FLOATING WIND AND HYDROGEN – THE PERFECT MATCH

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ER- MARINE' s green concept

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Summary

The rapid growth in offshore wind is well suited for developing a green hydrogen value chain in South Korea and could be an important showcase to demonstrate the wind developer’s capabilities in creating future value, industrial possibilities and becoming the global industry leader in offshore wind.

What is the concept?

The concept aims to produce green hydrogen using renewable energy from offshore wind to use the hydrogen as energy carrier on board the ships and offices involved in the windfarm exploitation and maintenance services making this a true zero- emissions operation. This as a demonstration project providing two value chains; producing renewable electric energy and a portion green hydrogen.

It is believed that small scale green hydrogen production is possible once the wind farm is operational and that the efficiency of producing green hydrogen in electrolysers will see a dramatic improvement once we can upscale the electrolysers based on the small- scale operating experiences.

The vessels alongside to be supplied by shore supply provided by the windfarm and office spaces to be powered by hydrogen fuel cell / solar power combination and the efficient use of water/ water heat pumps for heating purpose in winter and cooling in summer. This with the emphasis on low noise and maximal energy efficiency.

Several similar projects exist in Europe, e.g. NortH2 project to produce green hydrogen by using renewable electricity from offshore wind.

The South Korean version would be an “advanced” NortH2 version as to speak. The main difference is that the renewable energy from offshore wind still goes in the electricity grid; only a portion of the electricity produced will be used in Electrolysers to produce green hydrogen as energy carrier in fuel cells installed on board all vessels involved in the exploitation/ maintenance of the wind farms making it a true zero- emission project.

By implementing this concept; zero- emissions exploitation, wind developers can demonstrate their competitive position in hydrogen technology, creating future value by up- scaling into future industrial possibilities.

South Korea could become a leading region for green hydrogen, supporting economic development and meeting climate targets for 2030.

Hydrogen as energy carrier can provide scalable and profitable growth opportunities in the near future, in line with the climate roadmap aiming to ensure a competitive and resilient business model in the energy transition, fit for long term value creation and in line with the Paris Agreement.

Green versus blue hydrogen?

Green hydrogen is hydrogen produced by renewable energy, in our case offshore wind.

Blue hydrogen; hydrogen produced from natural gas with carbon capture and storage. The carbon capture and storage is an essential transition step for facilitating a longer term, sustainable, global hydrogen economy.

Many wind developers are partnering in various blue hydrogen projects where hydrogen is produced from natural gas and refinery fuel gas. The CO2 that is released during production is captured and stored in depleted gas fields.

By doing so, the Korean petrochemical industry and power reducers would be able to reduce its emissions in a relative short- time frame whilst preparing for the arrival of green hydrogen, which generates zero CO2 in its production.

Equinor as an example, has been operating CCS (Carbon Capture Storage) projects since the 1990's with massive operational experience.

Timeframe of availability

We are at early stage of floating offshore wind, installation of lidar buoys to analyze weather data for a period of 1 year.

Sourcing and selection of suitable vessels is ongoing in 2021 with in parallel development of suitable maritime fuel cell applications. Several projects are ongoing right now with a 400kW railroad fuel cell installation as to speak. We anticipate that we have a marine fuel cell application available within 1-2 years from now.

Various containerized hydrogen fuel cells 1000 kW are currently being installed and in operation.

Electrolysers to produce green hydrogen are available in the market but a breakthrough is expected the coming years to increase efficiency. Especially SINTEF as Partner with Equinor is focusing on development in new more stable coatings and concepts for bipolar plates to increase electrolyser efficiency.

Fuel cells 400 – 1000 kW are available and being produced in South Korea with massive involvement from Busan National University and major Shipyard R&D Centers.

In Europe and Norway in particular there is extensive experience from hydrogen as marine fuel, all with promising results where this experience could be used to kick- start the South Korean Zero- Emission project in a 2-4 year time frame.

