THE ANZ HYDROGEN HANDBOOK VOL II

HYDROGEN 101

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HOW IS IT PRODUCED?

An obstacle to realising hydrogen's clean energy potential is that it is virtually non-existent in its free form on Earth. Energy must be used to liberate it from the material forms in which it exists, such as in fossil fuels, water, biomass, minerals and naturally occurring underground deposits. The most common production methods include thermochemical reactions (utilising steam-methane reforming, gasification or pyrolysis processes with fossil fuels) or through electrolysis. With the application of carbon capture, utilisation and storage (CCS/CCUS), both of these methods can produce clean hydrogen to help decarbonise energy systems and industrial processes. There are a range of other hydrogen production methods which are explored further within this report, each resulting in different levels of carbon emissions, and they are classified under colourful names.

Green Hydrogen

Produced using renewable energy, green hydrogen is growing rapidly. Most commonly, electricity from renewable sources such as wind or solar power is used to drive the electrochemical dissociation (electrolysis) of water to form hydrogen and oxygen. This reaction is also known as water splitting.

The reaction occurs in a device known as an electrolyser. Two types of electrolyser systems are used most commonly commercially, being Alkaline and PEM technologies.

Hydrogen production via electrolysis requires high- purity water. Most commercial electrolysers have an integrated deioniser to purify the water. For every 1 kg of hydrogen produced, a minimum of approximately 9 kgs of water is required.[26] To get a sense of the amount of water required for large-scale hydrogen production, consider the challenge of producing enough hydrogen to match the energy content of Australia's LNG production. The energy content is equivalent to about 38 million tonnes of hydrogen, which would require 311 gigalitres of water to be electrolysed. This is a large volume of water but is comparatively a small proportion of Australia's current annual water consumption.

A third type of technology known as solid oxide electrolysis has solid oxide electrolysis cells with high efficiencies, but also operate at much higher temperatures than alkaline or PEM electrolysis, therefore requiring an external heat source.[27]

Blue Hydrogen

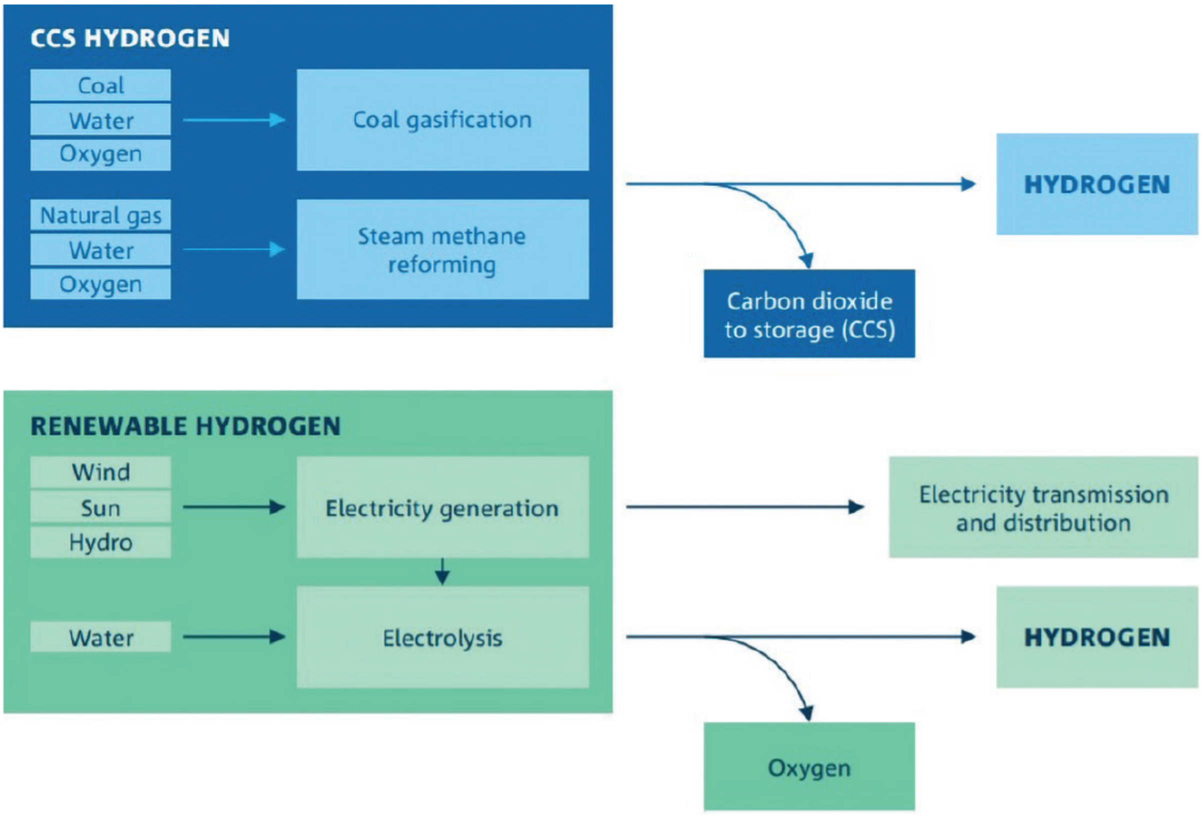
In fossil fuel-based thermochemical processes used to produce hydrogen, energy from fossil fuels drive chemical reactions that lead to extraction of hydrogen. In almost all cases CO_2 is a by-product. When the CO_2 is captured via CCS, it is considered blue hydrogen.

