation is a cul-de-sac.

- The benefit of hydrogen in heating is threefold: 1) optimized use of gas networks and storages for demand peaks in winter; 2) optimized electricity demand and "dimensioning" of dispatchable generation and infrastructure capacities; 3) optimized and flexible investment pathways for individualized building decarbonization.
- Every 5 mln heat pumps add roughly some 15 GW peak load to be provided reliably by the electricity system in winter - in addition to the growing fleet of e-vehicles.
- The price tag for energy system decarbonization is significantly lower with hydrogen in heating: for Germany alone, including hydrogen for heating in buildings lowers the system cost by 11 bln EUR[2] each year, until 2050.
- The individual needs of 450 mln citizens and the heterogeneity of buildings across the EU make emissions of buildings hard to abate. The heating sector is ready to process hydrogen admixtures up to 10% right away, and new appliances can process up to 20%.
- Blending in the early phase of the ramp up of the hydrogen economy provides a stable demand and scale, hence security for investments.
- Making new heating equipment hydrogen-ready for later changes in the gas mix is feasible. It is a no-regret.

Emissions of buildings are hard to abate. 450 mln EU citizens have to buy in. Think about it: the building stock is highly diverse, so are individual needs, preferences and financing capabilities - from Helsinki to Athens. 40% of the building stock was built over 60 years ago. Deep renovations, that reduce energy consumption by at least 60%, are carried out only in 0.2% of buildings per year and only 4% of heating systems are replaced per year. The current energy renovation rate of buildings, incl. investments in the envelope and equipment, leads on average to a reduction of the energy consumption of the building stock by only 1% per year. In many regions qualified professionals are scarce.

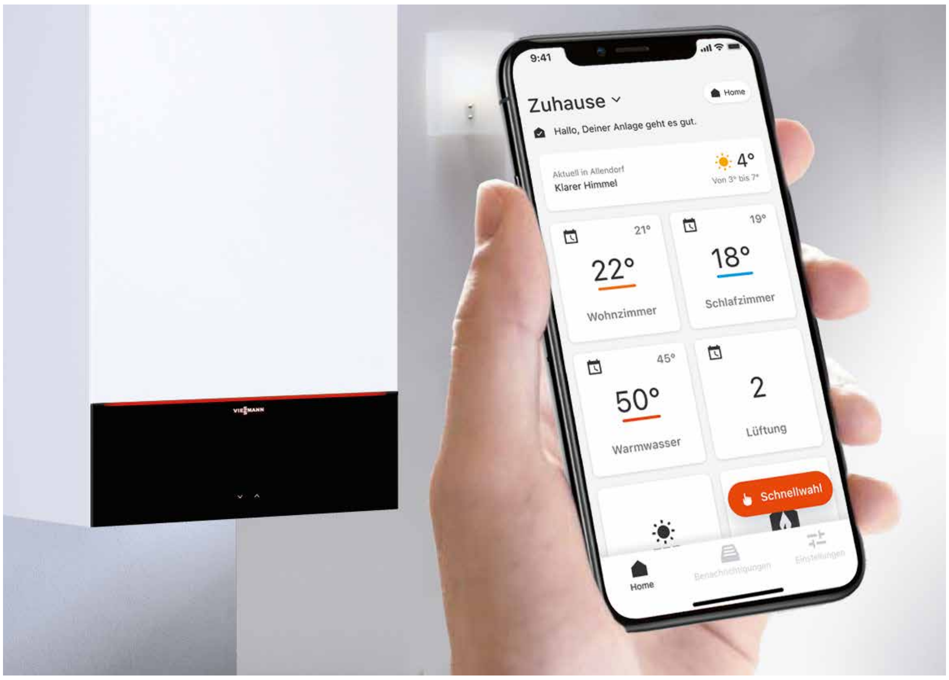
It is clear. We need to do more, we need the buy-in of people, we need speed and we need a long-term systemic view.

Hydrogen-readiness is a no-regret. In Europe, 64% of heating installations are old and inefficient[3]. If they had an energy label, it would indicate class C, D or lower. At the same time almost 7% of Europeans cannot afford to sufficiently heat their homes. High upfront

1 Frans Timmermans, Executive Vice-President for the European Green Deal.

2 German Energy Agency, www.dena.de/en/integrated-energy-transition

3 64% of the 104 million heaters installed in the EU-27 in 2017 (without the UK) / 57% if the 129 million stock of EU-28 is considered (with the UK).



cost for renewables based heating systems, split-incentives, and lack of long-term planning are amongst the reasons for slow heat generator replacement rates. Today, the urgency for modernising the installed stock of heating systems coincides with innovative technologies already on the market or in the making.

The equipment is ready. Each boiler, small-scale combined heat & power installation and heat pump/boiler hybrid will be capable of running on methane, or methane-hydrogen blend, or pure hydrogen. "Hydrogen ready" boilers are an affordable future-proof retrofit solution: initially they process methane or methane-hydrogen blends. If the gas supplier switches to pure hydrogen, they can be adapted with minor changes on-site. A no-regret for customers, without lock-in effects for fossil fuels. A priority is to make sure that the Green Deal synchronizes the replacing of fossil gas with the market uptake of future-ready equipment. Our sector supports ecodesign rules requiring all new heaters being hydrogen-ready, with an appropriate transition period that allows makers to convert their portfolios in time.

Hydrogen opens new options for people, on the road to climate neutral buildings. The trajectory is known: By 2030 we reduce emissions in buildings by 60% compared to 1990 levels and by 2050 we reach climate neutrality. The building sector is vastly heterogeneous, a one-size fits all approach is neither efficient nor realistic.

To get on track, we need a toolbox of measures targeting i) acceleration of renovation, in envelope and equipment; ii) electrification of heating with heat pumps; iii) greening of heating fuels incl. hydrogen. Hydrogen is an enabler of electrification, because it is a seasonal storage for renewable electricity, complementing biomethane with regionally varying potential.

Looking at Germany, about 90% of installed heating systems are based on gas or oil. For a part of it - for example a single family house built for 30 years or more recently - heat pumps can often be installed right away. For another part - e.g. old buildings or multifamily houses with individual gas heating - decarbonization is more difficult. Options include "deep renovation", or a switch to a decarbonized heating fuel, or a staged renovation approach combining decarbonized fuels with gradual investments into the envelope. Leaving nobody behind, without risking citizens' support for the energy transition means: we need all of these options.

Hydrogen in buildings contributes to system efficiency and energy security. Energy demand for heating shows high seasonal variations. Peak demands in winter often coincide with low electricity generation from renewables. In central Europe, the monthly average load in the coldest month in the gas sector is about a factor of 3 of the load in the warmest month. For the electricity load, this factor currently is only 1.2. The more electricity we use for heating, the more grid reinforcement, installed capacities and dispatchable back-up plants we need to deliver enough electricity at any time and ensure resource adequacy - that is secure electricity supply also when demand is high, and production of renewable electricity is low; also after the coal exit.

Studies with an energy system perspective[4] conclude that a mix of heat pumps and combustion heating with decarbonized gases is more cost-effective than "electricity only". The energy system cost-savings stemming from well-dosed volumes of decarbonized combustion outweigh the superior "factor six" efficiency of heat pumps taken "in isolation" - calculated over the heating season, and considering processes for producing and transporting hydrogen.

In EU-27[5] in 2018 about 20% of electricity production was from coal, and 25% from nuclear, often built decades ago. This fleet is currently often delivering the bulk of electricity supply, especially during winter days without wind and sun. Germany, for example, has to compensate for about 36 GW of installed "conventional" generation capacity due to the coal and nuclear phase out. On the other hand, every five million heat pumps will - with conservative assumptions - increase peak demand by about 12 to 25 GW, in addition to the demand from the growing fleet of e-vehicles - with every ten million vehicles estimated to add about 5 GW[6]. The numbers speak for themselves: Decarbonised gases delivered via existing refurbished gas infrastructures support energy system reliability and resilience, with optimized costs.

Hydrogen in buildings, via blending, can also facilitate the ramp up of the hydrogen economy in its early phase. The current natural gas infrastructure and space heating stock can already safely process up to 10 volume percent of hydrogen admixture. If needed, the heating sector provides a stable demand for decarbonized hydrogen - and hence security for ramping up investments into the hydrogen value chain, speeding up the learning curve to the benefit of all sectors.