Why Hydrogen and fuel cells?

The energy transition away from fossil fuels has started and when Hydrogen can be produced sustainably it offers several advantages:

- It is not a fossil fuel.
- Wind energy is ideally suited to produce hydrogen.
- H2 has an enormous capacity for energy storage.
- H2 is not an energy source, but an energy carrier.

A fuel cell marine vessel is a vessel that includes both a hydrogen fuel cell and batteries. In such hybrid architecture, the fuel cell provides all of the energy for the vessel operation, whilst the batteries are able to provide peak power to the propulsion motors. By using a fuel cell in conjunction with a battery, the size of each can be optimized for the vessel.

The fuel cell power module onboard the vessel generates electric energy through an electro-chemical reaction leaving only water and heat as by-products, thus there are no local emissions. The electric energy is used to provide direct electric propulsion and keep the batteries charged. The by-product heat is stored on the brake resistors and is used to maintain heating crew comfort and to increase energy efficiency. All the energy required for the vessel to operate is provided by hydrogen stored on board.

Hydrogen offers higher energy density compared to electrical storage systems such as batteries, this enables a longer range compared to systems where the batteries are used as stores of energy.
Refuelling of the vessel could take around 2 hours, with designs being developed to allow less than 1 hour.

A fuel cell vessel requires a centralized hydrogen refuelling station (HRS).

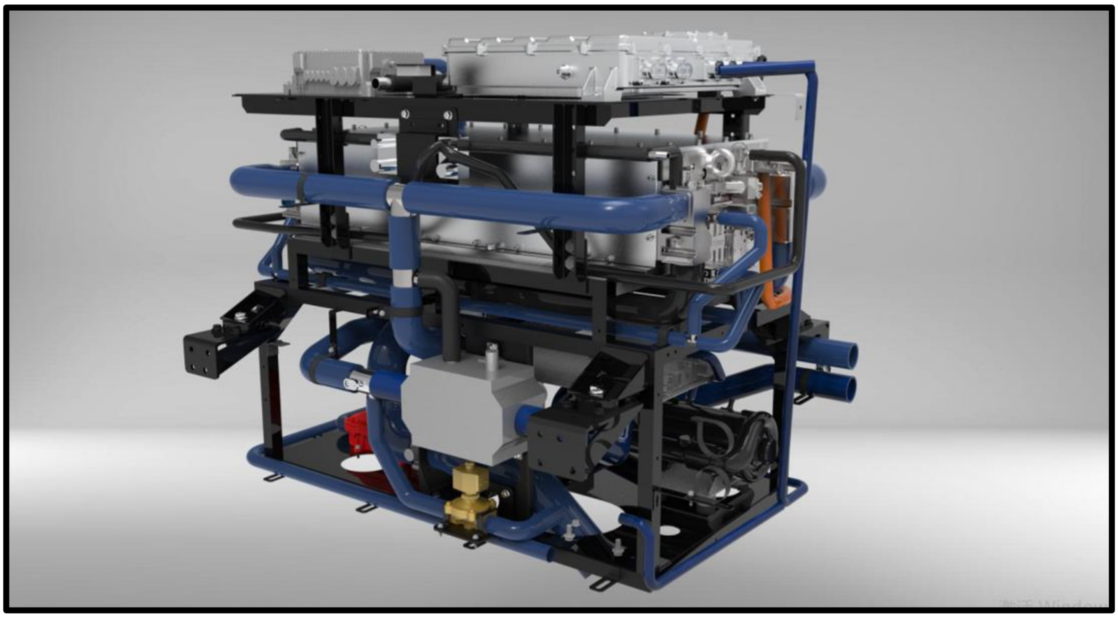
Because the fuel cell generates only water as an emission it will always be a zero emission vessel.

