SUBSEA HYDROGEN

HYDROGEN IS LIKELY REPLACE FOSSIL FUELS AS AN ENERGY SOURCE OF CHOICE. WHAT IS IT AND WHAT WILL IT MEAN FOR THE UNDERWATER SECTOR?

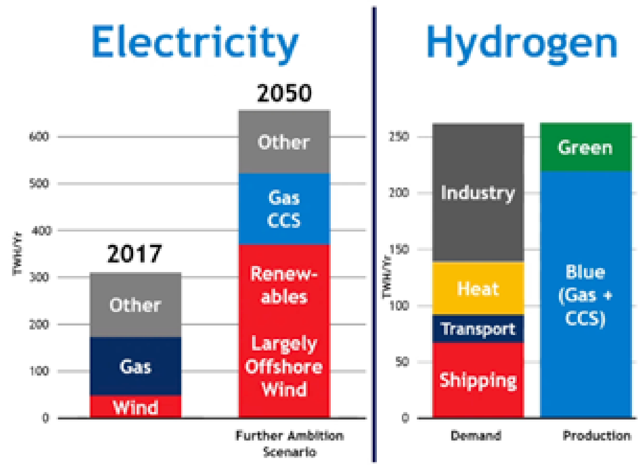
At present, 174 states including the US and China (which together, account for 40% of global emissions) are signatories to the Paris Agreement, a legally binding international treaty to limit global warming to (at least) below 2ºC when compared to pre-industrial levels. This essentially requires the limitation and ultimately removal of greenhouse gas emissions.

Greenhouse gasses include Carbon Dioxide (CO_2), Methane, Nitrous Oxide and Chlorofluorocarbons. These can absorb infrared radiation, thereby trapping and holding heat in the atmosphere. This greenhouse effect ultimately leads to global warming.

Of these compounds, the most prevalent greenhouse gas is CO_2. It is currently at its highest levels ever recorded. Its main source is from human activities in the consumption of fossil fuels.

The Paris Agreement will, therefore, require a transition from coal, oil and natural gas to more sustainable low carbon sources. Some people recognise this as renewables-only while others insist that nuclear has an important part to play in the energy mix.

Turning away from hydrocarbons is considerably more challenging than building more wind farms and electric cars that currently steal the headlines. It will mean using non-fossil fuels for much broader applications such as domestic heating as well as powering heavy industry such as energy-intensive cement and steel manufacture as well as running national transport systems, ships and even aeroplanes.



Left Side : Today's electricity production will be very different from the same profile in 2050 if zero levels are to be reached. It notably requires a huge increase in offshore wind. At the moment, the total installed capacity is 10GW but this will increase to-nearer 78-80gW. The energy mix will also need more gas to balance the intermittent nature of renewables. Corresponding CO_2 production will, therefore, have to incorporate a commensurate amount of carbon capture and storage.

Right Side : Balancing the Net Zero energy budget will also require Hydrogen to replace fossil fuels in providing power to the four main consumers Industry, Heat, Transport and Shipping. This will mainly come from Blue Hydrogen.

Images and text: OGTC

Climate Change Committee, Further Ambition Scenario, May 2019

In order to provide the necessary security of supply, it is important that the transition is managed at a sensible and realistic pace. While in recent years, power from renewables has made an important contribution to the energy budget, a well understood limitation is that energy is not always available at times when demand is at it highest.

The wind does not blow consistently and power demand is also cyclical. Typically, the main energy demand is high in the daytime but falls at night where electrical availability may be high.

One of the main reasons that hydrocarbons have been popular, is that they are very easy to store. The reverse is true of electricity which generally requires expensive batteries or conversion to another medium.

At present, hydrocarbons can fill in the energy gap between renewables availability but both governments and industry require a longer-term strategy if the complete removal of fossil fuels is to be successful. Many see the answer in Hydrogen.

HYDROGEN 101

At present, oil is used for transport, gas and oil for heating and gas, oil and coal for both generating electricity and providing the energy for heavy industry.