This is how electrons and hydrogen can reinforce each other on the road to decarbonization. This is how we ensure that everyone in Europe has "a home they can light, heat, or cool without breaking the bank or breaking the planet". With a strong commitment and fast deployment of readily available heating technologies, we can ensure that the energy transition generates benefits to people, the environment, and our economy.

4 E.g. dena Leitstudie Integrierte Energiewende; Gas for climate study by Navigant

5 EU energy in figures, https://ec.europa.eu/energy/data-analysis/energy-statistical-pocketbook_en

6 Assuming that 5% of the fleet are charging with 11 kW

Hydrogen blending standards: is harmonisation needed?


ALBERTO POTOTSCHNIG

Florence School of Regulation - Robert Schuman Centre for Advanced Studies at the European University Institute

ANDRIS PIEBALGS

Florence School of Regulation Robert Schuman Centre for Advanced Studies at the European University Institute

Hydrogen is one of the main pillars – together with increased electrification - of the EU decarbonisation strategy to achieve carbon neutrality by 2050. Currently, hydrogen use, mainly as a feedstock, is confined to local industrial clusters, but it is envisaged that it will also become a main energy vector transporting energy over longer distances across Europe and storing it over longer periods of time than it is economically feasible with electricity. Hydrogen is therefore a key component of the energy system integration strategy outlined by the European Commission in July 2020 and, to mark this, a specific hydrogen strategy was released at the same time.

The transition from the role of hydrogen as a feedstock in local clusters to a major energy carrier across the EU will require not only the development of hydrogen infrastructure, but also an appropriate regulatory framework, including in terms of standardisation. This is in fact likely to be the only area in which the current regulatory framework for natural gas could not fully be taken as an inspiration for the approach to hydrogen.

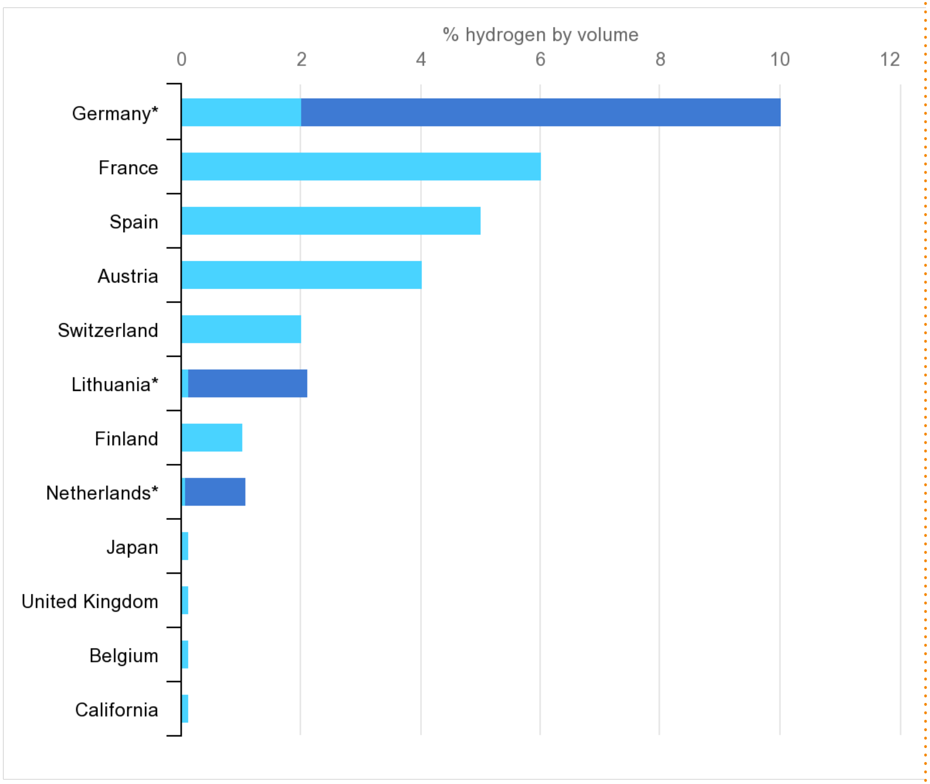
Standardisation will have to cover several aspects, including quality and safety. Here we focus on a specific aspect, which relates to the way in which hydrogen, as an energy carrier, could be transported in pipelines across Europe.

In essence, two approaches might be considered: blending hydrogen with natural gas and transporting the resulting mixture using the current gas network or transporting hydrogen as such in a dedicated separate network, part of which might be provided by refitted existing infrastructure.

It is clear that the blending strategy, while already contributing to the reduction of carbon dioxide emissions, can only have a transitional role, since full decarbonisation of the EU economy requires a much greater penetration of hydrogen in the EU energy mix than what could be accommodated through blending. Therefore, the question arises of whether and to what extent this transitional role should be governed by blending standards and whether they should be harmonised across Europe.

Blending of minor shares of hydrogen into natural gas does not create particular

Limits on hydrogen blending in natural gas networks, 2018



** Higher limit for Germany applies if there are no CNG filling stations connected to the network; higher limit for the Netherlands applies to high-calorific gas; higher limit for Lithuania applies when pipeline pressure is greater than 16 bar pressure.*

Sources: Dolci et al. (2019), "Incentives and legal barriers for Power-to-Hydrogen pathways: An international snapshot", International Journal of Hydrogen; HyLaw (n.d.), Online Database; Staffell et al. (2019) "The role of hydrogen and fuel cells in the global energy system", Energy and Environmental Science. Chart taken from the International Energy Agency website at Limits on hydrogen blending in natural gas networks, 2018 – Charts – Data & Statistics - IEA

technical problems in the transportation and usage of the resulting mixture, although some safety considerations might emerge given that the combustion characteristics of hydrogen greatly differ from those of natural gas. At present, different Member States in Europe – and other jurisdictions around the world - impose different limits on hydrogen blending in natural gas networks.

As it can be seen from the chart, among those EU Member States in which blending is permitted, the highest limits apply in Germany (10%, but only if no compressed natural gas filling station is connected to the network, otherwise the limit is 2%), in France (6%), in Spain (5%) and in Austria (4%). However, many jurisdictions do not (yet) allow hydrogen blending into the natural gas network. It is clear that, if blending is accepted as a transitional arrangement to facilitate the development of the hydrogen sector, at least in its initial stages, the seamless functioning of the internal energy market requires that harmonised standards be introduced for the maximum admissible hydrogen share. In choosing the level of such a limit, account should be taken of the need and the costs of refitting the transmission and distribution networks, the potential for using the resulting mixture in end-user industrial and commercial installations, as well as in household appliances and any associated costs. Of great importance in this assessment is also the extent to which these interventions and costs could end up being stranded once, in the future, hydrogen as such will become the main molecular energy carrier.

Moreover, given that increasing the share of hydrogen in the blended mixture reduces its calorific value, standards should also be developed for the valuation of gas mixtures with different shares of hydrogen.

Finally, strong coordination will be required in the planning of the transition from the initial phase based on blending to a sustainable future based on the use of hydrogen as such as an energy carrier. At that point, two types of molecular energy vectors will be coexisting: hydrogen and renewable gases (biogas, biomethane and synthetic natural gas). They will be competing for the use of existing pipeline networks (and, possibly, for any expansion). However, they will no longer be mixed, so coordination will be required, at EU level, on which infrastructure will be used by each of the two types of molecular vectors in order to avoid the stranding of assets and higher costs for European energy consumers.

DR ANTOINE HOXHA

Technical Director, Fertilizers Europe

Clean Hydrogen as A Major Enabler for Making **Carbon-Free Ammonia** and **Fertilizers**

"As one of the biggest producers and users of hydrogen Europe, fertilizer producers have all it takes to be frontrunners in scaling up the production of renewable hydrogen. Going beyond fertilizers, low-carbon ammonia could be the fuel of the future for maritime shipping and a viable energy storage solution".

The nitrogen fertilizer industry is main hydrogen producer

With a share of about 50%, the ammonia industry is today the biggest producer and user of hydrogen in Europe. Unlike hydrogen, ammonia is already being produced and transported worldwide in huge quantities (180 million tonnes annually are produced and 18 million tonnes are transported) as it is the basis of many chemicals and very importantly the starting phase for producing fertilizers (80% of the demand).

