The Evolving Landscape of Hydrogen Technology

by

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Background Information

Over the past few years, the interest in responding to climate change has increased, forcing policymakers, no-profit organizations and industrial leaders to put climate change on their agendas. This interest has gained momentum and finally 196 parties, including some of the most important governments in the world, agreed to forge "*The Paris Agreement*", which is an international treaty focused on tackling climate change. The treaty entered into force on November 4th, 2016. Its' objective is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of greenhouse gas emissions such as CO_2 and CH_4 as soon as possible, with the goal of a climate-neutral world by 2050.

To be able to achieve net-zero CO_2 emission by 2050, a very wide range of projects aiming at decarbonising the most polluting industrial processes saw the lights sustained by an impressive and unprecedented amount of funding. Based on a study conducted by Mackenzie Corp., the scale of global investment is around 500 billion dollars. Many governments including the UK, Germany, US, Australia have started to make funds available for all initiatives to reduce CO_2 emissions and create advanced technologies with zero input of CO_2 emissions. Those initiatives include the production of hydrogen.

Hydrogen

Hydrogen has always attracted the interest of politicians, scientists, intellectuals, and economists. In 1874 the science fiction author Jules Verne imagined a world where hydrogen would have been used as fuel, in his novel "*The Mysterious Island*". During the oil crisis in the 1970s, hydrogen appeared as a concept. The Bush Administration in 2003 considered hydrogen vehicles during the first wave of real concern about climate change. Hydrogen is both the most abundant and smallest element on the earth, but it is not easy to access. The current manufacturing process is very polluting, producing a high level of CO_2 and it is based on the scission of gas such as methane. However, there is an alternative way to produce hydrogen using renewable sources such as windmills – see Figure 1. The power generated is used to split water into its fundamental elements, oxygen and hydrogen, by using an electrolyser. The hydrogen manufactured by using the renewable resource is called **Green Hydrogen.** Although the electrolysing process is not very efficient and requires an elevated amount of water, the technology is constantly evolving, reducing its manufacturing cost. The lack of a capillary refuelling station and currently elevated prices are hindering hydrogen to be widely used. Most of the efforts from the highly industrialized governments are bridging the gap increasing the number of refuelling stations: there are only 15 in UK, 91 in Germany, and approximately 50 in California. Hydrogen has dual functionality: it can be used as energy storage and fuel to power cars, buses, trucks, tractors, airplanes etc.