Hydrogen is probably the only single material that can be used directly or indirectly for all these demands, while still satisfying environmental demands.

It can be used as a fuel to directly drive turbines and, with minor adaptations, any established gas distribution network can be modified to transport the fuel directly to where it is needed. Just as important, however, it can be stored. As such, it works closely *with* rather than an alternative to the renewable energy sector.

Hydrogen is actually available in natural accumulations but this is extremely rare. Around 95% of hydrogen is currently produced from fossil fuels.

The main uses of hydrogen in the UK today are in fertiliser production and oil refining to produce low sulphur fuel. There are effectively four major types.

GREY HYDROGEN

Methane can be considered by its chemical formula CH_4. Using well established processes such as Partial Oxidation (PO), Auto Thermal Reforming (ATR) or the most common, Steam Methane Reforming (SMR). Research is ongoing in include plasma- based processes

SMR

SMR involves mixing methane with steam over a catalyst at temperatures of 800°C – 900°C. This produces the hydrogen/Carbon monoxide Syngas. It is then fed onto a water-gas shift reactor to convert water and the carbon monoxide to more hydrogen, plus CO_2.

For each kilogram of hydrogen, it emits 8-10kg CO_2. The Hydrogen is captured and unwanted CO_2 is then released into the atmosphere. Natural gas accounts for over 70% of global hydrogen production.

ATR

This is used in the manufacture of methanol and ammonia. It uses steam and oxygen to form Syngas. It produces a purer, higher concentration form of CO2 than SMR.

BROWN HYDROGEN

Primarily used in China and Australia, Hydrogen is produced from the gasification of coal and lignite. Like Grey Hydrogen, it is associated with high emissions.

BLUE HYDROGEN

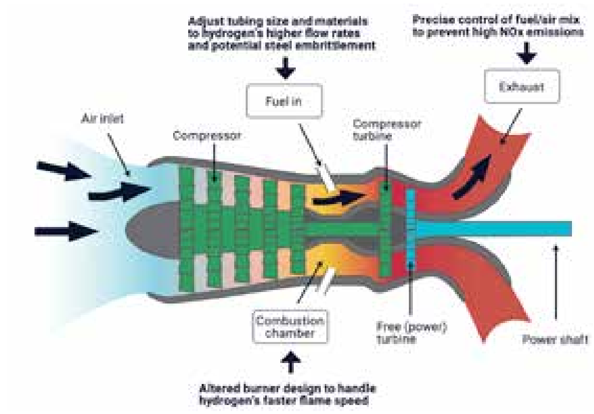
A cleaner version is "blue" hydrogen. This is essentially the same process as grey hydrogen but the carbon emissions are captured and stored through Carbon Capture Utilisation and Storage (CCUS) systems.

BP recently announced that it was it was working on plans for a major facility on Teesside, UK.

DIRECT POWER FROM HYDROGEN

The majority of turbines in the UKCS use gas to mechanically drive compressors or generate power Many of these, however, can already run on Hydrogen blends. Major turbine producers are working on turbines capable of running on 100% hydrogen or multiple fuels.

Hydrogen's low volumetric density and potential embrittlement of some metals mean that changes to ducting, seals and valves are required, as well as possible retrofits for turbine blades so that they can withstand higher flame temperatures.



Required modifications for hydrogen-fuelled turbines Image OGTC

It is currently produced by Quest in Alberta, Canada and by Air Products SMR in Port Arthur, Texas but BP recently announced that it was it was working on plans for a major facility on Teesside, UK.

This plant will produce as much as two million metric tons of carbon dioxide per year. Following a final investment decision in 2024, 500 megawatts of capacity could be in production by 2027

GREEN HYDROGEN

The ultimate clean fuel, thus is created using electrolysis, powered by renewable energy, to split water into oxygen and hydrogen. There are three basic electrolysis technologies.

Proton Membrane systems
The still relatively new PEM electrolysis achieves a significantly higher power density and extremely high power versatility.

The catalyst is relatively expensive bit it has a very rapid response time which makes it particularly suitable to work with fluctuating electricity feed-in from wind power and photovoltaic systems.