Today, the hydrogen for making ammonia is obtained by cracking at high pressures and temperatures the natural gas with the help of steam. This splitting process (steam methane reforming, SMR) generates significant quantities of CO_2.

A low-carbon route involves underground storage of at least part of this CO and gives what is commonly called blue ammonia (SMR + carbon capture and storage, CCS). Alternatively, when ammonia is produced from green electricity and water via electrolysis, or other sources of low carbon hydrogen, the process requires only air.

Green ammonia and low carbon food in 2050?

The world is today completely reliant on ammonia. Indeed, ammonia as a key component of mineral fertilizers contributes to half of the world's food production. Globally, the fertilizer industry is responsible for about 1.1% of annual carbon emissions due to using fossil energy as feedstock (approximately 80% of production uses natural gas, while coal accounts for approximately 15%).

By making a business case for low-carbon ammonia, we will at the same time help decarbonize food production and take a big step towards a hydrogen economy. **By 2050, under the right conditions, ammonia production could be based on decarbonised sources of energy, using alternatives sources of hydrogen and electrolysis based on renewable energy.**

Moving forward

Several big ammonia producers have announced projects to make hydrogen from water using renewable energy. Here are few examples:

- In Spain, Iberdrola together with the fertilizer producer Fertiberia are behind a project coming on-stream next year where solar panels will produce energy for a 20 MW electrolyser. This electrolyser will produce some 5 % or the hydrogen needed for ammonia production in the fertilizer plant. By 2027, it plans to install 800 MW of green hydrogen production capacity.

- In the Netherlands, a project has been announced where Orsted will build a 100 MW electrolyser based on wind energy to deliver hydrogen to Yara fertilizer plant. These 100 MW can produce 10 % of the hydrogen needed to run one of the two ammonia units of the plant.

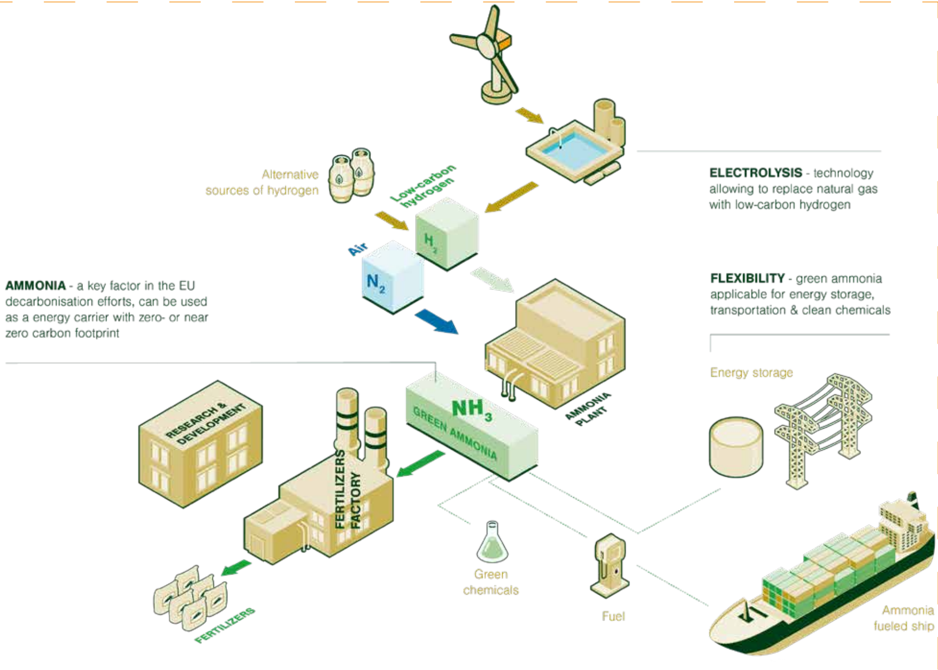


Figure: Green ammonia and low carbon fertilizer production in 2050

- In Norway, Yara recently announced plans to electrify its ammonia plant, thereby potentially removing 800,000 tonnes of CO_2 per year, provided the required public co-funding and regulatory framework are in place.

- Lately, the biggest ammonia producer in the US, CF Industries and the Asian Renewable Energy Hub and Fortescue Metals Group in Australia, amongst others, have also announced plans to develop ammonia based on green hydrogen.

Ammonia – the workhorse of the hydrogen economy

Although it might seem a paradox, ammonia is a better hydrogen carrier than hydrogen itself. Storing and transporting hydrogen is a challenge as it is the smallest and lightest molecule in nature and it liquifies only at the extremely low temperature of – 253 degrees Celsius. Ammonia on the other hand, liquifies at -33 degrees Celsius and can be handled better, similarly to liquified natural gas. Storing hydrogen under pressure is also possible but again, ammonia has three times the energy density of compressed hydrogen, and nine times that of Li-ion batteries, making it very attractive as a potential carbon-free energy carrier. Therefore, when hydrogen is needed, in many applications it makes more economical sense to transform, transport and use it in the form of ammonia.

Beyond fertilisers – decarbonising other sectors

In practice, ammonia is the only carbon free fuel. As such, it brings the promise to decarbonise the maritime shipping sector reducing its emissions by 95% by 2035 and the demand could reach about 1 million tons ammonia per day (reference Lloyd's Register Vessels 2030, how do we get there?).

Indeed, with limited modifications and technology improvements ammonia could be directly used in combustion engines of deep-sea vessels. Global ammonia transportation and storage infrastructure already exists with a presence in 120 seaports globally.

The ammonia molecule is also probably one of the best alternatives for the mid/long-term storage of electricity as chemical energy. As such it can be used in buffering a renewables-based electricity system by transforming electricity into hydrogen/ammonia when renewable energy is abundant and cheap and burned to produce electricity when needed.

Big scale projects have been announced in Saudi Arabia and Australia where energy from solar panels will be transformed into ammonia via electrolysers, and this ammonia will then be used to transport the energy around the world.

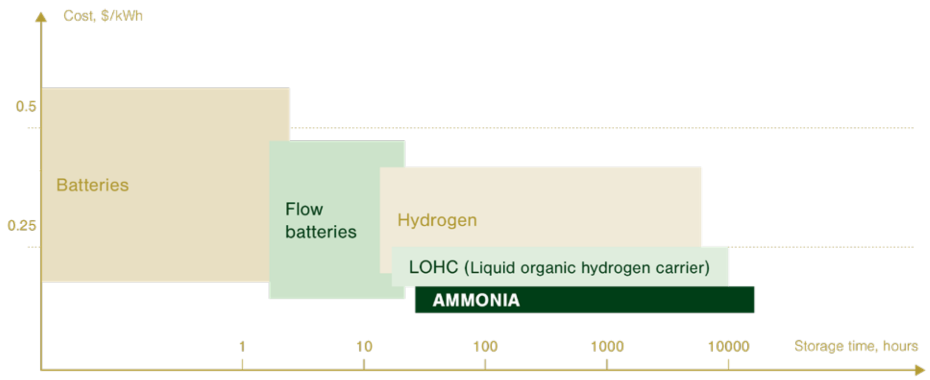


Figure 2 Ammonia as the most cost-effective energy carrier

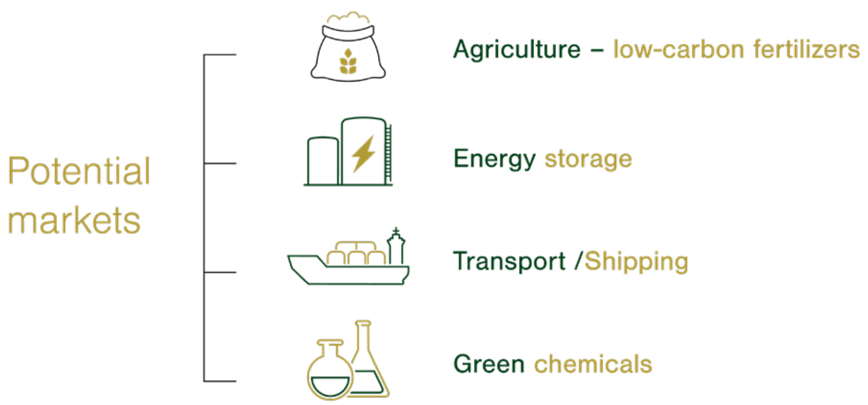


Figure 3 Beyond fertilizers, creation of the market for green ammonia

The challenges ahead

In the EU, the fertilizer sector produces and consumes 3,1 million tonnes of hydrogen and is best placed to help upscale new technology in the most cost-effective way. Balancing EU's climate ambitions with industrial competitiveness will be key to a successful implementation of this strategy. However, several barriers remain to gradually switch production from current SMR based hydrogen towards low-carbon routes.

