Julien Lafargue, CFA, London UK, Head of Equity Strategy;
Gerald Moser, CFA, London UK, Chief Investment Strategist

Hydrogen energy: the fuel of the future?

With the effects of climate change seemingly accelerating, the latest in our "See Beyond: thematic investing" series, introduced in August, focuses on the sustainable world thematic and the carbon aspect of it. This fits in with the initial report, which identified four structural, long-term themes changing society meaningfully: 1) Globalisation reversion; 2) Demographic shifts; 3) Smart everything; 4) Building a sustainable world.

CO_2 emissions may need to fall by 8-10% every year for the next decade for the warming in average global temperatures to be less than 1.5 degrees, according to last November's United Nations Environment Report. In the fight against global warming, a new potential solution has grabbed the headlines in the last few months: hydrogen (H_2).

At face value, the first element in the periodic table offers many advantages and could represent a credible alternative to fossil fuels in lowering carbon emissions, posing significant threats but also creating opportunities across industries. However, strong policy support will be indispensable to get there.

The basics

H_2 isn't new. The element has been around for more than 13bn years and is the most common substance in the universe. It is also the richest energy source for stars like the sun. Indeed, hydrogen has the highest energy content of any common fuel by weight.

Hydrogen is a high energy, low polluting fuel that can be used for transportation, heating and power generation. NASA has used liquid hydrogen since the 1970s to propel the space shuttle and other rockets into orbit while hydrogen fuel cells power the shuttle's electrical systems, producing a clean byproduct — pure water — for the crew to drink.

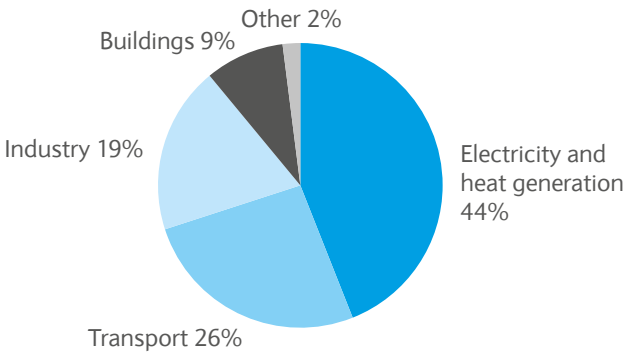
Although H_2 is thought to comprise 90% of the visible universe[1], it rarely exists on its own. Since it forms covalent compounds with most non-metallic elements, most of the hydrogen on Earth exists in molecular forms such as water or organic compounds. As a result, hydrogen needs to be "extracted", a process than can require a significant amount of energy. Once extracted, hydrogen can be a carrier and store of energy.

How can hydrogen help reduce carbon emissions?

The green attributes (hydrogen's only direct emission when burnt is water) and versatility of the element make it an ideal candidate to reduce carbon emissions. With applications as a direct source of energy (say for fuel or heat) or as a feedstock into chemical or manufacturing processes, H_2 appears to be a feasible alternative to fossil fuels, which still represent 80% of the energy consumed today[2]. In particular, hydrogen could help clean "hard to abate" sectors such as steel, cement or aluminium production.

H_2 could also play a role in reducing emissions in transportation, a sector that represents around a quarter of current CO_2 emissions (see figure one). This is why the BloombergNEF (BNEF), a provider of primary research on clean energy, estimates that hydrogen could generate a quarter of our energy needs by 2050 compared with 4% at the moment.

Figure 1: Annual CO_2 emissions
The CO_2 emitted in electricity and heat generation, transport, industry, buildings and elsewhere



Sources: BNEF, Barclays Private Bank, October 2020

[1] The Science Times, 3 April 2017, https://www.sciencetimes.com/articles/11524/20170403/hydrogen-is-the-most-common-element-heres-the-reason-why.htm
[2] Fossil Fuels, Oxford Energy, 2020, https://www.energy.ox.ac.uk/research/fossil-fuels/

Why is it becoming more popular?

