THE ANZ HYDROGEN HANDBOOK VOL II

COLOURS OF HYDROGEN

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Hydrogen is the lightest and most abundant chemical substance in the universe, however it rarely appears in its free form on Earth so requires energy to separate it from other compounds. The different methods of producing it have colourful names.

Main types of Hydrogen Energy		
	Green	Produced through electrolysis of water using a renewable power source. Zero carbon emissions in production and combustion.
	Blue	Produced from fossil fuels, including natural gas or coal. Similar to the process for grey or brown hydrogen, except carbon emissions are captured and permanently sequestered.
	Grey	Produced from methane or natural gas through steam methane reforming with material carbon emissions released during production.
	Brown	Produced from coal through gasification with material carbon emissions released during production. Also known as **black hydrogen**.

Other types of Hydrogen Energy		
	Turquoise	Produced when natural gas is broken down with the help of methane pyrolysis (as opposed to steam methane reforming). The process is driven by heat produced with electricity, rather than through the combustion of fossil fuels. The output of carbon in solid form (rather than CO_2) means there is no requirement for CCS. Where the electricity driving the pyrolysis is renewable, the process is zero-carbon or even carbon negative if the feedstock is bio-methane rather than fossil methane (natural gas).
	Pink/ Purple/ Red	Produced by electrolysis using nuclear power.
	Yellow	Produced by electrolysis using solar grid electricity.
	White/ Gold	A naturally-occurring geological hydrogen found in underground deposits and created through fracking. Several reservoirs have been found across the world, however there are no developed strategies to exploit this hydrogen at present.

GREEN HYDROGEN

As a low carbon option, the debate is narrowed to green and blue hydrogen, especially in Australia as there is no nuclear industry (which can also be included as a low carbon option for producing hydrogen in other countries).

THE PRODUCTION OF HYDROGEN WITHOUT THE GENERATION OF CARBON EMISSIONS.

Green hydrogen is the production of hydrogen without the generation of carbon emissions. Production occurs through a process of electrolysis, which uses an electrical current to separate the hydrogen from the oxygen in water. When the electrical current is powered through renewable energy such as wind or solar, the energy is produced without emitting carbon dioxide making it clean or sustainable.

Electrolysis occurs through an electrolyser, which can provide grid flexibility during period of excess renewable electricity load and mitigate curtailment and/or negative power price event. While currently more expensive than any other commercialised form of hydrogen production, electrolyser production costs are expected to fall sharply once at scale.

Most of the production costs are from electricity generation and as the price of renewable power continues to fall, so will the cost of the electricity generation. It also requires significant input of deionised water.

BLUE HYDROGEN

Blue hydrogen is produced using fossil fuels with the CO2 emissions captured and sequestered through a process known as Carbon Capture and Storage (CCS). Blue hydrogen is primarily produced by splitting natural gas into hydrogen and carbon dioxide through either Steam Methane Reforming (SMR) or Auto Thermal Reforming (ATR) with the emissions captured.

Currently, it is more economical than green hydrogen and can produce much larger volumes of low carbon hydrogen. However, blue hydrogen is at a premium over grey and can be exposure to price dynamics in the gas market (including geopolitical events).

While blue hydrogen is a viable option for some other nations, for Australia, the priority for Australia is green hydrogen. Blue hydrogen can be costly and while more environmentally friendly than brown and grey hydrogen, it does not remove the issue that the carbon will continue to exist, albeit not being released into the air and can be stored in existing infrastructure.

GREY AND BROWN HYDROGEN

Grey hydrogen is extracted from natural gas or methane using steam reforming, while brown or black hydrogen are produced via gasification where carbonous materials are heated into a gas. Both release carbon emissions into the atmosphere with no carbon capture mechanism.

Most hydrogen currently comes from natural gas, but this process also creates a lot of carbon waste. Natural gas contains large amounts of hydrocarbons – hydrogen chemically bonded with carbon. Catalysts can break these bonds, but the excess carbon then creates CO_2.[38]

Despite the use of a valuable resource, Special Advisor Hydrogen at International Energy Agency (IEA) - Noé van Hulst said that while grey hydrogen is currently the cheapest, "too often people assume that the price of grey hydrogen will remain at this relatively low level for the foreseeable future"[39]. He believes "that ignores the IEA's projection of a structural rise in natural gas prices due to market forces. And more importantly, it fails to take into account the potential volatility of gas prices."