Abundant and competitively priced clean electricity to produce hydrogen is a pre-condition for green ammonia to become competitive and challenge the current production technology. Furthermore, as fertilizer plants with ammonia production are scattered all over Europe electricity and/or hydrogen transport infrastructure is a required for a balanced development.

The next challenge is making the business case. Today ammonia production based on green or low-carbon hydrogen cannot compete with production based on natural gas. Public support for investment and operational cost is necessary now to get the ball rolling. It also includes considering schemes such as the Carbon Border Adjustment Mechanism to help maintain a level playing field and prevent green ammonia being outcompeted by cheaper imported grey ammonia. With such measures in place, European fertilizer producers should gain the confidence and the economic room to invest in new technologies.

The third challenge is creating markets that reward low-carbon ammonia. In the future there will be at least two major markets for ammonia: fuel for deep-sea shipping and for nitrogen fertilizers. We need to define and create certification schemes for green and low carbon ammonia and by extension fertilizers, so that farmers can make this a premium selling point the food chain.

Cooperation of all stakeholders is required, including the EU, Member States and regional authorities in supporting industries in rolling out new technologies, for example by providing financial incentives and partaking in development of regional hydrogen resources.

DIEGO PAVIA
CEO of EIT InnoEnergy

Unlocking the **Green Hydrogen Economy** through **Business Model Innovation**

Can business model innovation make a substantial difference for the uptake of the green hydrogen economy? When hydrogen is a promising way to decarbonise an industry, and when partnerships throughout a value-chain result in a CO_2-free end-product which incorporates a negligible premium, then the price of the green hydrogen molecule becomes irrelevant for the business case. Fostering investments and accelerating such type of industrial projects is what EIT InnoEnergy aims at with the European Green Hydrogen Acceleration Centre (EGHAC) launched in November 2020, and supported by Breakthrough Energy.

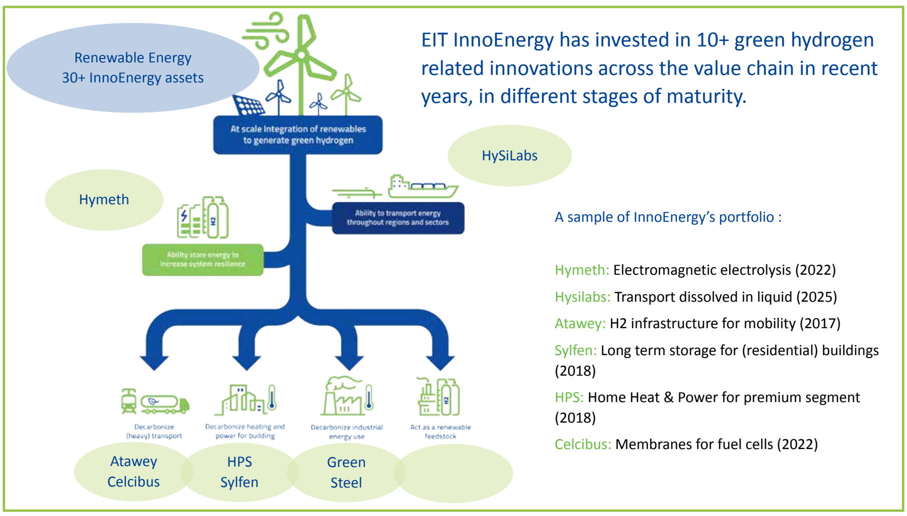
Fostering Investments and Industrial Projects with the European Green Hydrogen Acceleration Centre

In 2017, the European Commission entrusted EIT InnoEnergy to steer the European Battery Alliance (EBA). With over 500 industrial actors, research centers and investors across the entire battery value chain, from the ethical sourcing of raw materials to recycling and re-use, EBA supports Europe in becoming a battery industry hotspot. In 2019, investment in Europe across the whole value-chain reached over €60 billion (more than three times as much as in China), aiming to reach an annual market value of €250 billion from 2025 onwards, which represents around 3-4M direct and indirect jobs. This initiative is now a blueprint for the development of industrial value chains in Europe.

EIT InnoEnergy believes in the potential of green hydrogen to decarbonise Europe's (and the world's) economy and to achieve the Union's climate-neutrality ambition. It quickly appeared, however, that the model of EBA could be used as a reference but could not be fully replicated. The hydrogen landscape is today dominated by a debate on the production process of hydrogen (i.e. "green" from renewable electricity, "blue" from fossil fuel combined with carbon capture, "grey" from natural gas, "brown" from coal) and on the price of the molecule, making it difficult for a profitable business case to emerge in the short term.

Therefore, the EGHAC, while capitalising on the lessons learnt from the battery value-chain, treads a new path. It is with this in mind that, in November 2020, EIT InnoEnergy launched the EGHAC that applies a value chain approach and focuses on the cost of the end product (i.e. the steel, the cement, the vegetables grown with fertilizers, the fuels for heavy transport, …) using green hydrogen in evolved innovative industrial processes. **EGHAC promises to accelerate the green hydrogen economy and help achieve climate neutrality by targeting 1200TWh of final energy use based on green hydrogen by 2025, which represent investments north of €100 billion across the affected value-chains. This will result in half a million direct and indirect jobs across the green hydrogen value-chain.**

As an industry-led initiative, the EGHAC strives to be a key actor in Europe's green hydrogen ecosystem and works collaboratively alongside existing efforts in this space to achieve Europe's vision. The industrial projects supported by EGHAC span across a variety of value-chains with energy intensive applications, such as heavy industry (for instance the steel industry, which emitted 203MtCO2e in 2019, making it the largest CO_2 emitting industry the European Union, representing about 5% of its overall emissions), heavy transport and feedstock for chemical process and fertilisers. The initiative is supported by Breakthrough Energy, a network of philanthropic programs, investment vehicles, and policy advocacy efforts that offer a comprehensive, end-to-end approach to accelerating the clean energy transition and helping the world reach net-zero emissions by 2050.

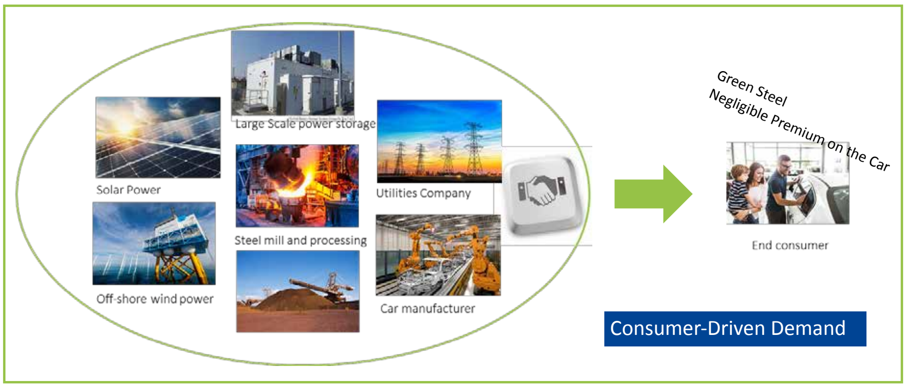


A Sample of EIT InnoEnergy's Portfolio of Assets in Green Hydrogen

Business Model Innovation to Square the Circle of Green Hydrogen Competitiveness

The EGHAC, covering solely green hydrogen, is stepping aside from a hydrogen production cost approach in order to boost the green hydrogen economy at the scale and speed required to achieve climate-neutrality. Instead, the **EGHAC supports and develops projects which pursue a value-chain approach and offer CO_2 free end-products on the market, at a negligible premium price, in key high-emitting economic sectors.** In the traditional approach, the multiplication of bilateral agreements along the value-chain, whereby each party needs to optimise its margin in each individual transaction, leads to uncertainties, additional risks, and sub-optimal economic outcomes. There, the price of the green hydrogen molecule may be a show-stopper.

