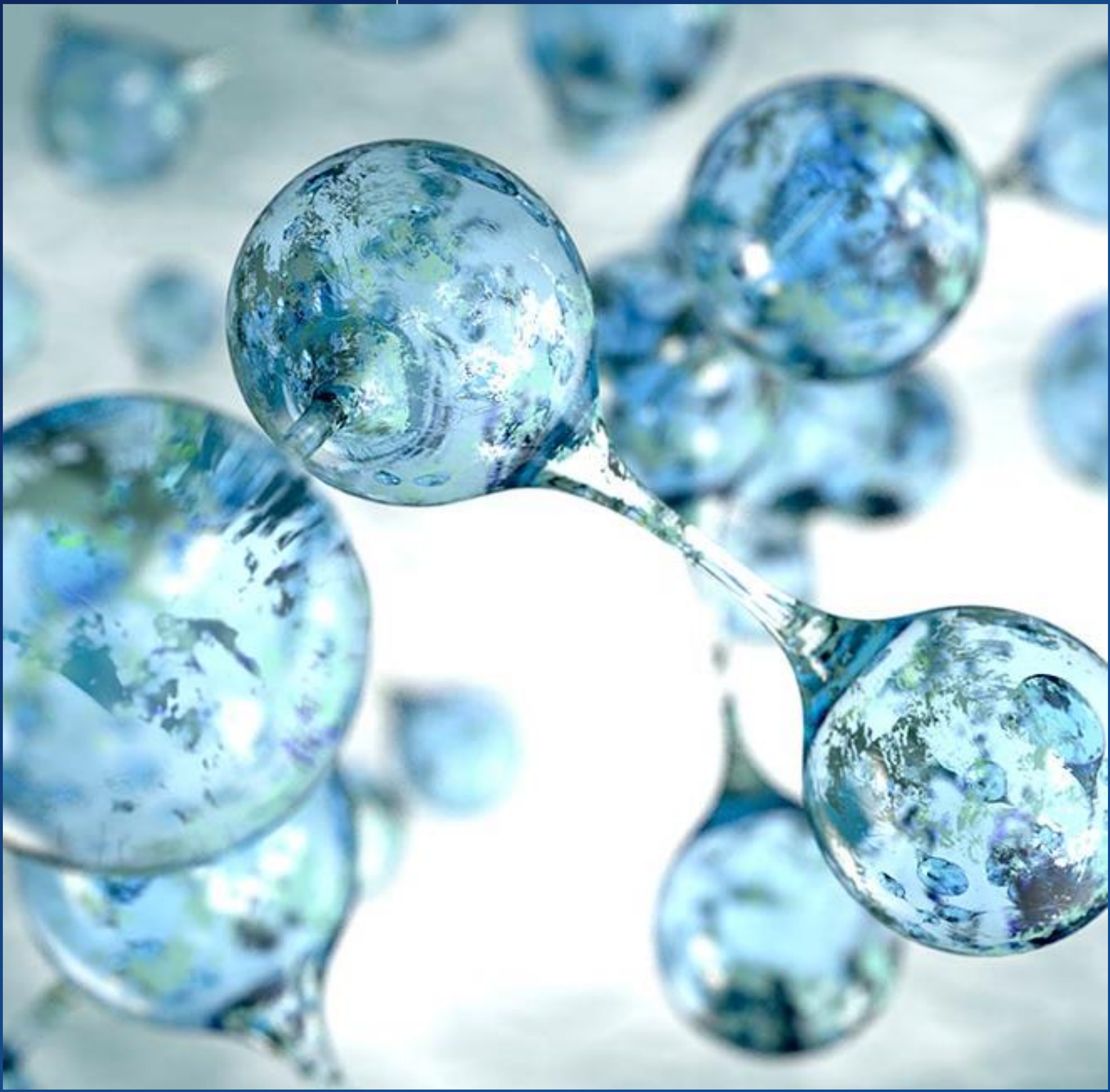
Crédit Mutuel
Asset Management

HYDROGEN
THE NEW FRONTIER FOR SUSTAINABLE DEVELOPMENT



07/09/2021

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INTRODUCTION

INTRODUCTION

The time for taking stock is over. We now have a duty to play an active role in making finance both responsible and sustainable: a duty to support the energy transition by investing in the companies contributing to it throughout the value chain.

Meeting the energy transition challenge will, first and foremost, mean being receptive to and offering an informed opinion on every opportunity we come across in relation to innovation and new technology.

Hydrogen has been clearly identified as one of the key criteria for achieving carbon neutrality and greater European sovereignty over its energy transition.

Despite the many obstacles ahead, this infinite and intangible – yet powerful – form of energy is helping and supporting the various market stakeholders. All players have their sights set on the ambitious goal of achieving carbon neutrality by 2050 as well as transitioning Europe's energy system through the widescale use of hydrogen.

