ESG Economist

Mining hydrogen? Not so fast…

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- **Green hydrogen is set to play an essential role in the future energy mix**
- **However, the development of green hydrogen faces multiple obstacles threatening the timely achievement of transition goals**
- **Other new ways to produce hydrogen, such as mining the hydrogen (gold hydrogen) or producing hydrogen from geological substrates (orange hydrogen) are other options**
- **Better understanding of the best locations, concentrations, most effective detection methods, along with associated costs are among the challenges facing the development of gold and orange hydrogen**

Introduction

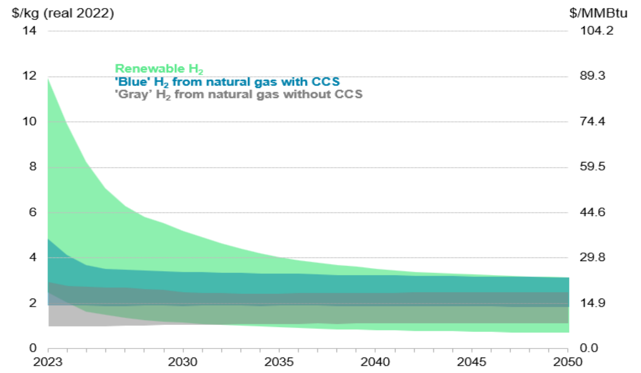
Hydrogen is the most abundant element in nature. It has the advantage of being climate neutral as burning it does not involve greenhouse gases, rather, it produces water. Accordingly, hydrogen is set to play an important role in the energy transition in Europe and other parts in the world. However, the challenge surrounding hydrogen is that it was assumed that it did not exist readily in nature. Therefore hydrogen needs to be extracted from other resources such as water, gas, or even mined from geological reservoirs. There are many advantages of using hydrogen compared to fossil fuels. Hydrogen can be used as an alternative feedstock fuel for hard to abate sectors that cannot electrify, such as in maritime shipping (in the form of ammonia or hydrogen). It also can play a role in storing excess power from renewable resources. Moreover, hydrogen can facilitate the trade of power off-grid between non-neighbouring countries. Hydrogen can be called many colours differentiated by its source or the way it was produced. Green, blue, and grey hydrogen, which we have touched upon in our previous note here, are most discussed in the literature. However, there are also other kinds of hydrogen such as white (also known as gold hydrogen) and orange hydrogen, which we focus on in this note.

Green hydrogen

Green hydrogen is produced through a chemical process known as electrolysis and in order to be labelled as green, only renewable energy sources should be used. Electrolysis uses an electrical current to separate hydrogen from oxygen in water. As the electricity used is from renewable sources, such as solar or wind energy, no carbon dioxide is emitted during the production into the atmosphere. But green hydrogen is also very expensive compared to blue hydrogen (generated from natural gas with carbon capture and storage) or grey hydrogen (uses natural gas without carbon capture and storage). The graph below on the next page shows the different levels of levelized costs for green, blue and grey hydrogen. For green hydrogen to become a viable option from a cost point of view, the costs would need to decline substantially.