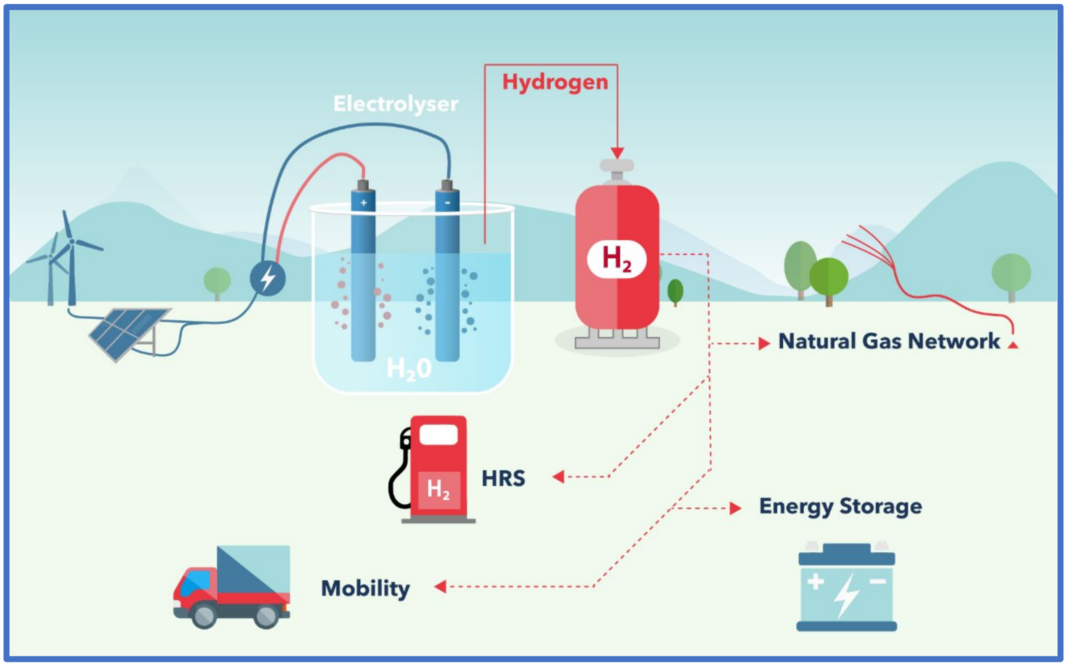


Figure 1 Hydrogen value chain

Type IV vessel

Rotomoulding can play a pivotal role and contribute to the success of the decarbonization process helping many global industries to achieve their environmental goals. Hydrogen and many other gases such as oxygen are currently stored in cylinders made from a metal called Type-3 liners. Those vessels, usually small containers, are used in a very wide range of applications including scuba, medical sector, life support, paintball, and aerospace. Important aspects to consider are the specific energy of hydrogen and the energy density of hydrogen versus conventional fuels and other gasses.

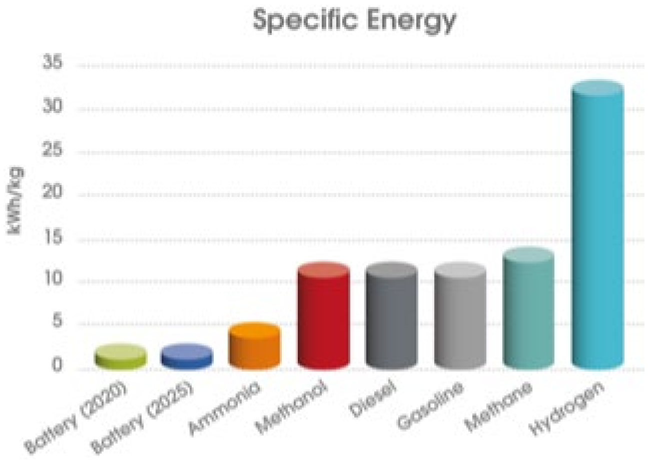


Figure 2 Specific Energy

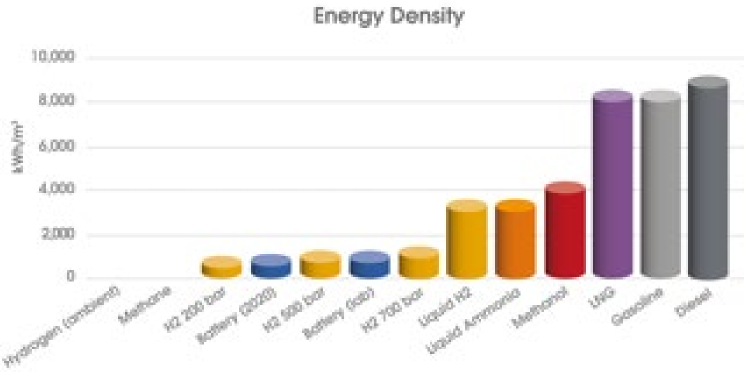


Figure 3 Energy Density

As it can be seen in Figure 2, the specific energy of hydrogen is very high, much higher than diesel and other conventional fuels. This makes the chemical a strong candidate to develop high-quality energy once it is used as fuel. However, its energy density is very low as illustrated in Figure 3. Therefore, it needs to be compressed at elevated pressure, usually from 60 up to 750 bars. If those levels of pressure are used with metal liners, their thickness and weight would be incredibly high, making the entire concept unpractical and unfeasible. This is why Type-4 vessels were considered for this application. The Type-4 vessel is a composite structure featuring a polymer liner with carbon fibre. The polymer liner acts as a barrier against the gas and can be rotomoulded. Those liners can reach a length of 2 or even 3 meters. The carbon fibre winded around the liner takes the applied pressure. This keeps the overall weight of the composite structure very low.

