AEM's unstoppable rise

Charting AEM's ascent as an electrolyser technology

By Stephen B. Harrison, sbh4 consulting

PEM electrolysis has its origins in the General Electric Company's Wilmington labs in the 1970s. The idea to create the PEM electrolyser was enabled by the invention of the solid polymer electrolyte (SPE) membrane. In recent years, the acronym PEM has gained preference, meaning polymer electrolyte membrane, or proton exchange membrane.

The need to innovate in the field of water electrolysis to make hydrogen or oxygen was clear. It was essential to overcome some of the challenges associated with alkaline electrolysis technologies.

The diaphragm in an alkaline electrolyser is porous and there is a chance that oxygen and hydrogen gases can pass through it and create an unsafe explosive gas mixture. The risk of this is especially high when the electrolyser turns down to a low percentage of its maximum operating power input. PEM electrolysers suffer less from this issue.

AEM: Challenging the green hydrogen paradigm

Green hydrogen from hydropower was proven to be possible on many large dams in Egypt, Norway, and Zimbabwe throughout the last century. These schemes operated alkaline electrolysers on a continuous basis. But connecting an electrolyser to variable and intermittent wind and solar was only deemed possible through the emergence of PEM.

L J Nuttall, working at General Electric, conceived the idea of a 74MW PEM electrolyser facility connected directly to intermittent and variable renewable power. The idea of connecting an alkaline electrolyser directly to wind and solar power would not have been considered at that time, since there was no facility for large scale lithium-ion battery backup, as is possible today.

In the same way that PEM electrolysers have innovated and scaled up in the past 50 years to challenge the dominance of alkaline electrolysers, new electrolyser technologies are now emerging.

One high-potential electrolyser technology that is in the ascendancy is called AEM due to the use of an anion exchange membrane. In the past 5 years, the rise of AEM appears to have gained momentum internationally and its entry into the major league of green hydrogen production processes would now seem to be unstoppable.

From start-up to scale up

Cavendish Renewable Technology, based in Melbourne, Australia focuses on AEM electrolyser technology development. Their rapid transition from startup to scale up will see them manufacturing electrolysers within the next few years for sale to the local market and export.

They have also licensed their technology to Adani New Industries ▶

Ltd (ANIL). ANIL will produce the electrolysers in India where there is a strong drive towards renewable energy and green hydrogen. To support this scale up of electrolyser manufacturing and deployment ANIL is setting up a state-of-the-art vertically integrated electrolyzer manufacturing plant in India which will have the capacity to produce 5 GW of electrolysers per year. As reported in the *Economic Times of India* in September 2022, the ANIL gigafactory is part of Adani Group's plan to invest $70bn in green technologies and projects by 2030.

Aniruddha Kulkarni, CEO of Cavendish Renewable Technology has been researching and working with PEM, alkaline and solid oxide electrolysers for many years. He says "this has given me the opportunity to experience the benefits and limitations of each of these incumbent technologies first hand.

"We started up less than three years ago. Since then, we have raised A$6.7m in capital to fund our AEM electrolyser technology development programme. I am convinced that the advantages of low capex cost, low cost of ownership and low cost of green hydrogen production from variable and intermittent renewable power will launch AEM into a leading position."

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Affordable green hydrogen

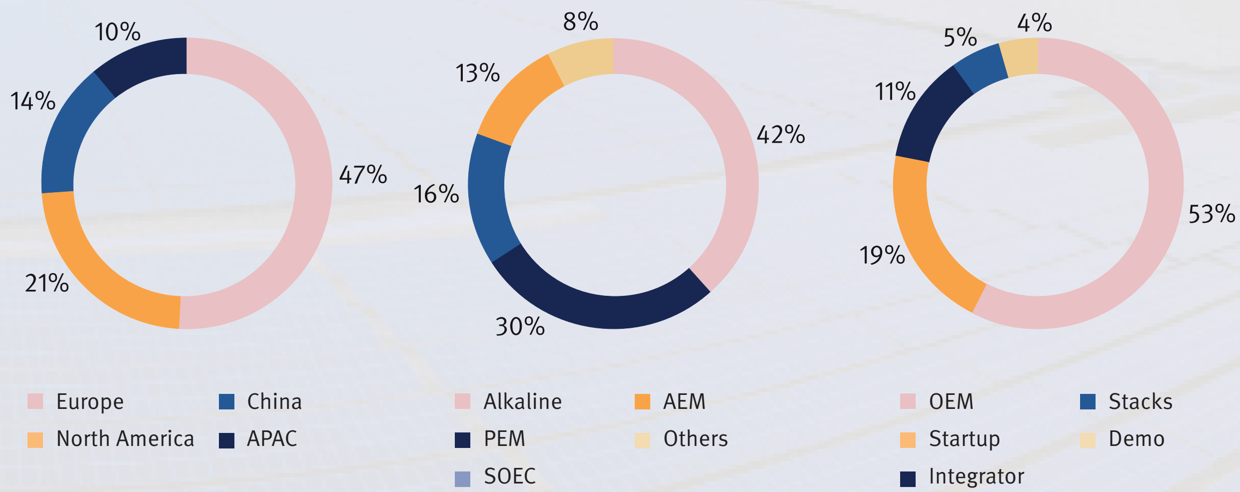
The team at Cavendish Renewable Technology has innovated an AEM electrolyser system that can be manufactured at less than $250 per kW of power input. That is significantly less than the cost of alkaline electrolysers available in the market today and will contribute to achieving a low levelized cost of hydrogen (LCOH).