Levelized cost for hydrogen along the transition

$ billion

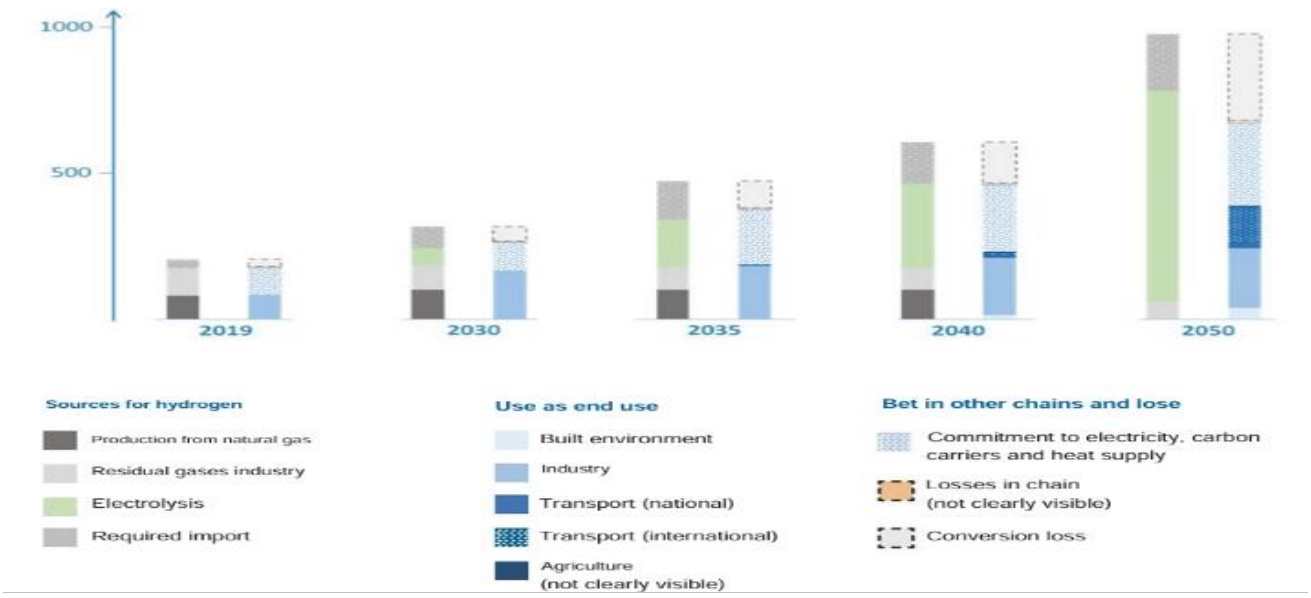


Source: Bloomberg, BNEF

Europe has put green hydrogen high on its transition agenda where it is viewed as the strategic transition fuel to achieve climate targets and energy security for Europe. By 2030, Europe has set a hydrogen strategy (see more **here**) aiming at satisfying half of its hydrogen needs by domestic production (10Mt of green hydrogen), while importing the other half. Accordingly, many European countries have set plans to incorporate hydrogen in their energy mix. For example, the Dutch National Plan for Energy (NPE) Laid down a roadmap for the development of hydrogen in the country chain up until 2050 as seen in the graph below.

Dutch sources and use for hydrogen (2019-2050)

$ billion



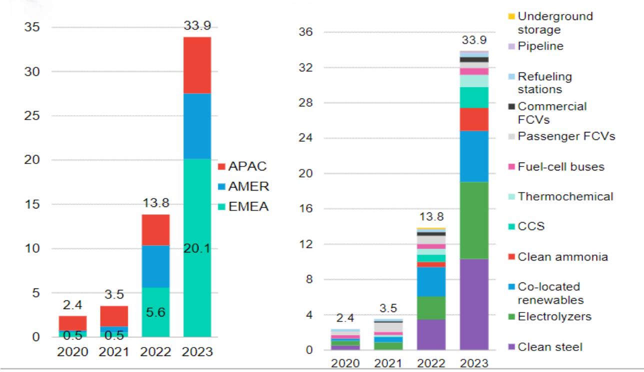
Source: Bloomberg, BNEF

Globally, hydrogen investments are gaining momentum with global investments of hydrogen related areas amounting to $34 billion in 2023. That translates to a rise of 246% compared to 2022, see graph below (more **here**).

However, the production of green hydrogen, is still at the early stages of development with doubts on its scalability especially with the current limited renewable capacity in Europe and emerging bottlenecks, such as limited grid capacity and long permitting procedures, along with the uncertainty about international market conditions that threaten the meeting of Europe's green hydrogen targets in time. Thus, other new ways to produce hydrogen, such as mining the hydrogen (white hydrogen) could play a role in the continent's energy transition.

Global hydrogen investments by region (l) and area (r)

$ billion



Source: Bloomberg, BNEF

White, gold or natural hydrogen

White, gold or natural hydrogen are different labels for the same thing. It was long believed that natural hydrogen deposits could not be formed, and, to date, no large-scale exploitation of geological hydrogen has been carried out. However, this view has changed with studies conducted in geological formations where hydrogen release occurs continuously.

What is natural hydrogen?

Natural hydrogen is hydrogen produced deep within the Earth and gets trapped by impermeable barriers on its way to the atmosphere, similar to the way petroleum was stored over time. White hydrogen describes any hydrogen generated through the passive capture of natural hydrogen from underground sources. In other words, simply extracting natural hydrogen out of the Earth (see more **here**). Although various sources of white hydrogen have been identified, scientists know much less about discovering white hydrogen than they do about locating oil and natural gas.

How is natural hydrogen produced?

Natural hydrogen is mainly produced through a geochemical process known as serpentinization, which involves the reaction of water with low-silica and ferrous minerals. In favourable locations, the hydrogen produced can become trapped by impermeable rocks on its way to the atmosphere, forming a reservoir (see **here**). The serpentinization of olivine involves two main reactions: hydration and oxidation. A critical property of ultramafic rocks that enables substantial H2 production is their low silica content. In contrast, silica-rich rocks like basalts tend to sequester a greater proportion of iron (Fe) silicate alteration minerals such as chlorite and amphibole. The rate of serpentinization of the parent rock is mainly controlled by three variables: temperature, pressure, and the water-to-rock mass ratio. The optimal temperature range for the process is between 200 and 300°C (see more **here**). Besides serpentinization, hydrogen can also be produced in the subsurface by other abiotic processes and by microbial metabolism. Many microorganisms produce H2 through fermentation and nitrogen fixation reactions in their metabolism.