CARBON CAPTURE AND STORAGE

Carbon Capture and Storage (CCS) is an integrated suite of technologies that can prevent large quantities of the greenhouse gas carbon dioxide (CO_2) from being released into the atmosphere.

There are three major stages involved in this technology[40]:

1. CAPTURE - the separation of CO_2 from other gases produced at large industrial process facilities such as coal and natural gas power plants, steel mills and cement plants.
2. TRANSPORT - once separated, the CO_2 is compressed and transported, usually via pipelines, to a suitable site for geological storage.
3. STORAGE - CO_2 is injected into deep underground rock formations, often at depths of one kilometre or more. CO_2 can be stored in oil and gas reservoirs, un-mineable coal seams and saline reservoirs.

OTHER CONSIDERATIONS

While the use of colours to distinguish the various sources of hydrogen production is useful, it fails to provide the full picture of carbon intensity and pricing. As the hydrogen industry develops and projects in the pipeline increase, end users are beginning to place emphasis on these factors.

The colour system simplifies the discussion around hydrogen sources, however it does not consider the carbon required to produce the hydrogen from the source or evaluate the carbon costs related to transportation.

From the regulatory perspective, there is also no single international body which governs the colour system and sets benchmarks for the carbon intensity allowed in each category. For example, while green hydrogen may not produce any emissions through production and combustion, the colour system lacks insight into the full value chain (including the high emissions that may come from transporting the hydrogen to end users). In Australia, the Guarantee of Origin scheme will measure the emissions intensity of the source of supply, for example, hydrogen buyers will consider the emissions intensity not the colour of the hydrogen.

The decline in the cost of renewables and increased incentives within the market position hydrogen as a strong option in global decarbonisation, particularly in Australia.

To achieve the full commercialisation of a hydrogen industry, there is still some way to go for hydrogen to reach cost-parity with its fossil fuel competitors. However, given its potential to play a significant role in the energy transition, many companies are already looking at where hydrogen capabilities may play a role within their business, forming early collaborations with key partners and engaging in selective M&A and subsidised pilot project activities.

Several countries are investing in research, development and planning around hydrogen with the emphasis on green hydrogen and blue hydrogen for nations which do not have the abundance of renewable energy sources.

Industry Considerations

- Environmental, social and governance factors impacting the future of hydrogen must also be considered by all those that participate throughout the hydrogen value chain.
- The safety of hydrogen is a common concern even though it is safer to handle and use in comparison to other commonly used fuels. Hydrogen is non-toxic and due to its light density; dissipates quickly when released allowing for rapid dispersal in the case of leaks.
- The use of water as a feedstock for developing molecular hydrogen can also be of concern due to availability and restrictions on the resource. Green hydrogen currently requires the input of high-purity water, however a number of studies are currently underway in order to utilise sufficient supportive infrastructure (e.g. desalination, reverse osmosis plants) to combat the restrictions and strain on Australia's water security. It is important to note that in order to maintain production being 100% green, these processes would also require firm renewable energy to operate, which is highly energy intensive by nature.
- The electricity requirements needed for clean hydrogen to meet global energy demands are vast. The production, storage and transportation of hydrogen itself can be quite energy intensive, however with global renewable electricity capacity expected to increase while costs decline, this is anticipated to support the consumption requirements.
- The use of CCS in the production of blue hydrogen requires investment in highly capital-intensive long-life assets. In addition, while capture technologies are well- developed, limited application in most industries increases perceived risk and regulatory acceptance.
- However, emissions reduction commitments require the adoption of a range of technologies and mitigation solutions and the acceptance of CCS projects are expected to come with scaling over time.
- The demand/customer offtake in comparison to supply availability for hydrogen will be increasingly important given the rapid pace of growth within the industry.
- To achieve an equilibrium between supply and demand of hydrogen, this will require further infrastructure build-out requirements and increased energy affordability.
- And finally, in regard to implications for other industries, hydrogen should be seen as an opportunity for oil and gas producers and infrastructure operators to expand the terminal life of their assets and reduce stranded asset risk. While the ramp up of a green hydrogen economy may take time to build, blue hydrogen is uniquely positioned to act as a bridge to transition the energy system, and help build the momentum required to achieve global decarbonisation in a thriving hydrogen economy.

REFERENCES

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