A value-chain approach, on the contrary, is about companies partnering in one industrial venture. The profitability of this new venture becomes the main target and the competitiveness of the CO_2-free end-product is the dominant factor This business model innovation creates a successful business case, offering a "think outside the box" solution to the decarbonisation of critical sectors, notably steel (e.g. for car manufacturing where steel currently represents 10% of the lifetime CO_2 emissions of a car and is expected to reach 30% by 2040, or for windmill towers) or for vegetables using fertilisers.



EIT InnoEnergy's Value-Chain Approach Applied to Steel & Car Manufacturing

EIT InnoEnergy's Vision to Accelerate the Green Hydrogen Economy

This business model offers three major benefits:

First, it provides an industrial response to the demand by the consumer for sustainable, "made in Europe" products. **The demand drives the project rather than the offer of green hydrogen generation capacity**. Building on a solid understanding of the customer, and their willingness to pay a small premium for CO_2 free products, it allows the consortium to accompany the changes in their customer base. For instance, looking at fertilisers, the demand for greener food and for more transparency in the carbon footprint of food products boosts the case for green fertilisers, and therefore, for green hydrogen. Would any citizen pay a premium of 0,01c€ for a tomato grown with CO_2-free fertilizer?

Second, **it allows hard-to-decarbonise sectors to start a transition. With this business model, it becomes possible to launch a new green field manufacturing capacity which acts as a disruptor and leads the transition of a sector towards long-term carbon-neutral sustainability.** For Europe's industrial base and for its transition to a low-carbon economy, it is crucial to accelerate the transition of sectors characterised by a strong international competition and reduced margins. The steel industry is one of those. In this area for instance, EIT InnoEnergy is supporting the effort of industrial players united behind the objective of manufacturing competitive green steel in Europe, which will be publicly disclosed before Easter. This will demonstrate that scale and an innovative value chain approach delivers competitive CO_2-free steel.

Lastly, it is the **replicability** of the model. **The EGHAC fosters the replication of such projects. The experience gained on the first projects will bring speed and scale at many levels: attracting investors and partners, emissions reduction, reshoring an industrial base in key sectors for Europe's economic transition and resilience.** The ambition of the EGHAC is to use that model in all "hard to decarbonate" and "hard to directly electrify" sectors, such as heavy road transport or shipping.

With this initiative, EIT InnoEnergy wishes to continue its efforts in accelerating strategic value chains in order to maximise the industrial benefits of the transition to a climate-neutral economy.

Since its launch in 2010, EIT InnoEnergy has invested €560 million in sustainable energy innovations, and for each Euro invested we have leveraged 6 Euros additional. EIT InnoEnergy is supported by the European Institute of Innovation and Technology (EIT).

EU Hydrogen at a crossroads: how to gear up?

DOMINIQUE RIQUET

Vice-President of Renew Europe
Co-chair of the intergroup on long-term & sustainable investments & Competitive European Industry

The Green Deal is a game changer. Reaching climate neutrality by 2050 will require unprecedented efforts by all sectors and transport - accounting for a quarter of the Union's greenhouse gas emissions - is at the forefront. In its new mobility strategy, the Commission considers that a 90% reduction in transport emissions is necessary, in spite of the fact the sector was still on growing emission trends... until the Covid crisis happened. The latter exposed our vulnerabilities and reminded us how much transport is the circularity blood system of our European societies. Being vital, the sector needs to find the right balance between accompanying economic growth while transforming itself to become climate-friendly, with tackling as top priority its dependency on fossil fuels.

How? "Clean Hydrogen", they say. Though the energy itself has been known and used for long, it is finally considered today by EU institutions and Member States as a credible alternative to fossil fuels for the transport sector. More generally, the EU's recent hydrogen strategy and the extensive investment projected for the sector in some national recovery plans (7 billion euros for France; 9 billion euros for Germany) confirm the new political momentum gathering behind for a hydrogen industry to emerge in Europe.

In these circumstances, can hydrogen square the circle of zero emissions mobility in Europe? If hydrogen has an indispensable role to play for reaching sustainable mobility, we as policy makers should keep in mind that it is no panacea. Beyond zero tailpipe emissions, hydrogen is at a crossroads between crucial issues, such as energy, industry, infrastructure, sovereignty even. If those interconnections are not well assessed, they will threaten the potential of a European hydrogen industry, with the risk of turning an old solution into a new problem.

A strategic use of low carbon hydrogen for EU mobility

In the transition towards sustainable mobility, it is interesting to observe from time to time a rediscovery of old technologies. Similar to electric cars, hydrogen production processes have been known for centuries and yet, our cars, trains and aircraft are still not fuelled by it. There are physical and economic reasons explaining why we have not collectively privileged this energy carrier over time: its lack of competitiveness when compared with fossil fuels. Fossil fuels have been abundant and accessible at low cost, while having a high energy density. Still further, they are easily transportable and storable, especially oil.

On the other hand, the production of hydrogen alone requires expensive infrastructures and substantial amounts of energy. In order to have a low carbon footprint under a life cycle analysis, the bill gets even higher for low-carbon hydrogen by electrolysis, due to its electro-intensive process. As such, using electricity directly will always remain a more valuable cost-beneficial alternative - for passenger cars for instance - than using it first to produce green hydrogen.

Nevertheless, electrification is not always achievable in transport, particularly for heavy mobility. This is where we should concentrate our focus. If the added value of hydrogen for trucks, buses or dustbin lorries still has to be improved, hydrogen is simply indispensable to decarbonise maritime and aviation in the long run. This achievement will be accelerated by considerable research and innovation efforts, which the EU must support further, especially for storage on board vessels and aircrafts (as a reminder, four litters of liquefied hydrogen equal one litter of oil). In rail, hydrogen powered trains could be an alternative for passenger lines that would be too expensive to electrify. Unfortunately, we can only deplore the budgetary cuts affecting these programmes in the new MFF, hampering sufficient European collective ambition for the task in hand.

An EU strategic deployment of low carbon hydrogen

Hydrogen does not only face production energy-efficiency difficulties. It is also a very light gas. Infrastructure-wise, as the volumes to be transported are much greater than with fossils, all existing gas pipelines cannot be used as they currently are; in addition to loses, security and lock-in effect concerns which may arise. Alternatively, transporting hydrogen in liquefied form by boat, for example, requires cooling it to -252°C, which in turn consumes more energy and further degrades its competitiveness.

In both cases, the less hydrogen travels, the more competitive and clean it will be. Imports should therefore be avoided where possible. This is an encouraging aspect which advocates in favour of the emergence of a hydrogen industry on the European soil! Additionally, by not transferring our importation dependency from fossil fuels to a new resource, it is our European autonomy strategy as a whole which is strengthened.

However, due to their additional costs, a strategic deployment of hydrogen is needed, with a precise mapping and careful selection of installations. Europe holds strong assets in this regard. Our success will rely on our capacity to establish key hydrogen valleys, such as inland and maritime ports, which are already essential hubs for our energy and industry supplies and offer a strategic leverage for multi/shift-modality.

An EU strategic production of low carbon hydrogen

This being said, the core question to appreciate the climatic and economic advantages of hydrogen remains the source of electricity used. As shown by the taxonomy debates, this is where today's real challenge lies and where the European approach starts to erode.

Production by electrolysers consumes huge amounts of electricity. The latter must then be produced with low-carbon power capacities to be climate friendly and with high load factors to be competitive. Caught in this vice, nuclear energy – the elephant in the room – appears then as the most valuable option at our disposal, and its exclusion from "clean hydrogen" classification, as a fallacy. Representing 70% of its electricity mix (for how long though?), nuclear enables France to base its strategy on existing national electricity production and gives more room of manoeuvre to foster its industrial autonomy. On another hand, Germany, by phasing out nuclear capacities and integrating more intermittent renewable energies, orientates its strategy towards a higher recourse to imports. This approach might solve our territorial emission reduction objective, but it would leave our dependency on third countries intact.

More generally, hydrogen appears here as a case study of the divergences encountered in the energy transition in Europe and questions the compatibility of the different European energy policies. Over the coming decades: the EU expects its electricity needs to drastically increase due to the electrification of whole sectors and activities; it has announced a multiplication of production of low-carbon hydrogen and it plans to face it thanks to the growing inclusion of intermittent renewable energy sources with low load factors. Meanwhile, transmission system operators are already raising the alarm on rising risks of blackout today! In the long run, can such a strategy be considered as credible?