What are the discovered reserves so far?

In April 2023, the US Geological Survey published a report on natural hydrogen (see more **here**). It said that the Earth is storing a vast amount of hydrogen. Using a conservative range of input values, the model predicts a mean volume of hydrogen that could supply the projected global hydrogen demand for **thousands of years**. However, a note of caution in interpreting this number. Hydrogen supplies that are too deeply buried, or too far offshore, or in accumulations that are too small, may never be able to be recovered economically (see more **here**). However, if even a small fraction of this estimated volume could be recovered, there would likely be enough hydrogen across all the global deposits to last for **hundreds of years**. But it is key to understand if hydrogen exists in significant accumulations that can be economically accessed, and if so, how to find these resources. There are countries with proven or suspected deposits of natural hydrogen. For example, researchers at the French National Centre of Scientific Research (CNRS) estimated potential deposits of between 6 and 250 million metric tons of hydrogen in northeastern France’s Lorraine coal basin (see more **here**). Similarly in Spain, Helios

Aragón company claims its discovery to a large reservoir that could contain up to 1.18 million tonnes of natural hydrogen (see more **here**).

Challenges to the development of natural/white/gold hydrogen

There are several challenges that could prevent the tapping of these enormous resources in the near term. First, researchers, engineers and geoscientists are still trying to determine where this hydrogen is most prevalent, especially at higher gas concentrations, and if/how white hydrogen gets trapped in various geological formations. Moreover, detection methods need to be improved. Second, natural hydrogen frequently occurs in areas that have not been explored by the oil-and-gas industry and that the science underpinning its exploration is very immature (see more **here**). Third, extraction and storage of this hydrogen needs to be optimized. The extraction of natural hydrogen can be carried out by adapting technology currently employed for natural gas extraction. Finally, natural hydrogen mining is in its infancy. It will take a long time from discovery to production. According to the IEA, the global average lead times from discovery to production is close to 17 years for a mining operation. S&P estimated an average of 15.7 years for 127 mines. Even if the process would be quicker, the hydrogen will not be on the market next year and even not by 2030. If the average time is taken into account the mines could be ready just before 2050. A more practical problem, is that in many discovered deposits, such as those discovered in Spain, hydrogen is found with methane, which needs to be separated and injected back to into the ground.

Moving forward with natural hydrogen, there are other crucial questions that need to be answered, for example:

- What is the carbon footprint of exploring and producing it?
- What is the cost of exploration, development and production?
- What is the cost of natural hydrogen compared to the green, blue and grey hydrogen?

By answering such questions, we will gain a better understanding of the contribution natural hydrogen can make to our low-carbon future.

Orange hydrogen

Besides natural hydrogen, another hydrogen source produced from geological substrates is being considered: orange hydrogen. Orange hydrogen results from the anthropogenic stimulation of the same geochemical processes that produce natural hydrogen. Indeed, orange hydrogen is formed by pumping a CO2 enriched water solution into reactive, iron-rich rock formations. When the CO2 solution interacts with iron, magnesium, and calcium oxide under sufficient geothermal heat and pressure, geochemical reactions lead to the precipitation of solid carbonates and hydrogen gases within just a few hours to days and are then recovered from the fluid (see more **here**). The advantage is that the targeted geological formations can also be used as a repository to trap CO2. The required energy is naturally provided by the environment as geothermal energy (see more **here**). So the process combines carbon sequestration and geothermal heating principles. Iron-rich rocks are some of the most common all around the world, which makes up about 5% of the earth's mass crust (see **here**). So there could be great potential for the development of orange hydrogen. Due to the prevalence of these materials, the supply of orange hydrogen would be enough to power the world for thousands of years. But the challenges and questions surrounding orange hydrogen are similar to those as for natural hydrogen, as the production of natural and orange hydrogen are both still in their infancy.

Conclusion

In order to move away from fossil fuels and achieve climate targets, incorporating hydrogen in the future energy mix becomes essential. Hydrogen is usually labelled using colours reflecting its production process. Many countries set up plans for incorporating green hydrogen in their energy mix, with global investments in different parts of the hydrogen value chain gaining momentum. However, the development of green hydrogen faces many obstacles that threaten the timely achievement of targets. Other new ways to produce hydrogen, such as mining the hydrogen (gold hydrogen) or producing hydrogen from geological substrates (orange hydrogen) are promising sources of hydrogen. However, the development of gold and orange hydrogen is still at its infancy and better understanding of the best locations, concentrations, most effective detection methods, along with associated costs are among the challenges facing the development of these types of hydrogen.