ELGA VEOLIA

Market Opportunity: The Hydrogen Economy

Hydrogen generation & refueling stations offer a 10,000 unit opportunity by 2030

WATER TECHNOLOGIES

The Green Economy

Due to its low carbon potential, Hydrogen power is likely to be central to the future energy mix of many modern economies.

However, building hydrogen distribution networks to refuel fuel cell vehicles, will involve significant financial investment. As a result, on site hydrogen production in containers or skid based solutions are likely to be an important first step. A number of new energy providers are leading the market.

ELGA, our partners and our ultrapure water systems are already playing a key role and its ultrapure water systems is already playing a key role in the delivery of new on site Hydrogen Generation & Refueling Stations (HGRS).

A Global Opportunity

The current demand for HRS' is being driven by the use of fuel cells to generate electricity in material handling vehicles (MHVs) or forklifts.

Using Hydrogen Europe figures[1], the **next decade could see a 8 fold increase** in the demand for modular HRS systems such as those manufactured by Ultimate Power, McFy, Sera Group, NEL, HySTAT, Linde & others. Many of these manufacturers will be targeting manufacturing and distribution sites with large numbers of MHS's.

Due to the use of ultrapure water in the generation of hydrogen, manufacturers of containerized and container sized combined hydrogen generations and refueling stations (HGRS) **represent a significant opportunity for ELGA**.

The volume of 1MΩ.cm water required typically sits within the range offered by ELGA's product set. As a result, **ELGA is already working with major manufacturers of modular HGRS** to integrate ELGA units into the final manufactured units.

Forklifts are the largest single type of fuel cell operated vehicle in use today.

Legislators in Canada, California, China, Germany, Japan, Korea, and the United Kingdom have all implemented investment support schemes designed to encourage the rollout and thus reduced the cost of HRS.

USA

As a result of government legislation changes, there are more than 15,000 already in use in the USA, many of them converted using fuel cells from the US company Plug Power[2].

Japan

Japan plans to have 30,000 fuel cell powered MHV's in use by 2030[3].

Europe

If any additional 3,300 HRS are required in Europe by 2030 the global figure is likely to exceed 10,000 units. All will require pure water at 1MΩ.cm in the range of volumes generated by the ELGA product set.

60%[4]

of MHV's globally are already electrified, so the market sector is ideally suited to fuel cells

At the end of 2019 431 HRS' were operational globally[5] Hydrogen Europe[6] estimates that 3,740 HRS' will need to be installed in Europe alone by 2030

References

[1] https://hydrogeneurope.eu/sites/default/files/Hydrogen%202030_The%20Blueprint.pdf

[2] https://www.ft.com/content/0cfe0c5e-88f4-11e8-affd-da9960227309

[3] http://www.fuelcellindustryreview.com/archive/TheFuelCellIndustryReview2018.pdf

[4] https://www.ft.com/content/0cfe0c5e-88f4-11e8-affd-da9960227309

[5] https://fuelcellsworks.com/news/in-2019-83-new-hydrogen-refuelling-stations-worldwide/

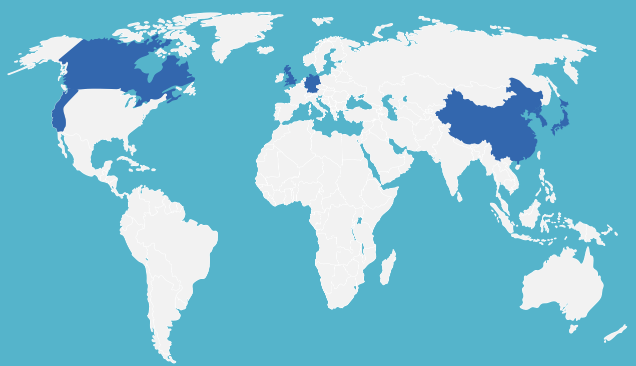
[6] https://hydrogeneurope.eu/sites/default/files/Hydrogen%202030_The%20Blueprint.pdf

Target Market Specifics

Over 90% of hydrogen in use globally today is manufactured at large industrial sites with a footprint similar to a petrochemical refinery. The hydrogen is then delivered to the refueling sites in cryogenic liquid tanker trucks, gaseous tube trailers, by rail or barge. Therefore transport costs are significant.