If we think of 2050 as a long way off, it is all too easy to adopt a wait-and-see approach. In reality, the scale of the task necessitates a more dynamic reading of the situation: the time for action is already upon us. We would like to take the opportunity, in this brief introduction, to refer to an article published by the EU [Research*eu #94 July 2020 – Special feature, pages 1-12] – entirely dedicated to the theme of hydrogen – with a title that speaks volumes: ***"Unlocking the potential of the most common element in the universe"***. The feature opens with the following powerful phrase: "The notion of using hydrogen as a means to power everything from factories to your car may sound a bit futuristic but actually it has been around since the dawn of the Industrial Revolution [...] ".

With that in mind, we will be turning our attention to specific advances in relation to hydrogen that successfully combine technological progress (in understanding the underlying processes and procedures behind hydrogen production) and economic considerations. National and supranational subsidies have a key role to play. Private investment is contributing to the development of a financial ecosystem favourable to the dominance of green hydrogen and large-scale use of renewable energy.

To conclude, the contents of this document are factual and informative. The aim is to propose a common thread that could indicate a direction of travel for collective, inclusive action on the part of all market players – without exception – so as to turn the situation around.

Green hydrogen is emerging as an essential research topic where the outcomes appear particularly promising.

NOTES

1. https://ec.europa.eu/clima/policies/strategies/2050_fr

2. https://op.europa.eu/en/publication-detail/-/publication/a151cf78-bf30-11ea-901b-01aa75ed71a1/

3. https://cordis.europa.eu/article/id/421533-hydrogens-growing-role-in-sustainable-energy-systems/fr

DECARBONISING HYDROGEN: ISSUES AND TECHNICAL ASPECTS

Crédit Mutuel Asset Management

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DECARBONISING HYDROGEN: ISSUES AND TECHNICAL ASPECTS

BACKGROUND

Europe has committed to achieving carbon neutrality by 2050. Alongside renewable energy, energy efficiency and battery-powered vehicles, hydrogen represents a strategic solution for the transition to a decarbonised economy.

This objective constitutes both a shared ethical and ideological stance and the specific pathway the European Union sought to put forward in its 2030-2050 action plan. However, there is a long road ahead of us if we are to achieve this ambitious goal.

For evidence of this, we need only consider how limited hydrogen production is at present: just 50 megatons per year (Mt/year) were produced in 2020, equating to just 1.5% of worldwide energy needs.

Moreover, hydrogen (H_2) production is still a source of pollution, with 96% of the hydrogen produced being derived from fossil fuels. Through a reforming process, natural gas (grey H_2), coal (black H_2) or lignite (brown H_2) is exposed to water vapour heated to an extremely high temperature, so as to release hydrogen, along with CO_2.

Unfortunately, this process has an immense environmental impact if we do not succeed in capturing the resulting carbon dioxide emissions (blue H_2).

THE NEXT FRONTIER

Hence, one of the solutions to speed up the process of transitioning to an economy based around green energy is already technically possible. It entails (i) increasing the amount of hydrogen produced using green processes and (ii) increasing consumption of decarbonised hydrogen, which can be used in a wide array of applications to meet the world's energy needs.

Increasing sustainable production: yellow and green hydrogen

How can we make large-scale hydrogen production more environmentally friendly?

Fundamentally, the answer is by using electrolysis: a process whereby an electrical current is used to heat water to an extremely high temperature. This causes the water to break down into oxygen and hydrogen, with no CO_2 emitted as a by-product.

Hydrogen produced using electricity from a renewable energy source is known as green hydrogen (green H_2). It is conceivable that an alternative source – nuclear energy – could be used to produce yellow hydrogen, which would also be free of CO_2 emissions. However, the question of whether nuclear energy can be classed as sustainable has not yet been settled.

Only 4% of the world's hydrogen is produced through electrolysis at present and of this 4% only 1% is produced using renewable energy sources.

The reasons for this poor environmental performance are fundamentally rooted in economics. We will be exploring this crucial point later in this document with our expert Emmanuel Rétif, who is a senior environmental, social and governance research analyst within the Responsible and Sustainable Finance division of Crédit Mutuel Asset Management.

The many applications of green hydrogen

A key benefit of using hydrogen, especially with intermittent renewable energy sources, is the fact that it has far greater storage capacity than batteries. It is a case of 1 gigawatt (GW) for hydrogen versus just 100-200 megawatts (MW) for batteries.

Plus, producing greater volumes of decarbonised hydrogen will open up multiple applications in the value chain and in everyday life.

Primary examples of these new applications, which could reduce the carbon footprint of our economies, making them greener and more sustainable, are as follows:

- **Power-to-Industry**: replacing carbon-intensive grey hydrogen with green hydrogen in industries that use it in their production processes (ammonia sector, refining, etc.).
- **Power-to-Gas**: injecting green hydrogen into the gas grids instead of natural gas.
- **Power-to-Power**: converting green hydrogen into electricity using a fuel cell.
- **Power-to-Mobility**: using green hydrogen to fuel electric vehicles by converting it into electricity within the vehicle using a fuel cell.