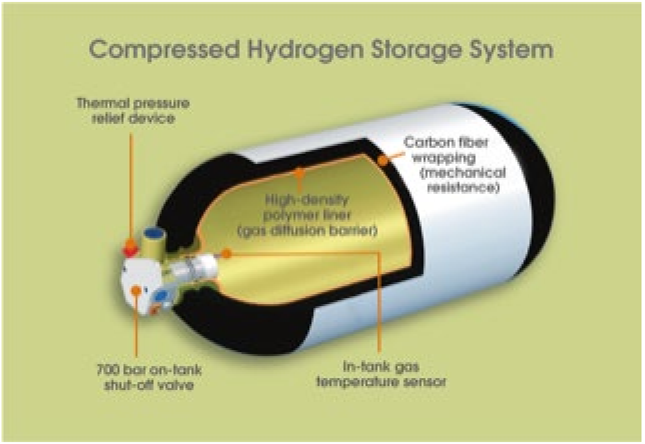
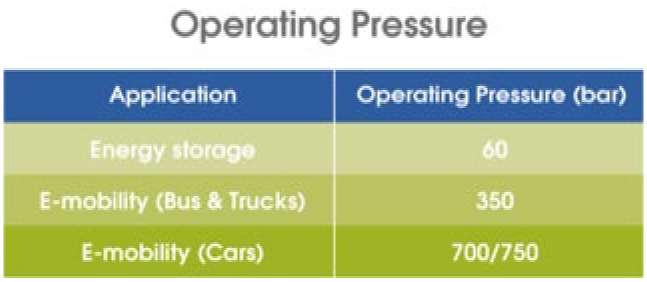


Figure 4 Type-4 vessel

Market Trends & Opportunities

The introduction of the Type-4 vessels has opened an incredibly wide range of opportunities for the rotomoulding industry which involves the transportation market segment and energy storage. It is possible to use the operating pressure of the Type-4 vessel to understand more about the operating life of the product and its requirements – see Table 1. Usually, hydrogen is kept at an operating pressure of 60 bars when it is produced through the electrolyser process in relatively small containers of approximately 1000 litres. Those containers can then be transported where it is needed. In E-mobility buses and trucks, the operating pressure is 350 bars. In cars, the operating pressure can be as high as 750 bars. Currently, the only car fully commercialised is the Toyota MIRAI made in Japan.



Operating Pressure

Application	Operating Pressure (bar)
Energy storage	60
E-mobility (Bus & Trucks)	350
E-mobility (Cars)	700/750

Table 1 Operating Pressure

Another critical aspect to consider is the permeation rate, as not all polymers will offer the same barrier against hydrogen. Hydrogen is the smallest atom and so it can permeate very easily. However, design of the vessel including the size, geometry, wall thickness of the carbon filament, boss design and operating pressure can all influence the overall permeation rate. This means that the values measured in the laboratory can differ from the values measured in real life.

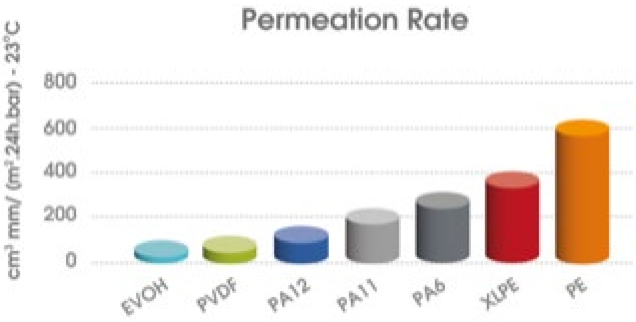


Figure 5   Permeation rate

It is advisable that rotomoulders or anyone who has an interest in this fascinating concept should carry out tests on their products to ascertain the permeation rate. Figure 5 shows EVOH as the polymer with the lowest permeation rate, whereas PE is the highest.

Technical Solutions

At Matrix Polymers we have been working on several technical solutions including engineering polymers such as Revolve® EVOH and Polyamide 6. Revolve® EVOH is a dual layer structure is based on a PE modified technology which generates a chemical bond between EVOH and PE during the rotomoulding process. This solution will provide the best barrier against hydrogen and will be the lightest solution possible

Figure 6   **Revolve® EVOH**

Polyamide 6 offers good barrier properties against many gases including hydrogen and also offers elevated flexural modulus and tensile strength which are requirements for hydrogen liners. This material has designed and developed with a unique Polyamide 6 modified with very good mouldability and improved resistance to thermal degradation making the material easier to rotomould with any rotomoulding machine.

Figure 6 Revolve® PA RDN

Matrix Polymers can bring a wealth of experience, expertise and knowledge of the rotomoulding industry thanks to its global footprint and capillary contacts across the industry. We believe that the rotomoulding process can play a key role in helping rotomoulders to penetrate new market segments by promoting unique technical solutions. The hydrogen value chain can present unique opportunities for organizations that are looking to differentiate and help the environment to decarbonize.

To find out more, get in touch:
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