For sites with significant local demand combining hydrogen production with the refueling infrastructure has the potential to reduce the cost of hydrogen use. A number of manufacturers globally are developing containerized or container sized products to reduce the cost of using Hydrogen to fuel fleets of vehicles using hydrogen fuel cells.

Generating hydrogen through electrolysis is the core operation which generates the need for ultrapure water within modular HRS. **As Canada, California, China, Germany, Japan, Korea and the United Kingdom** are leading the activity in the rollout of hydrogen as fuel these territories offer the strongest potential demand.



Hydrogen production globally is on a very large scale – about 500 billion m3 (4 million tons) per year

Mostly used in industries such as fertilizers, petroleum refining and petrochemicals. About **95% of global hydrogen** is produced by the reaction of steam with methane. This is cheap but environmentally damaging and produces lower purity hydrogen.

Within combined hydrogen generation and refueling systems, electrolysis of water is used to produce hydrogen.

Electrolysis is currently used to produce about **4% of hydrogen globally**. A voltage is applied across an aqueous solution; the water is decomposed and hydrogen is produced at the cathode. This method has the major advantages of producing high purity hydrogen and, if a green source of electricity is used, has minimal environmental impact.

Manufacturers of the small scale combined hydrogen generation and refueling stations are already purchasing ELGA units for inclusion in the hydrogen creation process.

By 2030 it is estimated that

10,000

of these units could be required globally

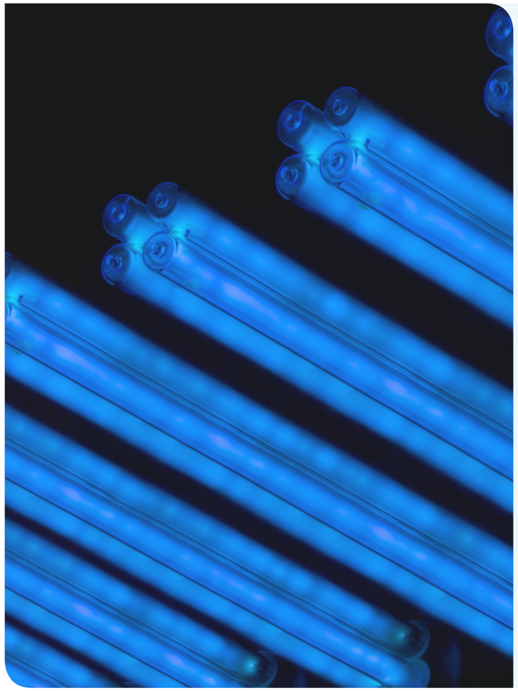
Hydrogen via Proton Exchange (PEM) Water Electrolysis

In PEM water electrolysis water is pumped to the anode where it is split into oxygen (O_2), protons (H^+) and electrons (e^-).

These protons travel via a proton-conducting membrane to the cathode. The electrons exit from the anode through the external power circuit, which provides the driving force for the reaction. At the cathode side the protons and electrons re-combine to produce the hydrogen, as shown in Fig.4.

The purity of water needed during electrolysis depends very much on the type of cell used – PEM, alkaline, solid oxide and microbial. PEM using an acidic electrolyte requires purer water to avoid fouling of the precious metal catalysts by chloride and fouling of the membrane with hardness ions e.g. calcium and magnesium.

Water with resistivity greater than 1MΩ.cm is typically adequate but higher purity would minimise contamination in the longer term. RO plus EDI has been proposed.



UV & Membrane

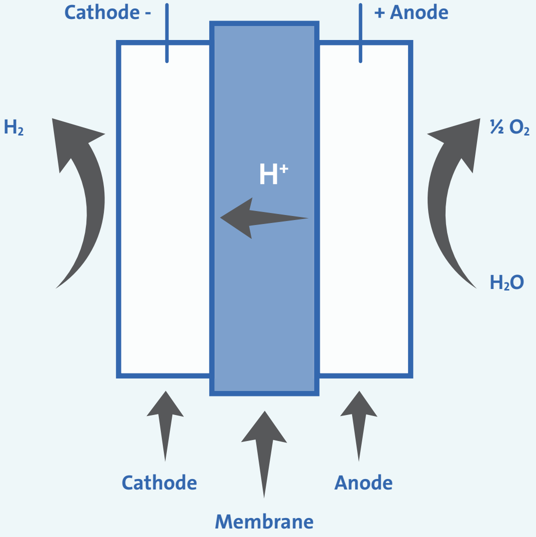
Another process under development is the use of UV and membrane distillation to produce a purified water feed for electrolysis.