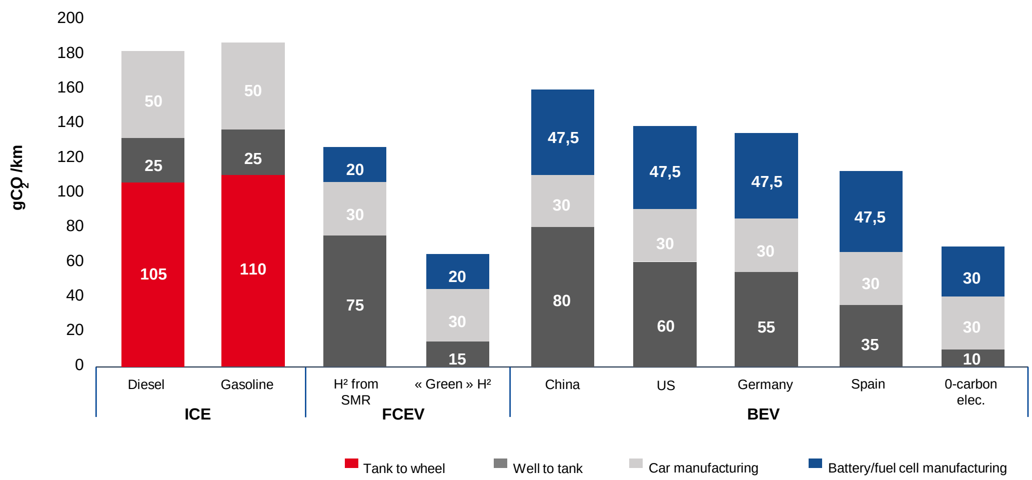
We will be diving deeper into the practical aspects of the above concepts in our interview with our expert Emmanuel Rétif in the next section.

It is worth stating at this stage, however, that of all the potential applications for decarbonised hydrogen, mobility could be the area in which it has the greatest impact on our goal of making the European economy carbon-neutral by 2050.

As a matter of fact, given that the transport sector represents between 25% and 30% of Europe's CO_2 emissions, the challenge will be to increase the use of electric vehicles powered by green hydrogen (FCEV – fuel cell electric vehicles) and BEV (battery electric vehicles).

The image below shows that the carbon impact of an electric vehicle is better than that of a vehicle with an internal combustion engine (ICE), which is hardly surprising. Conversely, it is interesting to note that the carbon impact of battery-powered vehicles is heavily dependent on the country in which they are driven. Overall, it is clear that hydrogen-powered electric vehicles have the lowest carbon footprint.

Vehicle lifecycle – FCEVs are the least carbon-intensive vehicles



SOURCE
Hydrogen Council, ODDO BHF Securities

Nevertheless, the fact that these vehicles are not competitively priced compared with BEVs continues to prevent a significant increase in demand for green FCEVs.

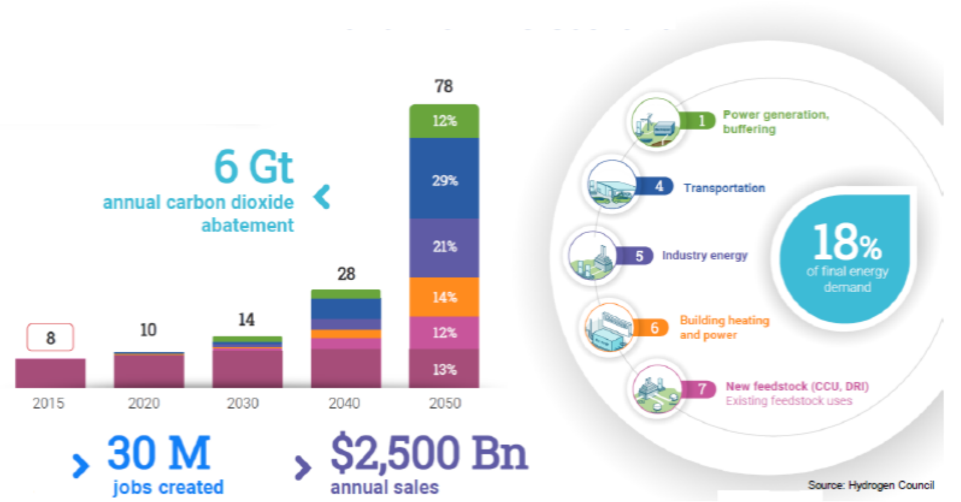
The price of a hydrogen-powered SUV, for example, is around €68,000 including tax, and that of a hydrogen-powered Renault Kangoo is around €48,000 excluding tax. This is over double the sale price of a battery-powered electric Renault Kangoo, which retails for around €23,000 excluding tax.

And yet hydrogen-powered vehicles should become competitive within the next decade thanks to plausible economies of scale on this promising market in terms of the cost of the tank, the fuel cell and the production of green hydrogen.