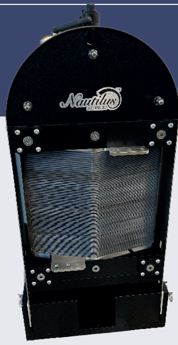
"About half of the cost or our system will be related to our unique AEM stack", confirms Kulkarni. "The other half is related to the balance of plant equipment." This cost ratio of BOP and stack is similar to that of manufacturing PEM electrolyser systems. Balance of plant refers to rectifiers, water purification and hydrogen conditioning equipment. One of the reasons that AEM electrolyser systems can be provided at low cost is that the ultra-pure water supply does not need to achieve the same degree of purity as a PEM system.

Furthermore, AEM stacks generally operate with potassium hydroxide (KOH) lye with a concentration of 1 mol per litre of water. This is much less aggressive than the 6 molar KOH electrolyte that conventional alkaline electrolysers use. The implications are that the pumps, pipes, and heat exchangers in the AEM system will have a longer life.

Kulkarni adds that "our AEM

Electrolyser producers and emerging players





© EVōLOH | **AEM electrolyser stack**

© Cavendish Renewable Technologies | **Modular and integrated AEM electrolyser**

electrolyser produces hydrogen at 30 bar pressure. In some applications, this can avoid the need for a hydrogen compressor which reduces the system cost."

If very high-pressure hydrogen is required for ammonia synthesis or hydrogen refuelling stations, the capex and opex of the downstream compression is minimised since the early stages of compression can be avoided with hydrogen being generated at 30 bar.

Making sure it all 'stacks up'

Cavendish Renewable Technology has innovated a proprietary electrode catalyst coating process that allows their AEM electrolyser to operate at 50-to-60°C, about 20°C cooler than existing AEM electrolysers.

"Through the implementation of an effective low-temperature catalyst and innovative stack architecture, we have extended the AEM stack life and proven its performance over 5,000 hours of dynamic operation involving start stop cycles", says Kulkarni. "This longer stack life will break down one of the historical barriers to the wide-scale deployment of AEM electrolysers."

The Cavendish Renewable Technology AEM stack is scaled up in area and has an active area above 4,000 cm2. The membrane that has been selected is not a fluoropolymer so there is no risk that legislation related to the banning of so-called 'forever chemicals' will make the stack technology obsolete.

Abundant, safe, and eco-friendly materials of construction

Dr Art Shirley, Chief Commercial officer at EVōLOH in the USA explains that his team "set out with the premise that existing electrolyser technologies cannot scale rapidly to what the world needs to control global warming.

"For example, the PEM electrolyser has inherent limitations related to the jewellery box of materials used to build the stack. AEM uses earth-abundant materials and is therefore highly scalable."

The EVōLOH AEM stack operates in a basic environment with a pH just greater than 7 to allow the anion exchange. Shirley adds that "the electrolyte is mildly buffered water. You could drink it if you chose to". At these conditions the electrolyte is safe to handle and compatible with the most common grades of stainless steel and plastics.

EVōLOH has elected to use an AEM membrane that is not a fluoropolymer. "Whatever the international environmental policy decisions related to the future of fluoropolymers might be, we are confident that neither our technology nor our scale up would be disrupted", confirms Shirley.

Efficient and durable stacks

EVōLOH's development team in California has access to more than 20 test rigs for testing and developing their AEM stacks. A key innovation behind the stack design is the electrode manufacturing process, for which patents have been applied. Another proprietary innovation is the method of controlling certain ions in the lye recirculation to extend the membrane life.