A geostrategic hydrogen: European autonomy at stake

Though hydrogen is no panacea, it remains indispensable to decarbonise some economic activities where there is no substitute, such as heavy mobility for the transport sector. To optimise its potential as an energy carrier, its limits must be realistically assessed, free from ideological concerns. Beyond any rainbow hydrogen classification, all options at our disposal must be considered and appreciated under their life-cycle assessment, including nuclear sources.

As such, a targeted use paired with a strategic deployment in Europe is necessary to maximise its economic and climatic added-value. Nevertheless, due its structural lack of competitiveness, private and public investments must support innovation and contribute to scale up the technological eco-system in order to lower the production costs. Alongside public mechanisms (such as a carbon border adjustment mechanism or higher CO_2 prices), the emergence of a European sector and the rise of European champions will generate high-quality jobs and position the EU as a global standard-setter and world-leading region for hydrogen.

This time, the Union cannot afford to miss the opportunity. For many, the loss of Europe's industrial leadership on wind turbines or solar PVs remains vividly and painfully in mind. After having called for years to initiate a common strategic autonomy and put an end to a certain "European naivety", the EU seems to be finally waking up. First and foremost, hydrogen is of geostrategic matter. If we, as Europeans, do not assure an autonomous European industry sector, which secures the full supply chain (including technologies, equipment, materials such as platinum for electrolysers…), we might fail to meet our climate objective and to resolve our long-term vulnerabilities. Time has come for the Union to gear-up!

© Alstom

Innovation – a key driver of the EU Hydrogen Economy

STEPHEN **QUEST**

Director-General Joint Research Centre, European Commission

When it comes to tackling climate change, we know that 'business as usual' is not an option. With the European Green Deal, the European Commission has set out an ambitious plan to transform Europe's economy and make the continent climate neutral by 2050.

To realise these ambitions, transforming our energy system is a priority as it accounts for 75% of the EU's greenhouse gas emissions. Hydrogen can be key to bringing this percentage down – it does not emit CO_2 or pollute the air when it is used. The potential for hydrogen in Europe is huge: from shipping to clean fuel cells that can power steel manufacturing and other heavy industries. The timing is right, given recent advances in underpinning technologies to boost the use of hydrogen and the impetus of the Green Deal.

Until now, the amount of hydrogen used in the EU remains limited, while the greenhouse gas emissions involved in its production are high, since it is largely produced using fossil fuels. The EU hydrogen strategy aims to decarbonise that production, setting a target to produce up to ten million tonnes of clean hydrogen by 2030, expanding its use in sectors where it can replace fossil fuels. To succeed, we need to innovate in several areas and create a full hydrogen supply chain in Europe's economy – from production, to transportation and end use.

As the Commission's science and knowledge service, the JRC develops and tests innovative technologies to produce, transport and use hydrogen, as well as new policies to foster an EU hydrogen economy. We also recognise the importance of working together – we open our facilities to collaborate with other scientists doing innovative hydrogen research and contribute with our expertise to initiatives like the European Clean Hydrogen Alliance .

Bigger, more efficient and more durable electrolysers – key for hydrogen production

Clean hydrogen means replacing carbon-intensive production with renewable-powered water electrolysis. Our research suggests that this is a feasible goal: hydrogen production currently takes place in 82 EU regions, and 76 of these already have sufficient solar, wind and hydropower resources to fully decarbonise both electricity consumption and hydrogen production.

To make this a reality, the key innovation will be to make the electrolysers bigger, more efficient and more durable. The Commission is funding research in this area: a recent European Green Deal call asked for proposals to design a 100 megawatt electrolyser, compared to the 20 megawatts that are the state of the art today.

Our research also finds that innovation is needed to develop technologies that are better suited than the current alkaline electrolysers to operating intermittently and exploiting wind and solar power, which produce different levels of energy at different times.

Innovation to boost demand for hydrogen

For an EU hydrogen economy to develop, demand for hydrogen is crucial. And that demand depends on hydrogen technology being advanced enough to make it a better option than other fuels.

At the JRC we investigate the performance of fuel cell vehicles under laboratory and real world driving conditions and are perfecting a tool to test that performance in different settings. Upcoming projects include testing a racing car fuel cell propulsion system (collaborating with a university) and a maritime one (collaborating with a company). A forthcoming JRC report will analyse the best option between battery electric trucks and hydrogen fuel cells to decarbonise long-distance road freight.

Innovative ways to transport hydrogen

The cost of production and transportation are key considerations in building an EU hydrogen economy. Our research shows that transporting hydrogen can be more cost-effective than producing it close to the point of use in many cases – due to the varying costs of wind and solar power across European regions.

Pipelines are the best option for transporting hydrogen within Europe, if existing natural gas pipelines can be converted or new ones can be built. In this respect, there is a pressing need to find innovative ways to convert the pipelines and improve compressors. At the JRC, we are looking into the possibility to test the reuse of different types of natural gas pipelines for hydrogen transportation.

In the absence of pipelines, 'packaging' options for hydrogen shipping need to be designed and commercially scaled up.

Innovative and fit-for-purpose regulatory framework

A successful EU hydrogen economy needs an appropriate regulatory framework to create markets for clean hydrogen in industry and transport, incentives to convert natural gas pipelines to hydrogen and methods to classify consignments of hydrogen as clean. Renewable energy legislation can be a reference point for developing this framework, but new techniques will also be needed, for example to track the type of electricity used to make imported hydrogen. The EU hydrogen strategy will help to build these regulations so that we enable the innovations needed to make the most of hydrogen.

The JRC is supporting these efforts, providing scientific insights and evidence to help Europe grasp the opportunity to be a world leader in this new and exciting technology.

How can **carbon-free hydrogen** become more **competitive**?

CHRISTOPHE GRUDLER

MEP (Renew Europe Group), Member of the ITRE Committee

Last December, 22 EU countries and Norway announced their willingness to engage into a new IPCEI (Important Project of Common European Interest) on hydrogen, highlighting the hopes that most of Europe has now placed in a technology that was until recently very much perceived as a niche. I strongly believe that hydrogen is indispensable for the EU to meet its environmental objectives, but also as a vector for job creation. The challenge is to make carbon-free hydrogen more competitive, so that it can be deployed as quickly as possible over Europe. This is one of my main objectives as Member of the European Parliament.

It is now widely accepted that we should reduce the share of hydrogen produced from natural gas, or "grey hydrogen", which today remains the main means of producing hydrogen. However, the debate gets more complex when it comes to the role of "blue" hydrogen. Blue hydrogen refers to fossil-based hydrogen combined with carbon capture processes, which reduce overall life-cycle emissions of the energy carrier. Blue hydrogen is expected to be a "bridge energy", allowing for a transition to "carbon-free" hydrogen. The latter includes renewable (or "green") hydrogen, which most often comes from electrolysis powered by renewable electricity. Additionally, carbon-free hydrogen (or called by some "low-carbon hydrogen") includes hydrogen produced via electrolysis from nuclear energy.

Despite the huge potential of carbon-free hydrogen, it has not yet been widely deployed in sectors which emissions are hard to abate and would greatly benefit from this solution. In fact, if we take the production of renewable hydrogen, it currently accounts for less than 1% of the annual hydrogen production in Europe. The reason is simple: it is simply not competitive yet. According to recent studies, whereas grey or blue hydrogen has a cost of €2-3 per kilo, the cost of renewable hydrogen varies between €5 and €6. There are indeed major barriers to the uptake of carbon-free hydrogen, especially due to an absence of appropriate regulatory framework.

I foresee several paths in order to address the lack of competitiveness of carbon-free hydrogen.

The production costs for carbon-free hydrogen is linked to the renewable electricity prices, the investment costs into electrolysers and the operating hours. These costs must be significantly reduced, through the scaling up of the production and the improvement of the technologies' efficiency.

Electrolysers currently have an efficiency range of 60 to 80%. Our research and innovation capacity will play a crucial part to improve these numbers. With the support of Member States, as well as the EU financial programmes such as Horizon Europe programme, I am confident that we will be able to mass-produce more efficient electrolysers in the coming years.

The cost of carbon-free hydrogen is also heavily reliant on the cost of electricity. The competitiveness of this electricity depends partly on the cost of CO_2 under the EU ETS, as well as the dependence to national subsidies. Nuclear electricity, however, represents a more affordable option, as it can provide electricity at a competitive price to produce carbon-free hydrogen.