Whilst most of the industrial hydrogen used in the world today is produced from fossil sources of energy (mainly natural gas) the majority of hydrogen fueling stations are based on hydrogen for low and zero carbon sources. Hydrogen can be produced from a range of ultra-low carbon routes, including renewable electricity, biomass and other hydrocarbons including carbon capture and storage. When fueled by hydrogen produced via any of these routes, the fuel cell vessel offers a completely zero carbon solution.

Hydrogen production, zero- emission if produced from wind energy;

Water electrolysis comprises the splitting of water molecules into their constituent parts (H2 and O2) by passage of an electrical current.
There are two main electrolyser technologies – **alkaline**, which contain liquid electrolytes (potassium or sodium hydroxide), and **solid polymer electrolyte electrolysers (PEM)**.
Besides the electrolyser unit, an on-site station generating hydrogen by electrolysis requires water purification systems and a hydrogen purification and drier unit to treat the hydrogen produced.
Most electrolysers generate hydrogen at relatively low pressure, e.g. 10 to 25 bar, so further compression is required to elevate the pressure to storage pressures.

What is a fuel cell?



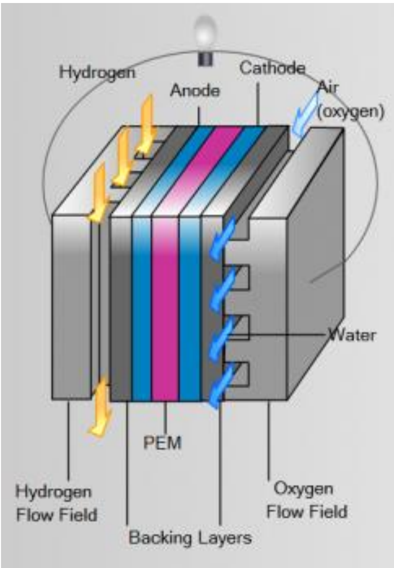
A fuel cell is a device that converts chemical potential energy (energy stored in molecular bonds) into electrical energy.

A PEM (Proton Exchange Membrane) cell uses hydrogen gas (H2) and oxygen gas (O2) as fuel. The products of the reaction in the cell are water, electricity, and heat.

This is a big improvement over internal combustion engines, coal burning power plants, and nuclear power plants, all of which produce harmful by-products.

Since O2 is readily available in the atmosphere, we only need to supply the fuel cell with H2 which can come from an electrolysis process

Hydrogen + Oxygen = Electricity + Water Vapor



A PEM fuel cell has 4 components:

1. **The anode**, the negative post of the fuel cell, has several jobs. It conducts the electrons that are freed from the hydrogen molecules so that they can be used in an external circuit.
   It has channels etched into it that disperse the hydrogen gas equally over the surface of the catalyst.

2. **The cathode**, the positive post of the fuel cell, has channels etched into it that distribute the oxygen to the surface of the catalyst.
   It also conducts the electrons back from the external circuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to form water.

3. **The electrolyte,** is the proton exchange membrane. (PEM)
   This specially treated material, which looks something like ordinary kitchen plastic wrap, only conducts positively charged ions. The membrane blocks electrons. For a PEMFC, the membrane must be hydrated in order to function and remain stable.

4. **The catalyst,** is a special material that facilitates the reaction of oxygen and hydrogen.
   It is usually made of platinum nanoparticles very thinly coated onto carbon paper or cloth. The catalyst is rough and porous so that the maximum surface area of the platinum can be exposed to the hydrogen or oxygen. The platinum-coated side of the catalyst faces the PEM.

As the name implies, the heart of the cell is the proton exchange membrane.

It allows protons to pass through it virtually unimpeded, while electrons are blocked. So, when the H2 hits the catalyst and splits into protons and electrons (remember, a proton is the same as an H+ ion) the protons go directly through to the cathode side, while the electrons are forced to travel through an external circuit. Along the way they perform useful work, like lighting a bulb or driving a motor, before combining with the protons and O2 on the other side to produce water.