We therefore believe that we are at the starting point of a virtuous circle that will ensure a green transition by 2050, in the context of a high-impact scenario, in part thanks to constantly growing demand for hydrogen. We expect to see a 40% rise in demand over the next decade; this volume should double between 2030 and 2040 and, in all likelihood, almost triple between 2040 and 2050.

Although hydrogen accounts for under 2% of total worldwide energy demand in 2020, this is projected to rise to 18% by 2050, which would allow for 6 billion tonnes of CO_2 emissions to be avoided per year for planet Earth – 17% of the target set by the Paris Agreement.

Hydrogen consumption in 2050 in a +2°C scenario



SOURCE
Hydrogen Council,

L'INTERVIEW: A WORD FROM OUR EXPERT EMMANUEL RÉTIF

Crédit Mutuel Asset Management

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INTERVIEW : a word from our expert Emmanuel Rétif

What do you think of the EU's current energy supply, especially as regards the "green" positioning it has adopted? How is Europe's energy supplied at present?

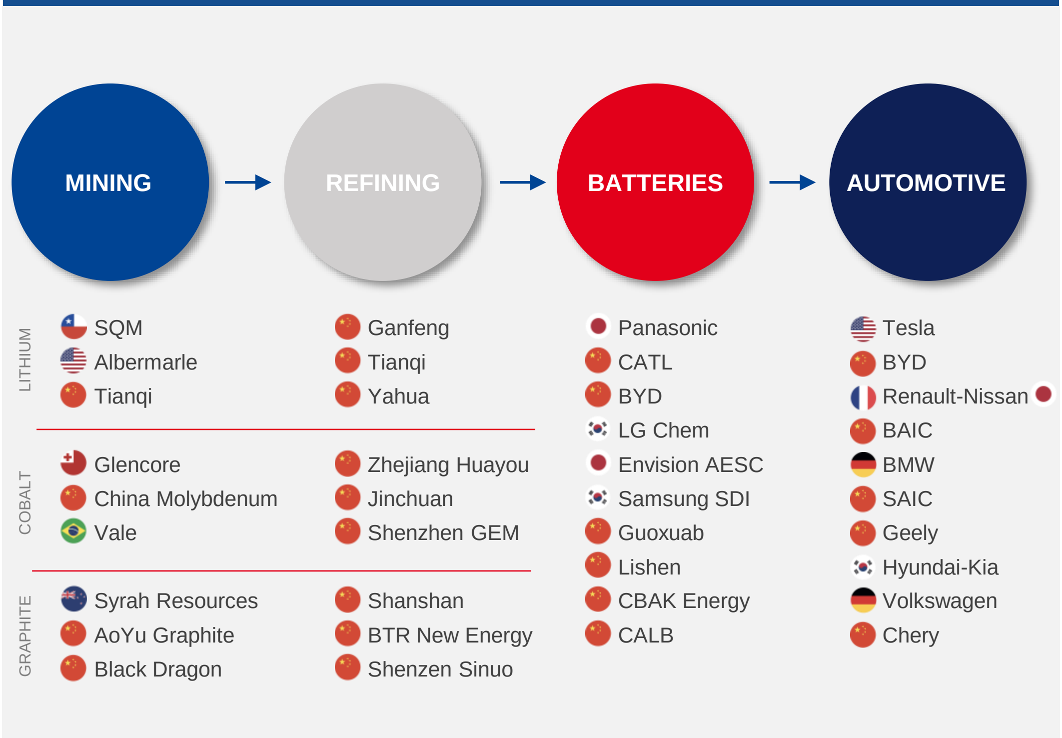
At a geopolitical level, do you think that greater use of hydrogen could help Europe become more "independent" as regards its energy transition?

Hydrogen has geopolitical and economic dimensions. As far as the supply of hydrocarbons is concerned, Europe has been reliant on the Middle East and Russia for a number of decades. This is the case for transport, electricity generation, residential heating and energy demand from industry.

With that fact in mind, digging a little deeper, Europe is now dependent on China for its energy transition and CO_2 emissions-free transport in particular. Specifically, over 70% of the batteries produced worldwide come from China. This is already a significant amount in itself, but if we add Japan and Korea, we find that Asia accounts for 95% of global production. The table below speaks volumes.

China continues to dominate when it comes to refining the strategic ores required to manufacture batteries, including lithium, cobalt and graphite. It is therefore an objective fact that we are not independent in terms of supply for our energy transition.