Solid Cell Electrolysis
This operates at very high temperatures of around 700ºC and it takes time to ramp up to this temperature. These factors make it largely unsuitable to working with intermittent renewables.

Alkaline Systems
Alkaline water electrolysis is a technology that has been established on the market for many years and does not require the use of precious metals. The liquid electrolyte is corrosive and susceptible to leakage however the catalyst systems are cheaper and the systems are well understood.

One company active in the Green Hydrogen business, Siemens, says that in contrast to the conventional method of steam reforming, around 55 MWh of electrical energy is required to generate one ton of hydrogen.

Green hydrogen systems come in at around £600–£720kW although proponents point to the fact that wind systems were once very uneconomic. This changed, however, with early government support and cost reductions through economies of scale. It will almost certainly require some sort of Carbon tax.

This has already been seen in Solar Power and battery development. Reports say that automation and scale- up could reduce costs by 30% In total, advances could reduce CAPEX to between £160 and £240/kW.

One technological venture could see seawater being used for hydrogen production. 200 MW Auto Thermal Reforming system can consume up to 30-40 m3/hr of water. This would be difficult to source in nations where fresh water but readily available offshore.

Electrolysis, however could not only form Chlorine gasses, but also produce salts that cause corrosion. Electrolysis systems may, therefore have to accompanied by water treatment systems- possibly requiring desalination technology. This could increase costs substantially.

STORAGE

One inherent advantage of fossil fuels is that they are easy to store. This is not true of electricity. While batteries can store electricity, these can be very expensive. Storing Hydrogen before converting it into electricity, could be less difficult.

One way of storing hydrogen and transporting is by compressing it to round 50-100 bar and sending it along a pipeline. It can also be frozen to-263ºC and stored in cryogenic tanks.

Alternatively, it can be combined with a carrier molecule such as Ammonia. Once the Ammonia is used, it releases the Hydrogen. Alternatively, it can be combined with a reversible carrier molecule such as Liquid Organic Hydrogen Carrier (LOHC) and then released as required.

SUBSEA

In a new industry which supplies power in the surface for use on the surface, it is unlikely that this would have any interest for the subsea industry. The cost of placing equipment or infrastructure offshore is far greater than it would be on land, and the cost of placing anything subsea would be even greater still.

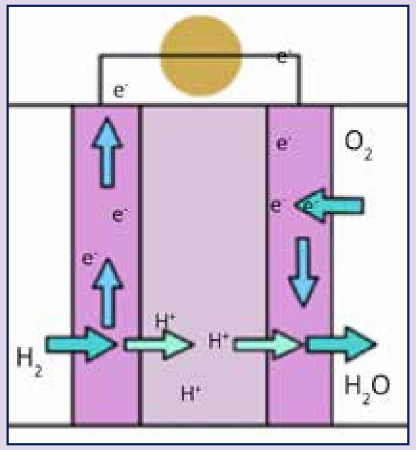
There are areas, however, areas where the subsea sector might take an interest. One such is in carbon capture.

A fundamental part of the Blue Hydrogen requires the capture and store of CO_2

INDIRECT POWER FROM HYDROGEN

One way of converting Hydrogen back to energy is to use a fuel cell. Numerous types of fuel cell exist, but all incorporate an anode and cathode encased in an electrolyte. They can be though of as the reverse of green hydrogen production.

The electrolyte allows only allows selected ions to pass between the anode and cathode. One of the most common electrolytes is a proton exchange membrane. A platinum catalyst on both sides of the membrane, facilitates the reaction of the hydrogen.



The fuel cell splits the hydrogen into H+ and e-. The H+ crosses the membrane while the e- is taken off to provide the power. The two parts are then recombined and Oxygen is added to form water

At the anode, a chemical reaction strips introduced Hydrogen atoms of their electrons. The hydrogen become ionised and the positive charge is allowed to pass across the membrane.

The free electrons, however, are conducted away from the anode to an external circuit to provide the DC electric current.