How does it work?

Pressurized hydrogen gas (H2) is entering the fuel cell on the anode side. This gas is forced through the catalyst by the pressure. When a H2 molecule comes in contact with the platinum on the catalyst, it splits into two H+ ions and two electrons (e-). The electrons are conducted through the anode, where they make their way through the external circuit (doing useful work such as turning a motor) and return to the cathode side of the fuel cell.

Meanwhile, on the cathode side of the fuel cell, oxygen gas (O2) is being forced through the catalyst, where it forms two oxygen atoms. Each of these atoms has a strong negative charge.

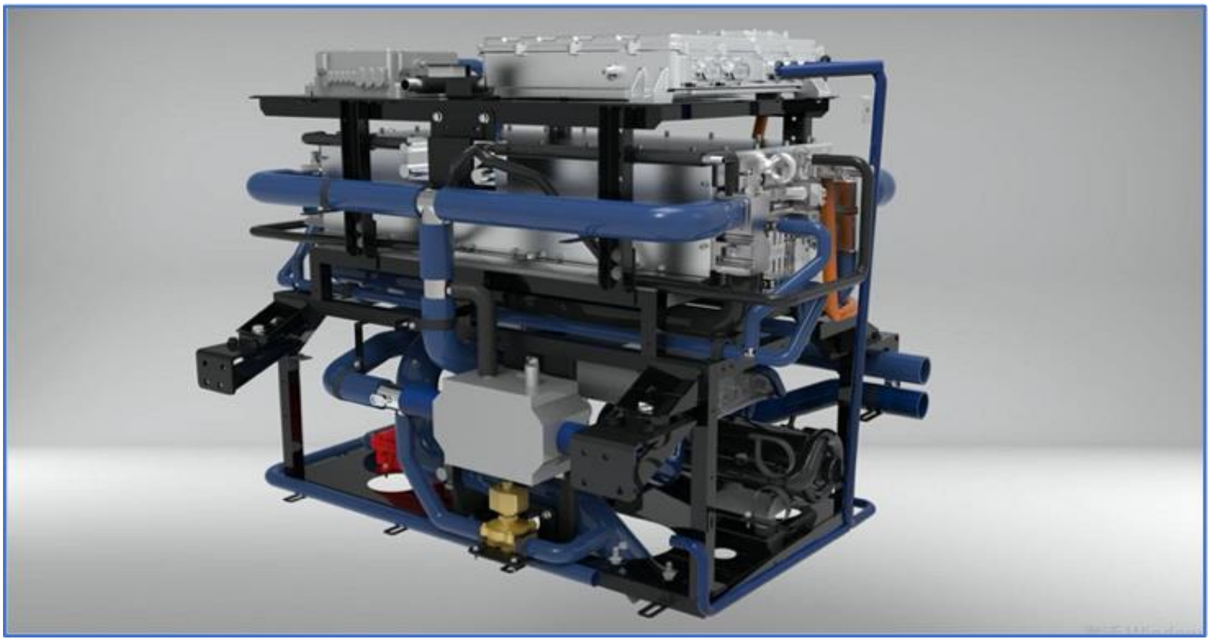
This negative charge attracts the two H+ ions through the membrane, where they combine with an oxygen atom and two of the electrons from the external circuit to form a water molecule (H2O). All these reaction occurs in a so called cell stack. The stack will be embedded in a module including fuel, water and air management, coolant control hardware and software. This module will then be integrated in a complete system.

Due to the high energetic content of hydrogen and high efficiency of fuel cells (55%), this technology can be used in many applications like transport (cars, buses, forklifts, ships, etc) and backup power to produce electricity during a failure of the electricity grid.