Batteries – Value chain

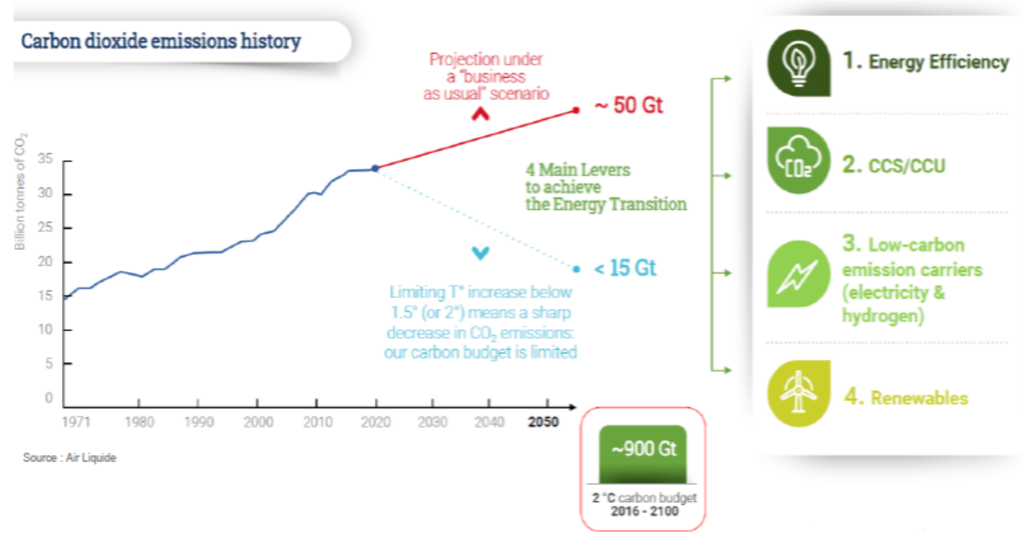


GRAPH
G. Albasini

As a result of the “dependency framework” outlined above, we are carefully considering the alternative solutions that may be possible in future. Hydrogen is therefore one way in which Europe may be able to safeguard its sovereignty over its energy transition. More specifically, green hydrogen could make a significant contribution to the goal of achieving carbon neutrality by 2050. In Europe, around 17% of the reduction in CO_2 emissions required to reach this target could come from green hydrogen.

The Paris Accords imply that we will have to avoid emitting 35 billion tonnes of CO_2 per year globally. Green hydrogen is therefore one of the four main strategies for achieving this goal (see graph below).

Carbon dioxide emissions timeline



Moreover, it represents an opportunity to develop a green technology on European soil and potentially trigger a powerful social driver at the same time that could create 30 million jobs worldwide by 2050.

Reducing the continent’s “energy dependency” is not an insignificant economic issue: hydrogen will play a central role in avoiding – or at least limiting – the risk of a bottleneck in the European energy transition. At this point, it is worth bearing in mind that China has set itself the goal of achieving carbon neutrality by 2060. And China currently accounts for around a third of the world’s CO_2 emissions. There is therefore a real risk that China could limit exports of batteries and processed ores in order to meet its own investment needs. In a situation such as the one described, green hydrogen once again emerges as a powerful complementary tool – and occasionally a replacement – for Chinese batteries, especially for transport.

Using green hydrogen addresses a high-priority goal set out in the EU's action plan to transition to a carbon-neutral economy by 2050. At a practical level, how do you see hydrogen being put to use in real-world applications in the near future?

To a certain extent, green hydrogen could be compared to a sort of energy transition Swiss army knife. This analogy may seem like a bit of a stretch, but looking closely it is clear that there are a wide array of possible applications. Four in particular stand out:

1. The first application is selling hydrogen to industries such as ammonia production and refining. The difference would be that instead of consuming grey hydrogen, which emits CO_2, these industries would be supplied with green hydrogen, which does not emit CO_2: this is what we call "***power-to-industry***".

2. The second application is "***power-to-gas***": this is where green hydrogen is injected into the gas grids instead of natural gas. For technical reasons, the maximum amount of hydrogen that can be injected into the gas grids at present is 20% of supply. However, there is an option known as "methanation". This is a process that involves mixing carbon and hydrogen to convert them into methane, which can then be freely injected into the gas grids without the 20% cap.

3. Thirdly, there is "***power-to-power***": this application is appealing because it could address the issue of intermittency within renewable energy. For example, one problem with renewable energy is that reduced sunlight in winter adversely affects solar energy production just when the need for heating is particularly high. Conversely, abundant sunlight in the summer months allows us to produce considerable amounts of solar energy at a time when little heating is required. The advantage of hydrogen is the ability to make use of the excess renewable energy produced during the summer, for example. How does that happen? Without going into all the technical details, at its most basic, the concept entails using this surplus solar electricity to make green hydrogen through electrolysis; the hydrogen is stored, and then turned into electricity as and when it is needed with a fuel cell.

4. The final application, and the one that will probably be most important for the general public when it comes to hydrogen is "***power-to-mobility***": in other words, electricity-based transport, including electric vehicles in particular, running on hydrogen. In these vehicles, the driver fills up with hydrogen and a fuel cell turns this hydrogen into electricity which, in turn, powers the electric engine. This is therefore a very important application because transport accounts for around 25–30% of CO_2 emissions in Europe. As such, it is clear that we need to very substantially decarbonise transport if we are to achieve the goal of zero carbon in 2050. Among existing technologies, the vehicles with the smallest carbon footprint are electric vehicles powered with green hydrogen. These come in ahead of battery-powered vehicles, whose carbon impact depends on the energy mix in the country where the battery is charged. A battery charged up in China, where electricity production is heavily dependent on coal-fired power stations, therefore "indirectly" emits a lot more CO_2 than a battery charged up in France, where fossil fuels emitting CO_2 only account for 8% of the electricity produced.