The free electrons then flow to the cathode where they recombine. Oxygen is introduced, which attracts the Hydrogen atoms to form water. As long as a fuel cell is supplied with hydrogen and oxygen, (also known as the reactants), it can generate electricity.

While individual fuel cells only produce relatively small amounts of power depending on their design and size, numerous individual units can be stacked together to form a much larger cell.

A commercial fuel cell also incorporates the necessary electrical controls required to metre the oxygen and fuel as well as oversee the process. Green hydrogen generation is essentially the reverse of the process within the fuel cell, combining hydrogen and oxygen to produce electrical energy and water.

– now, a relatively mature technology. While captured CO_2 has very limited uses such as refrigeration, dry ice manufacture, aerosol can propellants, use in fire extinguishers, carbonated drinks and in the development of plastics and other chemicals such as fertiliser and fuels, the uses far outweigh the volumes produced.

Once the gas is it is cleaned, compressed and then transported by pipeline or ship to storage sites. Many recognise that the depleted gas reservoirs around the North Sea and could be a very useful place to store carbon. In most cases, the pipelines effectively connecting the reservoir to land are still in place, but it is important to select the most suitable gas reservoir.

One group very interested in support the oil and gas industry in the acceleration to an affordable net zero North Sea is the OGTC.

One group very interested in supporting the oil and gas industry in the acceleration to an affordable net zero North Sea is OGTC. With more than £160m co-invested with industry in technologies from offshore electrification and net zero decommissioning, to autonomous robotics and renewable power systems, OGTC have screened over 1,000 exciting new technologies, completed or progressed 100 field trials, and generated £15 billion GVA potential for the UK economy.

With £180 million funding from the UK and Scottish Governments, through the Aberdeen City Region Deal, OGTC inspires and accelerates innovation, co-investing in industry-led projects to take new technologies from concept through to deployment in the oil field.

"We have a technology vision which reimagines the North Sea while also working to unlock the full potential of an integrated energy system," said Head of Energy System Integration Martyn Tulloch.

"The problem or challenge with using dis huge reservoirs is that all there are essentially lots of holes in them where from the extraction of hydrocarbons. They have been plugged and abandoned but this technique may not be suitable when the industry wants to re-pressure it with carbon dioxide.

Elements of the Deep Purple™ system include smart production, storage, re-electrification and distribution of green hydrogen enabled by tailored advisory, controls and safety systems.

"Perhaps a more appealing solution is to store the gas Saline aquifers of which there are many in the North Sea. Part of the rock formation contains sheets of impermeable salt. Injecting the CO_2 gas in there would provide a good seal.

"The pipelines and valves would predictably use infrastructure developed for oil and gas, but would probably be tied back to shore rather than is and offshore platform."

Subsea systems may also be used for Hydrogen.

"A typical scenario would mean using wind power generating the electricity and this would be used onshore to make the hydrogen," continued Tulloch.

"One drawback of Hydrogen, however, is that it is highly explosive. Storing this would have to be located on very selected sites. It may be more appropriate to not house these facilities on land, but instead at sea. It could be taken onshore on demand.

The prompted TehnipFMC to develop Deep Purple, a system that uses wind energy to extract green hydrogen from seawater.

The system consists of offshore wind turbines and offshore hydrogen technologies for the production, storage and transportation energy in the form of pressurised green hydrogen. It can also be used to produce, store and deliver hydrogen to consumers at sea or exported in a pipeline to shore.

One of the key elements to manage wind and wave intermittency is to combine renewable energy with energy storage, making Deep Purple a complete, sustainable offshore energy solution.

When the wind is active, wind turbines produce electricity that is delivered directly to the consumer. During periods of excess available power, water is spilt into hydrogen and oxygen by electrolysis.

Fresh water for the electrolysis process is produced from seawater using reverse osmosis. The hydrogen is transported to the seabed, where it is stored under pressure in dedicated tanks. During periods of low or no wind, fuel cells will convert the stored energy back into electricity to satisfy the energy demand.

The company says that its transferable core competencies, pioneering technologies and large global presence make us the partner-of-choice for carbon-free offshore energy projects.