Electrolyser technologies

PEM vs Alkaline electrolysis

By **Rob Cockerill**

So you know that green hydrogen is the ultimate shade of this clean fuel that can truly and deeply decarbonise industry and society. The costs have been dramatically improved in recent years alongside the ever-growing renewable energy assets operating in developed economies, its scale is actively being ramped up today, and there is now little doubt over the overwhelmingly positive impact that green hydrogen will have for us all.

You know too that electrolysers are one of the key building blocks of this green hydrogen society, cited as such by the International Energy Agency (IEA) and at the heart of all green hydrogen policies and strategies.

But do you know the difference between the different types of electrolysers? Do you know which type of electrolyser technology is best suited to your needs, or what the characteristics of each are?

Here we take a look at two of the most dominant means of electrolysis in the market today, proton exchange membrane (PEM) electrolysis and alkaline electrolysis (AE), with the latter having been around for over a century.

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Electrolysis at-a-glance

Green hydrogen is so significant because it's a form of hydrogen made with entirely renewable electricity – it's a case of pure energy meets pure water, and the result is a completely emission-free hydrogen fuel.

The process behind that end product, is electrolysis. As we explored in last month's edition of H2 View, electrolysers use an electrochemical reaction to split water into its components of hydrogen and oxygen and – using renewable electricity (whether from solar or wind power or both) – this process emits zero CO_2 (carbon dioxide).

The chemistry behind electrolysis is fundamentally the same, but as Hydrogen Europe explains, electrolysers are differentiated by the electrolyte materials and the temperature at which they are operated. This means electrolysers can be grouped into two distinct means, namely low-temperature electrolysis (LTE) and high-temperature electrolysis (HTE). The latter group is widely regarded as still being at an advanced R&D stage, or not as commercially available yet.

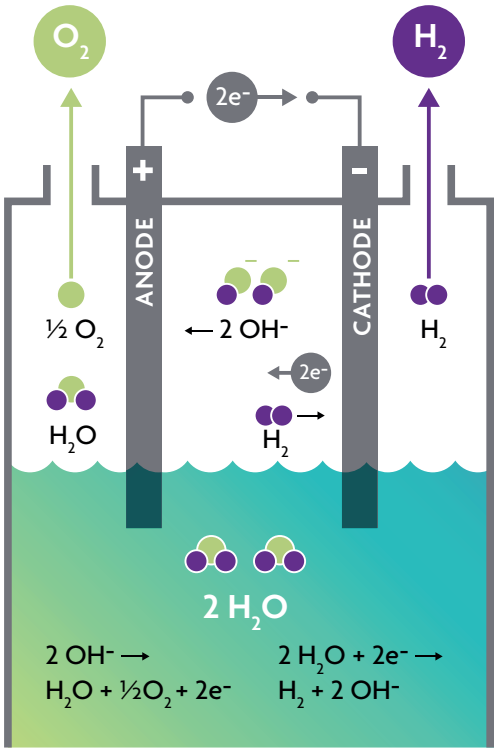
> **"Green hydrogen is so significant because it's a form of hydrogen made with entirely renewable electricity..."**

The LTE bracket of electrolysers includes alkaline electrolysis (AE), PEM electrolysis and AEM electrolysis (anion exchange membrane), and it is the former two types of commercial electrolysis today that we dive a little deeper into here.

PEM vs alkaline

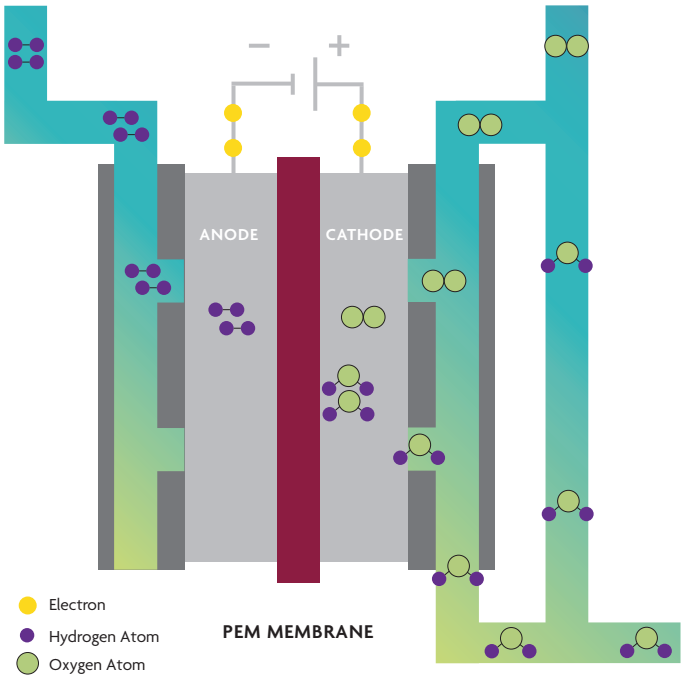
PEM technology utilises a solid polymer electrolyte membrane and an applied current to separate hydrogen (via protons) and oxygen from water. The electrons are then transported from the anode electrode to the cathode electrode via the electrical circuit. >>

Figure 1. Alkaline Electrolysis



Source: H2 View

Figure 2. Proton Exchange Membrane (PEM) Electrolysis



Source: H2 View

>> The electrons combine with protons to create hydrogen molecules.