At present, there are very few electrolysers and they are still very expensive. Hence Europe's project to invest €40 billion in building electrolysers with a capacity of 40 GW between now and 2030 and simultaneously promoting an increase in renewable energy capacity. Other technology can be used to produce decarbonised hydrogen, such as biomass.

In short, we are currently in a transition period during which the hydrogen ecosystem is being set up.

If you had to, how would you rank the four applications above?

1. I would put ***power-to-mobility*** first because, of all the applications for hydrogen, this is likely to make the largest contribution to the target of reducing CO_2 emissions by 2050 in Europe.

2. ***Power-to-industry*** would take second place. Industry players are currently the main users of carbon-intensive grey hydrogen, so they could constitute a major market for green hydrogen.

3. In third place would be ***power-to-gas***. This is an appealing solution in that it would enable us to gradually reduce our use of carbon-intensive natural gas, which still makes up the majority of the gas grid.

4. And, to conclude, I would rank ***power-to-power*** as more marginal than the other solutions discussed previously.

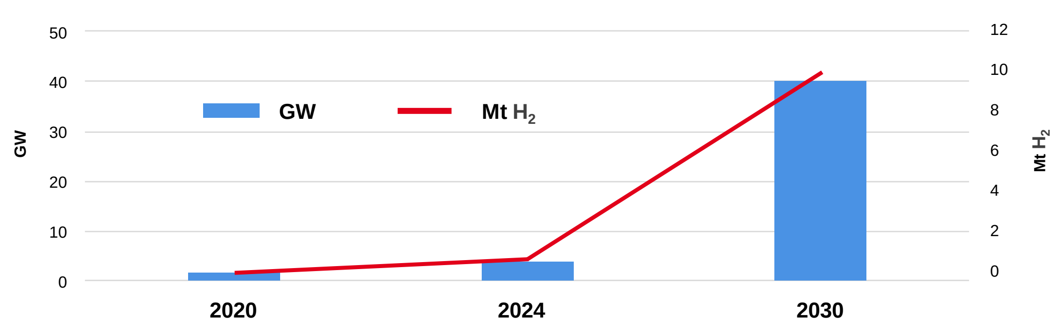
That's very interesting. However, we've noticed that hydrogen is still too expensive (both to produce and to use). Do you think that there are solutions to this issue?

There are definitely solutions that will lower upstream costs, i.e. those associated with hydrogen production, as well as savings that can be made downstream in relation to applications.

Let's start with upstream costs: right now, green hydrogen is not competitive. It costs around €6 per kilo to produce in 2020, whereas "grey" hydrogen with CO_2 emissions is produced for just under €2 per kilo.

So, how can we make hydrogen production less expensive? Economies of scale can be made in relation to electrolysers, especially given the EU's decision to finance electrolysers with a capacity of 40 GW between now and 2030. It is to be hoped that economies of scale will bring down the cost of investing in electrolysers. Reducing the per-MW cost of investing in renewable energy is a virtuous circle that will, through a rapid expansion of European capacity, allow us to pre-empt a fall in the cost of renewable electricity (the main expense in green hydrogen production). In parallel, the cost of producing grey (i.e. carbon-intensive) hydrogen should skyrocket in the coming years as the price of the CO_2 certificate rises.

A goal of 40 GW by 2030 versus 1 GW today



SOURCE
JPMorgan

ON THE GROUND: HAFFNER ENERGY

Crédit Mutuel Asset Management

07/09/2021

Interview with Philippe Haffner (left)
CEO of Haffner energy

Pictured with his brother
Marc Haffner (right),
co-founder and co-director

Technology – what does your green hydrogen production process entail and how does it achieve carbon neutrality?

The Hynoca process, which has now been brought to market, entails producing green hydrogen from biomass. Biomass is derived from organic material from vegetable or animal sources. Hynoca is designed to run on vegetable biomass of all kinds, as well as effluents from the rearing of livestock. France produces enough biomass to generate 1,000 TWh of electricity per year – double the country's annual electricity output – yet it all goes to waste.

Hynoca is very similar to steam reforming processes used with fossil fuels (carbon-intensive grey hydrogen). Such processes account for over 97% of the hydrogen produced worldwide, mostly through SMR (steam methane reforming). Hynoca is what is known as an SBR (steam biomass reforming) process. All fossil fuels are ultimately derived from biomass. The first phase in the Hynoca process is thermolysis, which allows us to replicate a natural process lasting millions of years in a matter of minutes. Hynoca therefore enables conventional, tried-and-tested technologies to be used downstream from the thermolysis process.

It is carbon neutral because the vegetable biomass is produced through photosynthesis within plants, which absorbs CO_2 from the atmosphere. Any CO_2 released through Hynoca is neutral (biogenic) because it equates to the CO_2 that was previously absorbed. However, Hynoca can also be used to sequester CO_2 and produce biochar, which is a carbon sink. Where this occurs, the process is not just carbon neutral – it's actually carbon negative.