In contrast alkaline cells operate in, typically at greater than >1MΩ.cm molar potassium hydroxide and have somewhat less strict purity requirements.

However, even here, minimising contaminants, especially carbonates and low solubility cations, would be advantageous. So again ultrapure water could be helpful.

Pem Electrolysis (Fig.4)

Anode: $H_2O \rightarrow 2H^+ + ½ O_2 + 2e^-$
Cathode: $2H^+ + 2e^- \rightarrow H_2$
Overall Cell: $2H_2O \rightarrow H_2 + ½ O_2$

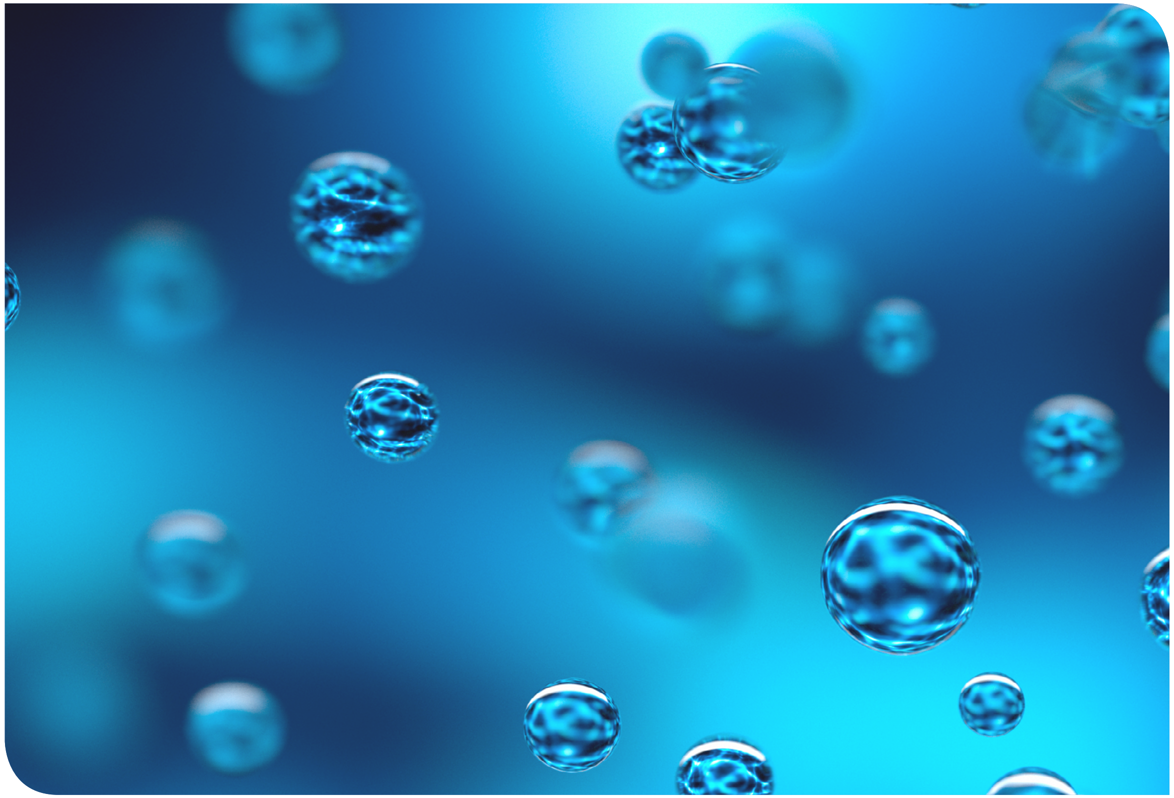


Wider Opportunities

The production of hydrogen for general use will always be on a very large scale and, if produced by electrolysis, will require purified water (typically with resistivity greater than 1 or 5MΩ.cm) in very large volumes.

Major Industry Players In HRS Manufacturer & R&D

- Air Liquide
- Air Products & Chemicals Inc
- Ballard Power Systems
- First Element Fuel Inc
- Fuel Cell Energy Inc
- Hydrogenics Corporation
- The Linde Group
- Nel Hydrogen
- Nuvera Fuel Cells
- Praxair
- Proton Onsite
- SunHydro
- Shell Global
- True Zero
- Ultimate Power.