Steam methane reforming (SMR) involves catalytically reacting natural gas with steam to produce hydrogen and carbon monoxide (a mixture known as syngas). A subsequent reaction involving more steam produces further hydrogen while also converting carbon monoxide (CO) to CO_2.

Gasification is used for solid feedstocks such as coal and waste biomass. Chemically it is a more complex process than SMR and produces a higher ratio of CO_2 to hydrogen.

Partial Oxidation (POX) and Autothermal Reforming (ATR) use partial combustion processes to generate the heat required to drive the thermochemical reactions of feedstocks such as natural gas, liquefied petroleum gas (LPG), naphtha and heavy oils. Both have higher CO_2 emissions than SMR.

Hydrogen production pathways considered in this report.



Source: Green and blue hydrogen (chiefscientist.gov.au).

TRANSPORTING AND STORING HYDROGEN

Hydrogen is a very light gas and requires conversion for storage and transport due to its low density. This can be achieved in predominantly three ways:

1. Compression
2. Liquefaction
3. Chemical compounding
    - With other molecules to form liquid organic hydrogen carriers (LOHCs)
    - With nitrogen to form ammonia (NH_3)
    - With CO_2 to form methane or methanol

Hydrogen liquefaction, for example, involves cooling via processes similar to those used in the LNG industry, albeit these are significantly more energy intensive given the lower temperature (−253°C) required.

Another attractive storage and distribution approach is to inject pressurised hydrogen into natural gas pipelines, which can utilise existing infrastructure.

Pipelines are predominantly made of steel and operate at pressures >1 MPa. Their ability to transport 100% hydrogen will depend on their susceptibility to the embrittlement caused by hydrogen in some metals. The previous view was that up to circa 15% hydrogen can be used in existing pipeline networks.[28] The Hydrogen Project South Australia (Hyp SA) project began operations in 2021 in South Australia and introduced up to 5% hydrogen in existing pipelines to monitor the impact on infrastructure and household appliances.[29] In 2023, the Hyp SA was able to successfully deliver 5% blended renewable hydrogen to nearly 4,000 additional residential and commercial properties.[30] Risk factors include the condition of the pipe and welds, grade of steel, thickness, types of welds and operating pressure. Recently, APA's 2023 laboratory study concluded that up to 100% of pure hydrogen can feasibly be transported through their existing pipelines.[31] The study successfully transmitted hydrogen through West Australia's Parmelia gas pipeline over a 43km section of the pipeline.

The gas distribution pipes transporting natural gas from local storage to end users can be more readily repurposed for hydrogen, due to the extensive upgrade work that has already taken place to replace all old cast iron or steel gas pipes with new-generation polyethylene or nylon pipes. This means much of the distribution infrastructure may be already compatible with 100% hydrogen.