Competitiveness – how do your costs at factory-level compare with those of carbon-intensive grey hydrogen (around €2/kg) and with the price of diesel at the pump? Are they competitive? If not, when do you expect to achieve this on both fronts?

The most price-competitive hydrogen produced through Hynoca will be intended for the industrial sector. This is primarily a question of linking up Hynoca with existing SMRs so as to significantly reduce the SMRs' CO_2 emissions.

For a Hynoca plant with a capacity of over 24 tonnes of hydrogen per day, the target of €2 per kg will be achieved in 2023.

For applications within the transport sector, it will be possible to get to €5 per kg of hydrogen at the pump in 2023, and €3 in 2025 (1 kg equates to 100 km of range). Hydrogen will then be competitively priced versus tax-free diesel.

The main reason behind this competitiveness is the very low cost of biomass, coupled with energy efficiency of over 70%.

Opportunities – your hydrogen facility in Strasbourg will be operational in 2021. What opportunities/usages will it offer? More broadly, how big is your potential market and what are the main opportunities?

Hynoca will have the potential to serve three segments of the hydrogen market: industry, mobility and injecting hydrogen into the gas grids. The Hynoca range will have a capacity from 200 kg of hydrogen per day up to 30 tonnes per day for industrial applications.

According to a market study carried out by EY/Element Energy, Hynoca's addressable market represents aggregate output of 11.9 Mt per year in 2025 and 20 Mt per year in 2030.

Hynoca's competitiveness, and its energy and climate efficiency, should enable it to gain a very substantial share of this addressable market. To finance the very strong growth we are expecting and position ourselves as a leader, Haffner Energy is actively preparing for an IPO.

CONCLUSION: THE CHALLENGES AND ABOVE ALL OPPORTUNITIES OF HYDROGEN

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CONCLUSION: the challenges and above all opportunities of hydrogen

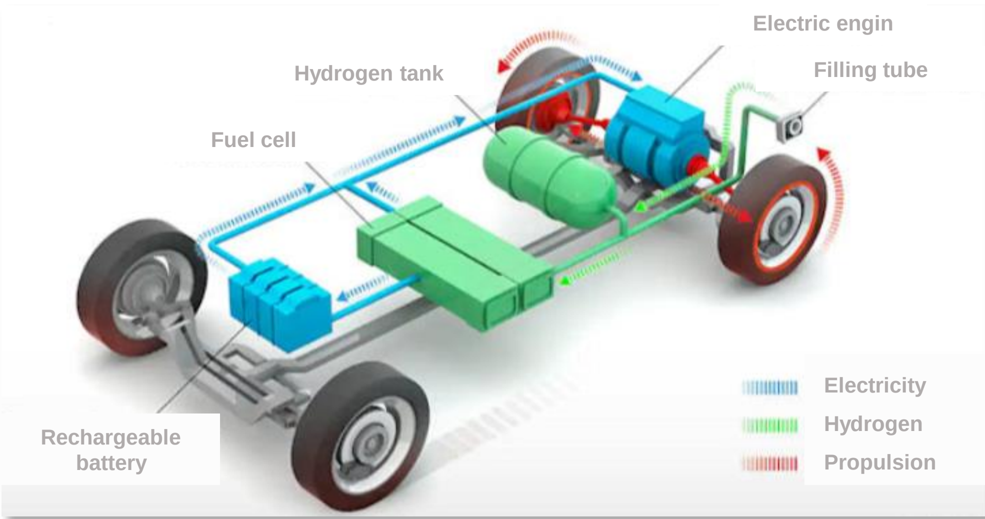
In the preceding pages we have set out the framework of our vision for green hydrogen, its production chain, its value chain and its real-world applications. All of these themes are of paramount importance if we are to effectively manage this essential paradigm shift. We could easily have filled entire pages with related data, analysis and projections. Instead, we have tried to explain – humbly and as clearly as possible – our viewpoint and the key issues surrounding the growth of this new ecosystem.

At this point, the question is how we close this white paper with a proposal for the types of concrete action we see as a priority for this decade, so that we are putting forward not just food for thought but also, and above all, an action plan.

To answer this conundrum, we would like to raise three key points that shine a spotlight on the challenges and opportunities ahead. When we assess the limiting factors that continue to hinder the momentum of the new hydrogen value chain, we observe that they constitute industrial, economic and financial challenges. If these are met, business and investment opportunities will flourish, laying the foundations for an entire ecosystem.

1. The first key element is a reduction in costs. This is essential because the hydrogen ecosystem simply will not get off the ground unless costs fall. Indeed, the sector is not economically competitive as of yet, as we explained in the technical section.

   If we take the example of a hydrogen-powered vehicle (see image below), production costs are very high because of the carbon-fibre tank needed to withstand pressure of 700 bars from the fuel cell, which turns hydrogen into electricity in the vehicle.