When considering the most cost-efficient ways to deploy hydrogen, an important element to consider is system flexibility. By focusing our attention on building new infrastructure or investing in new infrastructure, we tend to forget that the core principle of "energy efficiency first" ought to apply, not only to end uses, but to the entire energy value chain. By focusing on the existing energy infrastructure and making it more integrated and more coordinated, we can limit the need for new infrastructure. Innovative digital solutions can help us predict energy demand and manage energy supply, including the potential need for energy conversion, storage or balancing of the system. These ideas are enshrined in the concept of energy system integration, on which I am currently leading the work within the European Parliament as rapporteur on the Own-Initiative report exploring the matter.

While production costs and supply uptake are essential, the competitiveness of carbon-free hydrogen also lies in the creation of the right market conditions and incentives.

Several tried-and-tested instruments have the potential to create favourable market conditions for this uptake.

First, hydrogen being a new energy product for European consumers, I believe that there is a crucial need for transparency and information on its production and emissions. Guarantees of origin and certifications haven proved to be the best methods to inform customers, as well as to guarantee fair competition within the market.

Support schemes will also undeniably play a key role, if not the biggest role in the first years of commercialisation, to ensure that the price difference between fossil hydrogen and its greener alternatives is reasonable. Like for renewable electricity, CO_2 pricing, taxes and levies weigh in heavily on final energy prices and customers' decisions. Therefore, support schemes should go hand in hand with fiscal incentives for carbon-free hydrogen.

The EU is on the pathway to a real change of paradigm in its energy policy. From the presentation of the European hydrogen strategy, to the multiple national and even regional hydrogen strategies, all the options are on the table. Now is the time to find the right way to implement these strategies and make it a reality for all European citizens and businesses.

PIERO CARLO DOS REIS

Research Associate - Florence School of Regulation

JEAN-MICHEL GLACHANT

Director - Florence School of Regulation

Clean Hydrogen costs in 2030 and 2050: a review of the known and the unknown

Hydrogen (H2), an abundant element, has to be produced before being used for processes or as energy fuel. This implies separating it from other elements with which it combines before being used. Until today, 'dirty' H2 has been easily produced by using fossil fuels. To get this 'dirty' H2 'clean', we need to change the way it is produced. Exploring innovative processes to get it clean may also enable the use of H2 to do other things that it does not do in large scale or well today. Of course, innovating is facing the unknown: bringing novelties always challenges conventional wisdom, similar to how solar PV or offshore wind seemed anecdotal 20 years ago, or Tesla's cars just ten years ago.

H2 keeps asking us the same question: what potential does it have for our 2030 and 2050 economies? Of course, no one knows the precise answer, yet. This does not impede us to think about it rationally. First, by disentangling the main dimensions; then by putting clarity on some of these dimensions. The main dimensions are five:

1. Will clean H2 be used to substitute existing usages of dirty H2? If yes, potential users already have money, infrastructures, equipment, technologies, and human know-how to deal with H2. Therefore, the main issue is replacing dirty H2 with clean H2, leading to new technologies, equipment, and costs for producing it.
2. Do we know all possible new usages of clean H2 by 2030 and 2050? How many new uses of H2 do we foresee, for example using liquid H2 as rocket propellant for trips to Mars?
3. If clean H2 has to enter into new usages where dirty H2 is not used yet (e.g. as a direct substitute to fossil fuels), many additional questions appear. Firstly, how potential new hydrogen users would invest in infrastructures, equipment, technologies and human know-how to shift their current non-H2 usages to H2?
4. How will existing H2 delivery infrastructure transform itself to bring H2 from new production facilities to new users and new usages?
5. Lastly, will the EU have enough investors, primary resources and new H2 production facilities to feed all new users and new usages? Or would a significant amount of H2 be imported (supposing an adequate set of available delivery infrastructures and production facilities abroad, with the willingness to trade)?

In our paper, we will take a look at producing clean H2 able to substitute dirty. We will focus on the production technologies and costs of clean H2, circumventing technologies and costs of equipping new users and getting new delivery infrastructures ready for the new usages – be they inside the EU or foreign countries.

We will contrast Horizon 2030 and 2050. Why? Anything able to substantially impact clean H2 potential in 2030 is nearly in existence: thinking about it is like deliberating the likely paths of changes within what is already known. Beyond 2030, looking at 2050, many revolutionary or unforeseen changes might occur. This contemplates the unknown, while also contemplating the already known— two different types of reasoning and two legitimate horizons.

The Florence School has more than 15 years of experience examining what established 'policymaking institutions' are doing and claiming. Over the last year, we have worked on understanding how key references used by policymakers have calculated their findings. We investigated their more intimate roots, scrutinising their strength and limits of validity: what is known or unknown today about the costs of 'clean' H2 in 2030 and 2050. Our most significant output was a report looking into EU policies and technological costs towards 2050 decarbonisation. Our findings have to be distinguished between the various alternative technologies to produce clean H2 for Horizon 2030 and 2050. Because alternative technologies of clean H2 production may have different cost drivers and various potential for improvement at the two horizons.

We have identified 22 technologies for H2 production. Nineteen are meant to mainly produce H2. The remaining three are meant to mainly produce industrial goods and have H2 as a by-product.

Today, decarbonising H2 supply mainly forces the existing two mature technologies producing 'cheap and dirty H2' (Steam Methane Reforming (SMR) fed with natural gas and coal gasification) to either change or be substituted.

It is still very challenging for three main reasons:

1. 'Cheap & dirty H2' dominates almost all H2 production.
2. Few 'mature enough' competitors exist; and the other competitors are only "researchers' ideas", "baby prototypes" or "teen demonstrators."
3. These other competitors have not demonstrated how to become 'cheap' enough and 'clean' enough. For example, to produce 'cleaner H2' from natural gas, one has to overcome infrastructure methane leakages.

Costs are addressed in the next section.

1 - Today's knowledge of 2030 costs potential of clean H2

At Horizon 2030, we identify two main possibilities for cleaner H2 production:

1. Electrolysers, fed with water & 'clean' electricity;
2. Steam Methane Reduction, with Carbon Capture and Storage (CCS), fed with natural gas.

The costs of clean H2 electrolysers can be split into two electricity feeders - based on different renewables: solar PV and offshore wind. Other electricity sources are guessed to produce more expensive clean H2 (nuclear), or H2 that is not clean enough (as the foreseen 2030 regional power mix, including remaining fossil fuels).

At present, we do not believe that 'ideas', 'baby' or 'teen' technologies can reach maturity in the current decade, via any accelerated growth from strong policy support. As methane pyrolysis with Carbon Capture and Utilisation (CCU) and coal gasification with CCS. We expect their maturity only after 2030.

2 - Today's knowledge of 2050 costs potential of clean H2

At Horizon 2050, costs remain mostly speculative. We acknowledge three technologies for clean H2 production: electrolysers fed with water and clean electricity; SMR with CCS fed with biomethane; and methane pyrolysis with CCU fed with biomethane. We add a scenario for clean H2 from electrolyser technology – with electricity taken from the 2050 regional decarbonised power mix.

We exclude the 'ideas' and 'baby' technologies due to today lack of enough information. Out of those we would categorise as a 'teen' technology today, we would include one of the most 'mature': methane pyrolysis with CCU; combining it with biomethane (although costs speculation built on today's scarce data is less reliable). Fuel switching to biomethane is considered feasible only by 2050 when biomethane production could potentially be much cheaper and more available than today. The spectacular potential of absorbing GHG emissions from the atmosphere by coupling biomethane with CCS/CCU will, however, depend on the availability of enough clean biomethane, the avoidance of biomethane leakages, and availability of a CO_2 transport and storage infrastructure for CCS.

3 - Conclusion

Today, the cleanest and most mature new H2 production technology in 2030 would be the electrolyser. It could steal a larger market share from dirty H2 through lower renewable electricity price while increasing efficiency and full load hour factor. SMR with CCS, fed with natural gas, would also be a cost-competitive challenger, supposing that CO_2 storage and transport infrastructure is built at an acceptable price.

While results are still highly hypothetical for Horizon 2050, mature technologies like electrolysers could establish an absolute reference in 2050 "Net Zero" market economics. All the more if their clean electricity would come from solar PV, rather than offshore wind or the regional decarbonised power mix. SMR with CCS has the potential to be a challenger in close second and could innovate in cleanness by switching its fuel source to biomethane, but it would be hard to become cost-competitive. Methane Pyrolysis with CCU, fed with biomethane, which is today still a 'teen' in the prototype phase, could eventually grow to become a worthy competitor of electrolysers, through lower enough biomethane price and good sales of solid carbon.