1 Million Tons

Current global water requirements for electrolysis are estimated at 1 Million tons per year. Clearly there is scope in this expanding market.

Expanding

Canada, California, China, Germany, Japan, Korea and the United Kingdom are leading the activity in the rollout of hydrogen as fuel, these territories offer the strongest potential demand.

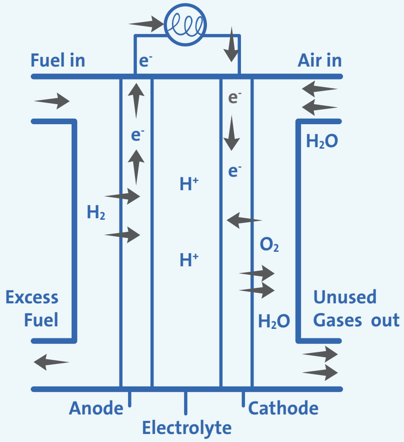
Hydrogen Fuel Cells

Fuel cells produce electricity using an electrochemical cell in which a fuel (often hydrogen) reacts with an oxidant (usually air) to produce water, electricity and heat.

They cause minimal global warming and have played an increasing role in the moves towards a carbon-neutral world. They have been developed commercially over the past 60 years and exist in a number of different forms and sizes, based on various chemistries and designs.

Fuel cells are used to provide primary and backup power for commercial, industrial and residential buildings and in remote or inaccessible areas. They are also used to power vehicles, including forklifts, cars, buses, trucks, ships, motorcycles, trains, satellites, space capsules and submarines.

A fuel cell converts chemical potential energy (energy stored in molecular bonds) into electrical energy by two separated electrochemical reactions. A PEM (Proton Exchange Membrane) cell uses hydrogen gas and oxygen in air as fuel. The products of the reactions are water, electricity, and heat.



Electric Current (Fig.1)

As shown in Fig.1, in a hydrogen-fuelled polymer electrolyte membrane fuel cell (PEMFC), hydrogen enters on the left and is oxidised to protons and electrons by the action of a precious metal catalyst at the anode. Protons move through the membrane electrolyte to the cathode. As the membrane is an electric insulator, electrons are forced to flow in an external electric circuit, producing an electrical current. At the cathode (usually nickel), oxygen from air reacts with the protons to produce water, the only chemical waste product from a hydrogen-operated PEMFC.

Hydrogen Fuel Cells

The energy efficiency of a fuel cell is generally between 40–60%; however, if waste heat is captured in a cogeneration scheme, efficiencies of up to 85% can be obtained.

The differences in the technologies depend mainly on the electrolytes used in the cells: proton exchange membrane fuel cells (PEMFC), phosphoric acid fuel cells (PAFC), molten carbonate fuel cells (MCFC), solid oxide fuel cells (SOFC) and alkaline fuel cells (AFC). Direct methanol fuel cells (DMFC) use a methanol and water feed. The difference in start-up times range from 1 second for PEMFC to 10 minutes for SOFC. PEMFCs are the most widely used type of cell.

The 70,000 fuel cells sold in 2019 can produce over 1,100 megawatts (MW) of electricity, an increase of 40% in 2018.

They range from those small enough to be hand-held up to large fixed units suitable for providing power for a small town. **Over 15,000 vehicles** of all types and **55,000 stationary** systems were shipped in 2019.

Hydrogen fuel cell electric vehicles offer a unique combination of features as a **zero-emission alternative** to conventional vehicles. Fuel cell powertrains, converting hydrogen to electric power to propel the vehicle, tend to be about twice as efficient as those on conventional vehicles.

Hydrogen fuel cell vehicles are typically capable of long trips (i.e.,**over 500 kilometers or 300 miles**) and a time that is comparable to conventional vehicles. Furthermore, fuel cell vehicles are expected to be less expensive than conventional vehicles in the long run.

A typical fuel cell produces a voltage from 0.6–0.7 V.

To be of any practical use many cells are operated together in a “fuel cell stack”. To deliver the desired amount of energy, the fuel cells can be combined in series to yield higher voltage, and in parallel to allow a higher current to be produced. The cell surface area can also be increased, to allow higher current from each cell. By varying the number and size of the cells, the fuel cell system can be adjusted to suit almost all kinds of requirements.