As the world struggles to control climate change and CO_2 emissions, the search for alternative sources of energy is accelerating. Renewables (solar, wind and hydro power) have made good progress in terms of both capacity and efficiency, driving down costs. This, together with technological improvements, is key for hydrogen to become a feasible source of energy.

As mentioned earlier, hydrogen is not a readily available energy source but an energy carrier. As hydrogen production requires the use of a primary energy source, the cost of hydrogen is always going to be higher than the cost of a primary source. Depending on the energy source used to produce hydrogen, the resulting hydrogen produced is defined according to a colour:

- Green hydrogen: H_2 generated from renewable sources
- Blue hydrogen: H_2 generated from natural gas with CO_2 emissions reduced thanks to carbon capture, utilisation and storage (CCUS)
- Grey hydrogen: H_2 generated from natural gas without CCUS
- Brown hydrogen: H_2 generated from fossil fuel without reduced emissions via the use of CCUS
- Black hydrogen: H_2 generated from coal.

Over 99% of the hydrogen produced today is made using fossil fuels, accounting for 6% of natural gas demand, 2% of coal globally, and consequently 2.2% of global carbon emissions[3]. In order for this fossil-powered hydrogen to turn green, it is imperative to use renewable sources of energy to extract H_2. This process, called electrolysis, takes place in an electrolyser and uses electricity to split water into hydrogen and oxygen.

Green hydrogen costs set to plunge

Green hydrogen typically costs between $2.50 and $4.50 a kilogram versus traditional carbon-intensive methods that can cost as little as $1 a kg[3]. The efficiency factor of green hydrogen, the energy produced compared with that used, is around 65% to 75% and acts as a drag on its use[4].

However, the cost of generating green hydrogen could fall by more than 60% in the next decade[5], aided by falling renewables prices, increasing policy support to better price carbon, ramping up of the private sector hydrogen investments and improving technology. In turn, this would make the element a credible source of energy.

Green H_2 also becomes competitive at times of negative power prices. The rising use of renewable energy results in more volatile power prices and it is likely that negative power prices – when the electricity supply exceeds demand – will happen more and more. In that case, hydrogen production from renewable energy is an attractive solution to store energy, especially as it can be stored for a long time compared to electricity.

Hydrogen can only be part of the solution

Despite all its advantages, hydrogen is not a panacea. Indeed, storing H_2 is a relatively inefficient process (two-thirds of the original electricity can be lost). In addition, the element is highly flammable and its low density means that, outside of a pipeline, it requires almost four times more transport capacity or needs to be transformed before being transported (compression, liquefaction or chemical components). This makes the overall production process pricier.

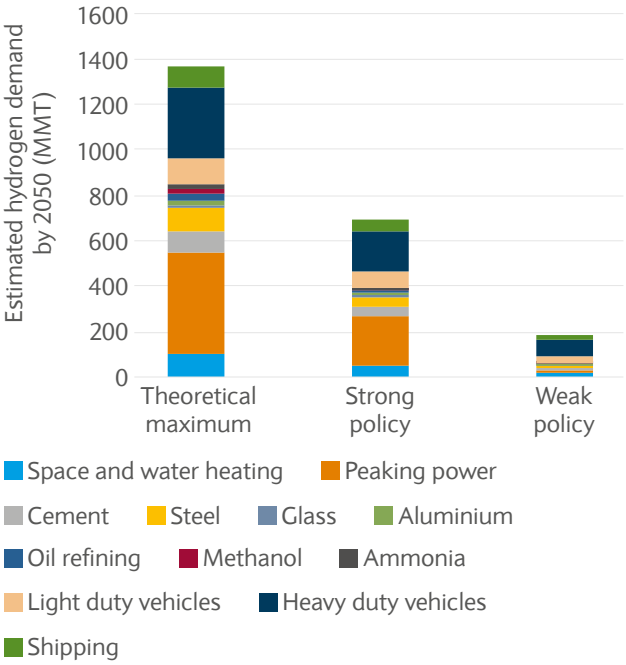
As such, hydrogen should be seen as a possible complement to other renewable sources of energy rather than a one-size-fits-all solution. H_2 is particularly relevant as an energy source for areas of the market that are difficult to electrify, such as industrial use or long-haul transport mobility.