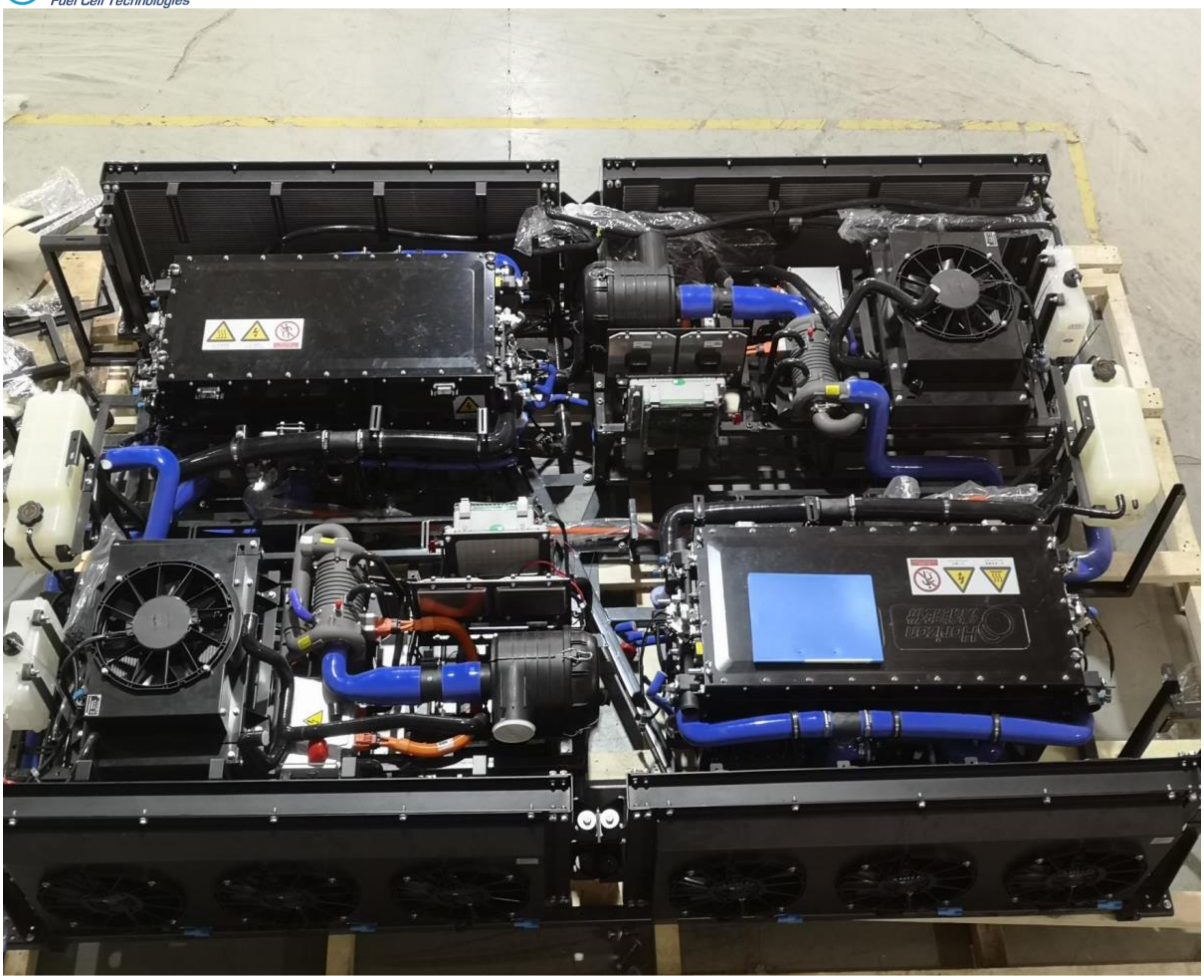
Fuel cells in South Korea anno 2021

Fuel cell technology is not something new but the last years we see rapid developments of fuel cells being implemented in the transport sector.

Currently a 400 kW fuel cell is being installed for a train application in Euiwang, KRRI.



Horizon
Fuel Cell Technologies



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