THE ECONOMICS OF HYDROGEN PRODUCTION

Currently, fossil fuel-based processes produce hydrogen at a lower cost than renewable electricity electrolysis technologies. While recent volatility in gas prices from various geopolitical events has impacted prices, Bloomberg conveys that hydrogen from natural gas without CCS costs in the range of US$0.98-2.93/kg (A$1.50-4.37/kg) hydrogen. Grey hydrogen is the cheapest form at present as blue hydrogen (with CCS) costs US$1.80-4.70/kg (A$2.69-7.03/kg) hydrogen.[32] Green hydrogen remains the most expensive form as its costs vary greatly from US$4.5-$12/kg of hydrogen. Costs across all forms are expected to decrease in line with research and development of technologies. The production cost of hydrogen from natural gas is influenced by various technical and economic factors, with the most important factors being gas prices and capital expenditure. Costs for coal gasification are similar to those for natural gas steam reformation, where project viability is mostly dependent on the size of capital expenditure requirement, coal availability and coal prices.

At present, blue hydrogen is a more cost-effective way of producing hydrogen without large emissions and this is a route some nations are taking. However, Australia is pursuing green (or renewable) hydrogen as it seeks to replace and reduce fossil fuels. Renewable electricity electrolysis technologies currently produce hydrogen at a higher cost and does so with inherently low emissions. While electrolysis technology is still relatively immature, ongoing innovation is developing the industry Unpredictability across electricity prices and supply chains impacts hydrogen costs, however, green hydrogen costs are likely to decrease over time as a number of influential factors around it decrease.[33] Australia is targeting hydrogen production at less than A$2/kg[34] which the Australian Government announced in 2020, calling it the 'H_2 under 2' strategy.

BUILDING AT SCALE WILL BE KEY TO BRINGING HYDROGEN SUPPLY COSTS DOWN.

Building at scale will be key to bringing hydrogen supply costs down. In particular, minimising large- scale transport and storage costs will be critical to ensure that Australia's competitive advantage from its abundant natural resources is not offset by its distance from potential markets.[35]

Ultimately hydrogen must be cost competitive with other fuels in specific application areas if it is to achieve widespread adoption. For example, hydrogen would achieve competitiveness at A$2/kg with the landed costs of natural gas in importing countries.[36]

WHAT IS THE MARKET FOR HYDROGEN?

The worldwide demand for hydrogen is increasing as imported hydrogen is becoming central to multiple nations' economies. Production costs are falling, technologies are progressing and the push for non-nuclear, low- emissions fuels is building momentum. Australia is well-positioned to benefit from the growth of hydrogen industries and markets.

Hydrogen's versatility means it can play a key role across all energy sub-sectors. It can be used as an exportable zero- emissions fuel. It can be burned to provide heat for buildings, water and industrial processes. It can power transport through fuel cells, being particularly suitable for long-haul heavy transport. It can help make the entire energy system more resilient by providing a flexible load, frequency control services and dispatchable electricity generation. It can also be converted into a number of other products such as methanol which has a range of different uses from clothing to fuel and ammonia for fertilisers.

The most immediate economic opportunities for Australia are to establish itself as hydrogen supplier of choice to other nations that are hungry for hydrogen as a cost- effective route to reducing emissions, while also decarbonising our own industries domestically.

Due to its potential for decarbonising energy systems, many countries around the world are investing to develop hydrogen energy value chains. For example, Japan and South Korea which depend heavily on imported fossil fuel energy, are seeking to replace those fuels with imported hydrogen. Their emerging import demand equates to a large export opportunity for Australia.

Australia has an abundance of low-cost renewable solar and wind energy, and an abundance of low- cost brown coal alongside CCS sites. Coupled with existing expertise in natural gas infrastructure and shipping, Australia is well- positioned to take a lead in the emerging hydrogen export market.

Export of hydrogen represents a key opportunity for Australia. Demand for hydrogen exported from Australia is estimated to be at more than three million tonnes per year by 2040, which could be worth up to US$10 billion per year to the economy.[37]

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