Seizing the opportunity

Forecasting the potential growth of any market is usually more of an art than a science and hydrogen is no different. A lot depends on whether the strong political will to develop the industry continues.

If there is strong and comprehensive policy, the BNEF estimates that 696m metric tons (MMT) of hydrogen could be used a year by 2050, a six-fold increase on current levels, representing $700bn in annual sales (see figure two). This scenario would require over $11 trillion of investment in production storage and transport infrastructure. If, on the other hand, policy is piecemeal, then the consumption could rise more modestly to just 187MMT.

Figure 2: Potential hydrogen demand



Source: BloombergNEF, 2020
Note: Aluminium demand is for alumina production and aluminum recycling only. Cement demand is for process heat only. Oil refining demand is for hydrogen use only. Road transport and heating demand that is unlikely to be met by electrification only: assumed to be 50% of space and water heating, 25% of light-duty vehicles, 50% of medium-duty trucks, 30% of buses and 75% of heavy-duty trucks.

[3] Hydrogen Economy Outlook, BloombergNEF, 30 March 2020

[4] Carbon commentary, 5 July 2017, https://www.carboncommentary.com/blog/2017/7/5/hydrogen-made-by-the-electrolysis-of-water-is-now-cost-competitive-and-gives-us-another-building-block-for-the-low-carbon-economy

[5] Path to hydrogen competitiveness: a cost perspective, Hydrogen Council, January 2020

Country	Commitment	Announced
US	The US has shown increased support for hydrogen and fuel cell technologies each year, especially within the inclusion of many hydrogen provisions in a proposed $1.5 trillion infrastructure package.	
EU	The EU Hydrogen Strategy targets total investments of up to €400bn through 2030.	July 2020
Germany	As part of its €130bn economic stimulus package, €9bn was earmarked for the expansion of hydrogen production as part of a national hydrogen strategy.	June 2020
France	A third of France's €100bn coronavirus recovery package will be spent on green energy policies, with €7bn going towards the development of green hydrogen for the transport and the industrial sectors by 2030.	September 2020
UK	Although no details have been given, the prime minister has committed to "invest massively in hydrogen".	Summer 2020
China	As many as 12 state-owned companies are actively laying out their hydrogen plans as President Xi Jinping committed China to be carbon neutral by 2060.	Summer 2020
Australia	The Australian minister for energy and emissions reductions created the "Advancing Hydrogen Fund" that offers A$300m to finance hydrogen projects.	May 2020

The current state of play

Encouragingly, hydrogen energy could benefit from the COVID-19 pandemic to some degree. Indeed, as governments rushed to find ways to stimulate their domestic economies, a series of unprecedented stimulus packages have been unveiled in recent months, many of which included investments to help boost hydrogen usage.

While significant, these funds remain small in comparison to the total amount required to make hydrogen a real contender to fossil fuels. Yet, the intention is clearly there and the momentum is supportive. In addition, a lot of private capital — whether it is early stage venture capital funding or capital expenditures by larger and established groups — is being channeled towards the development of hydrogen production and distribution.

Potential winners and losers

In a scenario where, supported by strong policy, hydrogen use takes off, we believe that it may create significant opportunities and challenges across many sectors. The most obvious winners are likely to be the producers of hydrogen.

Utilities and renewable electricity providers are naturally seen as best positioned to prosper from a surge in demand (perhaps doubling by 2050) as grey and brown hydrogen sources turn green. However, most of the value may be created higher up in the value chain, in the industrial and chemicals space. Winners will be able to use their expertise to capture a significant portion of the infrastructure build-up (such as electrolysers development and pipelines).

On the other hand, the emergence of green hydrogen poses existential threats to the oil, gas and coal industries. While oil and gas majors could pursue vertical integration from their nascent positions in renewable electricity generation, from the production of green hydrogen and to distribution via their retail service stations (offering potential upside to downstream margins). However, this may not be enough to offset a likely collapse in demand. In any case, such vertical integration would require significant investment in the short term.