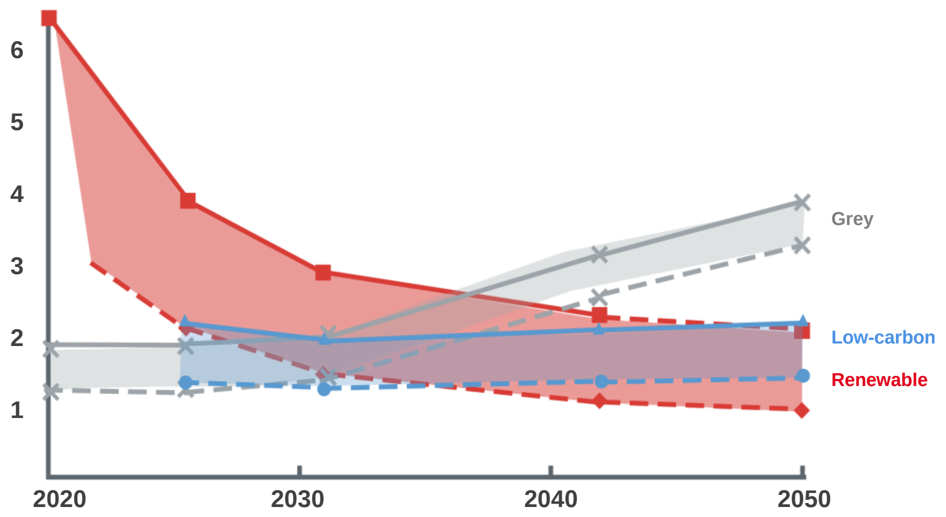


SOURCE
BMW

If we add to this the fact that there is very little hydrogen availability in the fuel distribution network, it is unsurprising that hydrogen vehicles are practically non-existent on the transport market.

Nevertheless, worldwide demand for hydrogen vehicles is expected to grow strongly between now and 2030, with 10 to 15 million new cars registered, equating to market share of around 11%, versus under 10,000 in 2019. This exciting prospect assumes a massive inflow of investment, driving substantial economies of scale. Hence, the starting point – the key challenge to meet upstream of the ecosystem – is driving down green hydrogen production costs, as shown in the graph below ("Renewable"), especially in relation to carbon-intensive hydrogen ("Grey").

Reducing costs throughout the value chain



SOURCE
Hydrogen Council,

2 Secondly, we also need private investment, through industrial players, asset management and bank financing, to take over from public-sector investment in the production of electrolysers. Electrolysis of water is a key technology for green hydrogen production. Electrolysers are expensive to make because they are still mostly manufactured in small batches. It is important that large-scale European investment occurs, especially given that China has been determined to develop hydrogen (and hence manufacture electrolysers) ever since it announced its goal of reaching net zero greenhouse gas (GHG) emissions by 2060. If Europe hopes to avoid finding itself just as dependent on Chinese hydrogen as it is on Chinese batteries, and instead plans to reshore some industrial processes and energy transition jobs, it is vital that electrolyser production be expanded rapidly. The EU's investment budget of €40 billion by 2030 will not suffice, alone, to meet this challenge.

3 The third point is investing in renewable energy. The EU's goal of net zero emissions by 2050 implies an 80–95% reduction in GHGs. With this in mind, renewable energy will be key to decarbonising electricity generation as well as hydrogen and its ecosystem, as we have seen in this white paper. To achieve its green hydrogen production goals, the EU will invest in electrolysers fuelled by renewable forms of energy that do not emit CO_2. The EU's climate plan already contains highly ambitious targets to increase the weighting of renewable energy in the European electricity production landscape; this trend must be further strengthened to reflect the demand for green energy from electrolysers. All the same, we have a few doubts about the most fundamental question: will we have built enough new renewable electricity capacity by 2030 to achieve the EU's goal of producing 10 Mt of green hydrogen in 2030, versus practically 0 in 2019? In short, the question of the pace at which new renewable energy production capacities can be developed is at the heart of the decarbonisation of hydrogen and the emergence of a new green sector. This is a challenge but also an opportunity for Europe to use green hydrogen to develop new applications with a view to achieving net zero CO_2 emissions in 2050.

IN CONCLUSION…

In this document, we have outlined topics for further reflection as well as the essential, tangible conditions that must be met if green hydrogen is to be rolled out throughout the value chain, from production to end uses.

While we firmly believe in the benefits of the new decarbonised hydrogen sector and its wide array of applications, green hydrogen from renewable energy is not the only technology to be developed.

Blue hydrogen, for example, is likely to be a complementary solution, especially in countries that still derive most of their electricity through thermal production based on fossil fuels (including China and the US). CCS (carbon capture and storage) and CCU (carbon capture and utilisation) technology allows for CO_2 emissions from thermal power plants to be captured and stored so that they do not end up in the atmosphere. This promising process will also contribute to the goals of the Paris Agreement. We have only touched on it briefly in this white paper; analysing it would take another entire white paper.