"We have eliminated membrane degradation and fouling issues by focusing on the absence of certain critical impurities." The first commercial stacks, which are due to be available in 2025 will have a similar or better lifetime than their AEM and PEM peers.

"The EVōLOH AEM stack has demonstrated almost no stack performance decay during our multi-month test periods, some of which have been running for around a year", adds Shirley. "Our testing has validated that high operating temperatures in

the range of 70 to 75 °C are possible without membrane degradation."

A high operating temperature simplifies the balance of plant requirements for cooling the stack. In AEM systems, higher temperatures can also yield better efficiency. EVōLOH's plan is to go to market with a stack level efficiency of 47.9 kW/kg of hydrogen. That would typically result in a system efficiency around to 50 kW/kg of hydrogen.

The first-generation product is proposed to produce hydrogen in the range of 10 to 15 bar which avoids the costly first stages of compression when producing ammonia as a hydrogen derivative.

Unlocking the potential of low-cost stranded green electrons

The AEM stack developed by EVōLOH is highly tolerant to intermittent power. It can ramp down to zero power input and can resume operations from a cold start in less than two seconds. It is tailored for use with intermittent and variable renewable power generation.

Shirley says that there are "large amounts of stranded renewable power generation potential around the world. These low-cost green electrons where there is no demand for GW of cheap power. This potential can be tapped by project developers who see the potential to produce green methanol or ammonia for export.

"However, large projects can only be viable if they can secure multiple GWs of electrolyser capacity. This is where our scalability wins. We are unlocking the biggest renewables and green hydrogen projects for the coming decades."

Designed for manufacturing scalability

The stack design was iterated not only to yield high technical performance and durability, but also to enable low-cost rapid, automated manufacturing of the stack. "Take the stack tensioners as an example," injects Shirley, "our stack design avoids stack assembly costs associated with conventional structures. We started with the end in mind when we designed the stack."

During large scale green hydrogen project execution, EVōLOH would rely on EPC contractors to integrate their stacks into a functional electrolyser scheme. The contractor would be expected to procure the balance of plant equipment around the stack according to the best local supply conditions.

To enable scalability, the EVōLOH approach is to look beyond the stack as a product and view the stack manufacturing factories themselves as a product. The scale up strategy will involve stack production partnerships with green hydrogen project developers as manufacturing partners. "They want to manufacture for themselves", asserts Shirley. "Our technology allows AEM stacks to be made at speed and scale."

"Then they can control availability, which can be a more important driver than cost in many project timelines. In total, I have talked to multiple project developers about 600 GW of market potential. Much of this is being held back by limited by electrolyser capacity today." gw

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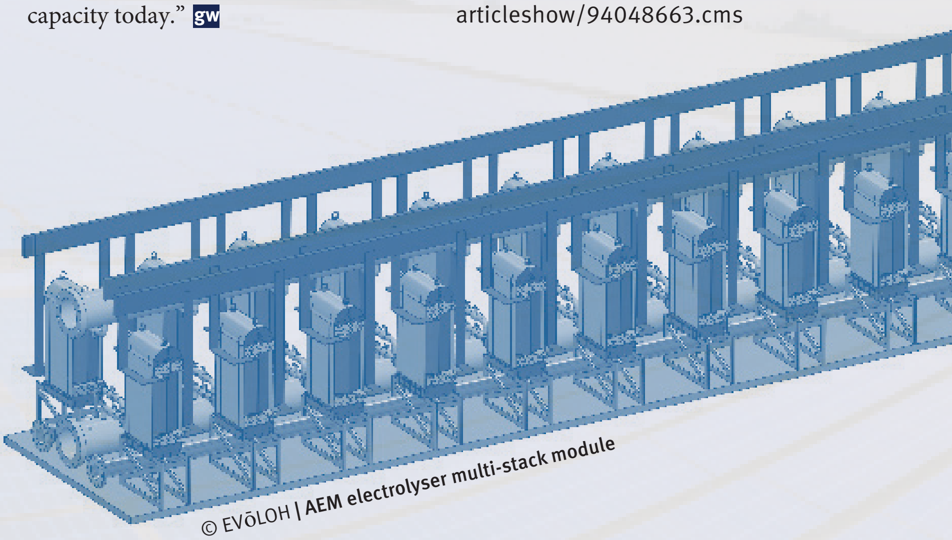
MORE INFORMATION

1. https://economictimes.indiatimes.com/industry/renewables/adani-group-to-build-3-giga-factories-as-part-of-70-billion-clean-energy-investment/articleshow/94048663.cms



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