When it comes to the advantages of PEM technology, it's often noted that PEM electrolysis has a fast response ramp-up and ramp-down capability, as well as a wide dynamic operating range of 0-100% – making it ideal for generating hydrogen using excess renewable energy. PEM technology for off-grid operations is also compact, reliable, and low maintenance; suitable for small-to-medium industrial applications. Another advantage of PEM electrolysis is its synergies with PEM fuel cells and the ability to capitalise on advancements in materials and processes already being implemented at scale. All of which are factors which could be seen as crucial to the hydrogen society moving towards realisation of its potential.

Alkaline electrolysers, however, use a liquid electrolyte (potassium hydroxide solution in most cases) with a porous separator between the anode and cathode. In this case, hydroxide ions cross the separator via the liquid solution to form oxygen and water. At the other electrode, hydrogen is co-generated with hydroxide ions.

One company at the forefront of all things electrolysis, is Nel Hydrogen. The famously purple-branded pure player provides – and pioneers – hydrogen solutions covering the entire value chain: from hydrogen production technologies to the manufacture of hydrogen fuelling stations, through to providing all fuel cell electric vehicles (FCEVs) with the same fast fuelling and long range as conventional vehicles today. The company is a leader in all things electrolysis and has installed several of the largest hydrogen plants in history.

The company is active across both PEM and alkaline electrolysis, and Pietro d'Erasmo, Technical Consultant at Nel Hydrogen

Electrolyser and a stalwart of the industry, told H2 View about the benefits of alkaline electrolysis – affirming that this technology today is extremely efficient, reliable and cost-effective. "The alkaline electrolyser is a robust and simple way to generate hydrogen gas from water having electric energy as the main input," he explained. "The technology is mature, and the safety aspects are well known. An electrolyser plant is very flexible. It can be started and brought to maximum production within less than 30 minutes. The capacity can be changed between 15% and 100% in around 10 minutes with the alkaline atmospheric electrolyser."

"With high pressure electrolysers, the variations of capacity between 10% to 100% take only seconds, and even less than a second can be achieved. The water splitting process has no emissions to the atmosphere, so green electric power will give green hydrogen and in turn, green energy (for the transport sector)."

Co-existing and complementary

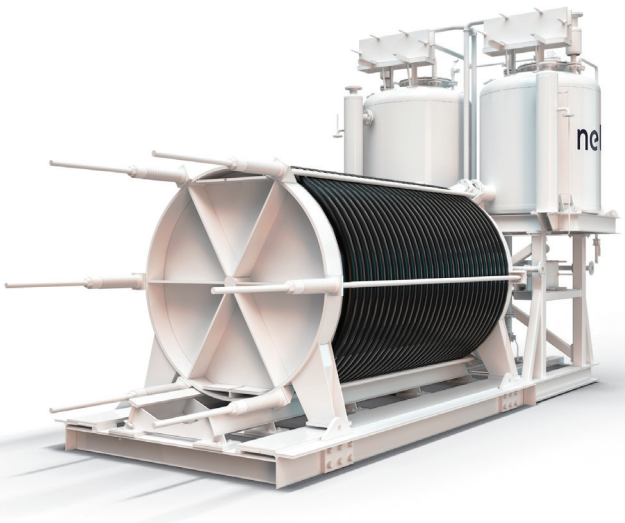
Both PEM and alkaline electrolyser technologies have the ability to deliver hydrogen onsite and on-demand, and hydrogen that is 99.999% pure, dry and carbon-free.

The question of PEM vs alkaline, therefore, comes down to the application and parameters at play. Indeed, a colleague of d'Erasmo's at Nel, Vice-President of Research & Development Dr. Kathy Ayers, previously told H2 View that, "They both have their advantages for different applications, and neither has reached the end point for improvement."

"Scale, input power characteristics, electricity cost, and rate of technology development will all likely be factors in which technology fits a given application in a given timeframe."

Asked himself if he sees a 'winner' between alkaline or PEM electrolyser technology sometime in the future, d'Erasmo responded, "Who knows? I believe that both technologies will play a role in the future. I think we will see huge alkaline plants providing hydrogen gas to huge industrial processes, for making fertiliser or steel or huge central plants for fuel, for example."

"Maybe the PEM electrolyser will be preferred for decentral production of hydrogen or where very compact (small footprint) plants are required. It may also be preferred where the electrolyser is located in public area, as PEM electrolysers utilise pure water and do not have a liquid chemical solution as the electrolyte."



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Future developments

It might be argued that the electrolyser industry has taken baby steps over the last decade(s), largely due to a lack of a volume market. Previous steps forward have seen electrolyser installations move from kW size to MW side, driven by technology measures.

As 2020 draws to a close, however, we can see the scale of both electrolyser projects and electrolysis significance rapidly growing. Now and over the course of the next decade, we are moving from MW size to GW size – driven not only by technology advances but most pressingly by necessity and the various policies and market forces delivering against that need. This year alone has seen a multitude of announcements of huge new offshore wind projects linked to GW scale electrolysis. The supply chain is developing, the scale-up is in-progress and the vision shows signs of being realised.

That vision will evidently comprise a balance of PEM and alkaline electrolyser technologies, with companies like Nel known to be leveraging their expertise in actively developing both. H2V

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