Table 1 shows 2030 costs and four key costs drivers (free of any "regulatory" costs or subsidies).

Technologies	Electrolyser & solar PV	Electrolyser & offshore wind	SMR + CCS & natural gas
Costs – 2030 (Note: HHV used for conversion)	0.9-2.3 EUR/kgH2 22-59 EUR/MWh	1.7-2.8 EUR/kgH2 44-72 EUR/MWh	1.0-2.8 EUR/kgH2 25-71 EUR/MWh
Cost driver 1	Electricity price 10-25 EUR/MWh	Electricity price 36-46 EUR/MWh	Natural gas price 3–32 EUR/MWh
Cost driver 2	Efficiency- LHV 69-75%		Efficiency-LHV 69%
Cost driver 3	Full load hour factor 15%-38%	Full load hour factor 40%-57%	CAPEX 1155 EUR/kW-H2
Cost driver 4	Electrolyser CAPEX 98-200 EUR/kWel		CO_2 transport & storage 17-55 EUR/tCO_2

Table 2 reports the costs and key costs drivers.

Technologies	Electrolyser & solar PV	Electrolyser & offshore wind	Electrolyser & electricity from regional decarbonised power mix	SMR + CCS & 'sustainable' biomethane	Methane pyrolysis with CCU & 'sustainable' biomethane
Costs – 2050 (Note: HHV used for conversion)	0.6-1.7 EUR/kgH2 14-42 EUR/MWh	1.4-2.1 EUR/ kgH2 36-53 EUR/MWh	1.2-2.7 EUR/ kgH2 31-68 EUR/MWh	2.4-4.3 EUR/kgH2 60-101 EUR/MWh	1.7-2.8 EUR/kgH2 44-72 EUR/MWh
Cost driver 1	Electricity price 4-20 EUR/MWh	Electricity price 30-40 EUR/MWh	Electricity price 28-62 EUR/MWh	Biomethane price 30-60 EUR/MWh	Biomethane price 30-60 EUR/MWh
Cost driver 2	Efficiency- LHV 74-76%			Efficiency-LHV 69-70%	Efficiency – LHV 55%
Cost driver 3	Full load hour factor 16%-40%	Full load hour factor 45%-60%	Full load hour factor 90%-99%	Overnight CAPEX 1088 EUR/kW-H2	Costs reduction (selling by-product solid carbon) 0.25-0 EUR/kg solid carbon
Cost driver 4	Electrolyser CAPEX 68-110 EUR/kWel			CO_2 transport & storage cost 17-55 EUR/tCO_2	CAPEX 1261 EUR/kW-H2

JEAN-MARC JANCOVICI

President - The Shift Project

MATTHIEU AUZANNEAU

Director - The Shift Project

Hydrogen will not be the new oil of the XXI century

For the fourth time over the last fifty years, hydrogen is in the spotlight. However, this time, things have seemingly changed: with the Green Deal, the EU is committing to reach carbon neutrality by 2050. The clock is ticking. And energy, as the backbone of our entire economy, representing 75% of EU GHG emissions, is undeniably the field requiring most efforts.

In this context, hydrogen is praised by EU institutions and Member States as tomorrow's "green" energy. In July, the EU announced plans to produce 10 million tonnes of renewable hydrogen by 2030 as a kick-off for the sector, and to invest up to €470bn by 2050. Its advantages are numerous: it is energy-dense, versatile and does not emit CO_2 when used, only water! Hydrogen appears therefore as a credible competitor to reduce our dependence on fossil fuels (70% of EU's energy consumption), especially for sectors where electrification seems compromised.

Though the hype over hydrogen is strong, it is not new. Against this renewed praise, it is important to recall that, despite how promising hydrogen may be, it is still governed by physical laws, and therefore has structural limits. If those constraints are not well anticipated, they will hamper hydrogen's potential, wasting precious time and energy to reach carbon neutrality.

Inherent limits of low-carbon hydrogen as an energy carrier

Hydrogen is not an energy source *per se*, but an energy carrier: it needs to be produced before being consumed. Here lies today's real challenge. In order to be low-carbon under life cycle analyses, it must be produced by electrolysers with low-carbon electricity (wind, nuclear, hydro…). This process requires a lot of electricity and expensive infrastructures, making production costs on average several times higher compared to its fossil alternatives. Unsurprisingly, being cheaper, fossil-based production accounts for 95% of hydrogen produced today.

Of course, mass production will inevitably lower production costs in the future. However, for physical reasons, they will remain higher than the fossil energies we have been appreciating for decades. Fossil fuels enjoy high energy volume density, are easily stored and transportable and the resource itself is free: you only have to get it out, refine it and deliver it. On the other hand, producing, compressing and transporting low-carbon hydrogen induce severe energy losses (40-50% of the overall energy initially used). Even if there is public aid and mechanisms to improve its competitiveness (an increased CO_2 price or a Carbon Border Adjustment Mechanism), shifting towards hydrogen will be at a higher collective cost than today's fossil-based energy mix.

The limits of our electricity system for low-carbon hydrogen

Being very energy-intensive with limited energy-efficiency progress expectations, mass production of low-carbon hydrogen will require even higher mass production of electricity. However, the European electricity networks are already under strong pressure and their operators have been warning about growing risks of blackout. Pulsed by EU policies, the increasing inclusion of intermittent renewables with small load factors and the closure of dispatchable power plants are expected to further contribute to this trend. The coherence and compatibility of those two energy strategies may then raise questions.

Examples offer a better idea of the order of magnitude involved: producing one million tonnes of hydrogen (MtH2) – the amount France already consumes annually – through electrolysis would require the equivalent of 9,000 to 11,000 wind turbines of 3 MW, or 5-6 EPRs. The EU aims at producing 10 MtH2 by 2030… over a decade where electricity needs are expected to increase significantly, due to the energy transition and the decarbonisation of other sectors and activities (e.g. the rise of electric vehicles).

Rapidly, we see the holistic limit of a "full hydrogen economy" praised by some. Hydrogen is essential but with a limited potential, and therefore requires targeted uses. Countries with a carbon-intensive power mix should focus on decarbonising their electricity first, before considering initiating the production of hydrogen. For those with a low-carbon mix, focus should be put on decarbonising the 9.8 MtH2 Europe consumes annually, predominantly in chemicals and industry. Alongside heavy mobility, these activities cannot be directly electrified. Low-carbon hydrogen should be dedicated to those first, before planning to multiply production within the next thirty years thanks to renewable energies alone.

Low-carbon hydrogen: use with caution

Tomorrow's hydrogen already has to navigate through a double constraint: being economically competitive and environment-friendly. Its potential has to be realistically assessed, without overestimating it nor neglecting its necessity. Hydrogen will remain a "luxury" energy vector due to its structural limits. To increase its competitiveness, electrolysers will have to operate with high load factors. Hence, the future of hydrogen in Europe also relies on the dispatchable low-carbon power capacities available.

From a strategic autonomy perspective, it is fundamental that a European industrial sector emerges to not repeat the solar panels' scenario. The industrial supply chains must then be secured. Otherwise, our dependency will shift to other mineral resources, technologies or equipment (like imported electrolysers), but our vulnerabilities will remain.

In any case, believing that hydrogen will enable us to maintain our current levels of production and consumption, while meeting our climate targets, is a myth. And it would be a severe political mistake. Today's society has to navigate through a tougher double constraint: the irreversible growing consequences of climate change and the upcoming scarcity of fossil resources. To face it, reducing energy consumption is inevitable. "*When?*" will only depend on whether we are prepared to do it willingly, or not.

The European Investment Bank

SUSTAINABLE INVESTMENT FOR CLIMATE AND ENVIRONMENT

Aligned with the **Paris Agreement** by the end of 2020

50% of our new commitments go to climate and environmental goals by 2025

€1 trillion of climate and environmental investment by 2030

© Shutterstock

The European Investment Bank is the European Union's bank and the world's biggest multilateral lender. From small businesses to massive infrastructure projects, we back sustainable investments.

www.eib.org/climate

European Investment Bank *The EU bank*