A possible game-changer

Hydrogen's impact should not be limited to the energy sector and could have repercussions across a wide array of industries. Transport — whether its trains, trucks, autos, commercial aircrafts or ships — is at the epicenter of the H_2 revolution and could be one of the most affected by such a change in demand.

While shipping could benefit the most from the reduction in emissions that hydrogen will provide, road transport is likely to be the fastest adopter. There are already several hydrogen-fueled cars publicly available in some markets. As with electric vehicles, a move towards hydrogen-powered engines could completely reshuffle the cards and see the emergence of new contenders and leaders. This could be true for original equipment manufacturers (OEM) as well as suppliers.

A long-term plan

The move towards hydrogen could revolutionise entire industries, potentially offering numerous opportunities for investors. However, as with any other similar paradigm shift, this process won't happen overnight and not every company will succeed (or possibly survive) in this new environment.

For investors this has two main implications. First, hydrogen investing should be seen as a long-term commitment rather than a short-term trade. Second, as it matures, the industry's fundamentals will likely change, requiring investors to adopt an active approach and adjust exposure accordingly.

"696m metric tons of hydrogen could be used a year by 2050, a six-fold increase on current levels, representing $700bn in annual sales"

Hydrogen energy: the industry's response

Gerald Moser, Chief Investment Strategist, Barclays Private Bank, explores the potential opportunities that may emerge with Daryl Wilson, Executive Director of the Hydrogen Council. The Hydrogen Council promotes collaboration between governments, industry and investors in deploying hydrogen solutions globally. The coalition represents 92 companies and investors with total revenues of over €18.9 trillion.

Renewable energy solution

Gerald Moser: Why the interest in hydrogen now?

Daryl Wilson: A confluence of factors have accumulated over the last two years. First, renewable energy costs have fallen more quickly than expected and hydrogen extends the reach of renewables into the whole energy system. Another factor is the growing interest around climate change, more specifically, that transitioning to a low-carbon world is not going to be possible without a solution like hydrogen to complement renewable energy and electrification. If you look at the Energy Transitions Commission report "Mission Possible[1]", hydrogen is a critical component in reaching our objectives.

Finally, there has been great progress in technology and scalability in hydrogen production that has reduced the cost of production. Those three factors, in addition to the green focus of the economic recovery, that are leading governments around the world to consider using public funds to support hydrogen in the energy transition process.

Gerald Moser: What is required for the hydrogen market to take off?

Daryl Wilson: I think this question triggered the creation of the Hydrogen Council back at the World Economic Forum in Davos in 2017. The questions of scale and cost go together: as the scale of an industry increases, the cost of production usually goes down. There is a learning curve. We have seen this movie before with wind, solar or battery technology. Our latest analysis suggests that the cost will come down, that the technology solutions are scalable and that hydrogen can achieve a meaningful contribution to climate change objectives through energy transition because of these improvements.

There are other factors required for the industry to scale. For example, recent announcements around infrastructure expenditure by governments are very important. Whenever we have faced a major transition in society, there has always been an infrastructure cost to make the transition. We saw that with highways, gas infrastructure, mobile phones and wifi.

All those various changes have required significant infrastructure expenditure and hydrogen is not different. It represents a major change in our energy system and there is going to be a need for significant infrastructure spending. But it looks like this might happen very soon.

Government policies around incentives, taxation, energy pricing are as important to support the hydrogen industry as the infrastructure effort previously mentioned. And we start to see movements in those areas as well. It is very encouraging for the industry.

Gerald Moser: How does hydrogen compare to battery as a means of storage?

Daryl Wilson: There are many ways to store energy and batteries are the one we are the most familiar with. But when you transfer electrical energy into hydrogen, the capacity for storage is among the highest capacities available.

Today the most widespread use of high-scale energy storage is pumped-storage hydroelectricity – water pumped from a lower elevation reservoir to a higher level one and let to fall to recover the energy. Hydrogen could also play that role. Batteries lend themselves better to smaller scale storage application. The amount of energy used is dramatically lower than the power you can store using hydrogen. So the main difference is about scale.

[1] Mission Possible, Energy Transitions Commission, November 2018

Greener governments

Gerald Moser: Are government incentives necessary and how best can governments incentivise the market towards hydrogen?

Daryl Wilson: The Hydrogen Council looked at this question carefully and identified in our January 2020[2] report on cost that nine out of the 35 use cases studied for hydrogen will be cost competitive with conventional options by 2030. This is not very far away and there are solutions today and in the near-term which can make contributions without government incentives.

It is not necessarily about financial incentives but also about policy structure. For example, in Switzerland, the country is in the course of deploying a thousand delivery trucks fuelled by hydrogen. There are no financial incentives for those trucks directly but there is a recognition that the alternative solution in trucking will be disadvantaged in the years to come because of their carbon footprint.

Whether it is the price on carbon or some policy recognising the impact of carbon, this is likely to be a necessary support to see the ongoing growth in hydrogen solutions.

Industry impact

Gerald Moser: In which parts of the economy could the effect of hydrogen be the most important?

Daryl Wilson: Apart from transportation, which I alluded to with the trucks example, there are two sectors I would highlight briefly. First, utilities and energy. At the moment we use liquid fuel and natural gas to move energy around, but hydrogen also has a wonderful ability to carry energy around. It has a great potential for energy storage which becomes critically important as a growing share of energy stems from renewable sources. If you start using hydrogen as storage, it can be coupled with the application in transportation.

Then there is the industrial sector. It is relevant for heavy industrial processes such as steel, glass or cement making. Those industries require very large amounts of energy and many players in those industries have expressed a commitment to be carbon-neutral in the near future. Really the only way to do that is to use hydrogen, which is carbon free.

> "The hydrogen market could reach $2.5 trillion by 2050"

Countries battle for a $2.5 trillion market

In a report in 2017 about scalability of hydrogen[3], we forecast that the hydrogen market could reach $2.5 trillion by 2050. This is a huge market opportunity and certain countries are off to a very strong start, having invested in hydrogen for the last few decades. One of the attractive attributes about hydrogen is that it is less about natural resources endowment than is the case with most energy sources. Hydrogen is something that can be developed almost everywhere by almost anyone.

There is a democratisation of energy when you start to use hydrogen. There are countries in Europe which have taken a lead, notably thanks to their investment in renewable energy. They have realised the potential of hydrogen to extend that low-carbon direction. Korea, Japan and China have all made big commitments in hydrogen and are making very good progress. In North America, there are states like California where there is a lot of interest and are making a good start with renewable energy.

Across the world there is the potential to develop hydrogen as an energy vector and there is little real impediment for anyone to participate in this game. In our 2017 report about scalability, we estimated that hydrogen could reach 18% of total energy demand by 2050. That is a very significant piece of the pie.

Hydrogen headwinds

Gerald Moser: What could be the main headwinds for hydrogen?

Daryl Wilson: For a long time, awareness about the potential for hydrogen was the main headwind. But as mentioned before, there is a willingness for the different COVID-19 recovery plans around the world to accelerate the energy transition effort from carbon sources. And with the progress on scalability and the increasing share of renewable energy in the energy space, the momentum in favour of hydrogen has never been stronger.

The current general headwinds facing the economy have not been so for hydrogen. But major changes are never easy or linear and there is still a need to grow awareness about the potential for hydrogen. There is also a need to develop much larger scale projects. As those would be the first of a kind, it is likely that progress will initially be slow because of learnings that still needs to take place. But the larger projects there are, the faster we can climb the learning curve.

Finally, governments need to put in place effective strategies to make the infrastructure expenditures where it would have the biggest impact in the shortest period of time.

[2] Path to hydrogen competitiveness: a cost perspective, Hydrogen Council, January 2020

[3] Hydrogen scaling up; Hydrogen Council, November 2017

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