# Challenges of Scaling up Electrolyzer Manufacturing Paves the Way for Innovation

**Selene Law, Alex Crutchfield**

**Abstract**

**The green hydrogen industry faces challenges like rising costs, policy uncertainties, and supply chain issues. Established players and innovators are striving to improve electrolyzer technology, with potential for cost reductions, increased efficiency, and wider applications. Despite hurdles, the need for affordable green hydrogen to decarbonize hard-to-abate sectors is evident.**

## Introduction

Only few years ago, green hydrogen—hydrogen produced from renewable electricity by electrolysis was poised to be the one-size-fits-all saving grace of a solution to decarbonization, but as the enthusiasm and cheap money flowing into the green hydrogen space abate, a much more sober picture is starting to emerge.

Despite a raft of announced gigafactories that would help scale up established technologies, developers are struggling to take final investment decisions (FID) amid escalating project costs as interest rates across the world have boosted inflation while convoluted policy environment in key demand markets adds to uncertainty. The cost competitiveness of large-scale green hydrogen production remains a challenge when compared to grey hydrogen, which is produced from fossil fuels without carbon capture.

There is also some upside. A key piece of legislation emerged from the US last year, which is catalyzing the electrolyzer market. In 2022, the US government ratified a key piece of legislation, the Inflation Reduction Act (IRA), which has been the greatest step forward policy-wise in addressing this issue of high hydrogen costs by creating a tax credit for up to $3/kg of green hydrogen with an inflation adjustment of 2% per year for the first 10 years of operation (their lifetimes are typically up to 30 years). The tax cuts run only through 2032, so projects starting up in 2023 would benefit from the full 10-years' worth of credits, while plants opening later would receive progressively less.

## Growing Pains of Scaling up Hydrogen

Large developers have had to lock in their chosen technology, regardless of how effective or expensive it is, to benefit from the IRA tax credits. Many have announced gigafactories that would help scale up their production but have struggled with streamlining manufacturing and securing concrete offtake contracts. Added to this, the lack of transparency and merchant market for pricing is piling on uncertainty. Even though a number of pricing agencies, such as Platts and ICIS, are publishing hydrogen prices, no volumes are traded on the open market yet, and the majority of deals are done on a bilateral basis. This also explains the buyer's reluctance to sign up for long-term contracts.

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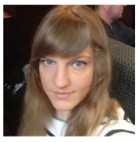

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**While alkaline water electrolysis and proton exchange membrane (PEM) technologies have both been around for decades, neither have never been utilized on a large scale, so developers have run into difficulties when scaling up manufacturing. An electrolyzer-equipment that uses electricity to break apart a water molecule into hydrogen and oxygen-can be a rather complex technology, where the electrolyzer stack is only a part of the system and the remaining balance of plant (BoP) mainly serves the purpose of supplying the electrolyte and power to the stack, as well as separating gasses from the electrolyte. BoP costs can typically account for 50% of the project costs.**

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Developers have faced problems with ensuring a stable flow in the system as well as overall stable and reliable performance. US industrial conglomerate and PEM electrolyzer developer Cummins recently confirmed that 15 of its HyLYZER 500 electrolyzer units had to be switched off because of performance issues.

## A Few Instances

British electrolyzer producer ITM Power has built a 1 GW gigafactory in Sheffield, but the company has been plagued with cost overruns and project delays despite announcing a major expansion to its Bessemer Park electrolyzer project in 2023. The company has struggled to take FIDs and secure funding for its projects, and in its most recent capital market update, ITM Power conceded that "ITM underestimated the competencies and capabilities required to transition from a research and development company to a volume manufacturer". Unfortunately, capital markets are unforgiving, and ITM's share price has slid from its peak of $682 in 2021 to $79.54 in September 2023.

American electrolyzer producer Plug Power is also facing challenges, as its share price has tumbled more than tenfold from its 2021 peak of $65.77 to $7.99 in September. Plug Power has previously argued that the temporal matching requirement that the US government is proposing, which requires green hydrogen production to be matched with renewable supply on an hourly basis, is detrimental to the green hydrogen landscape. The company has similarly been embroiled in lawsuits, faced production delays, and recently announced that it will be expanding its production in Finland, where the regulatory environment is more supportive compared to the US.

**Comparison of Key Electrolyzer Technologies**

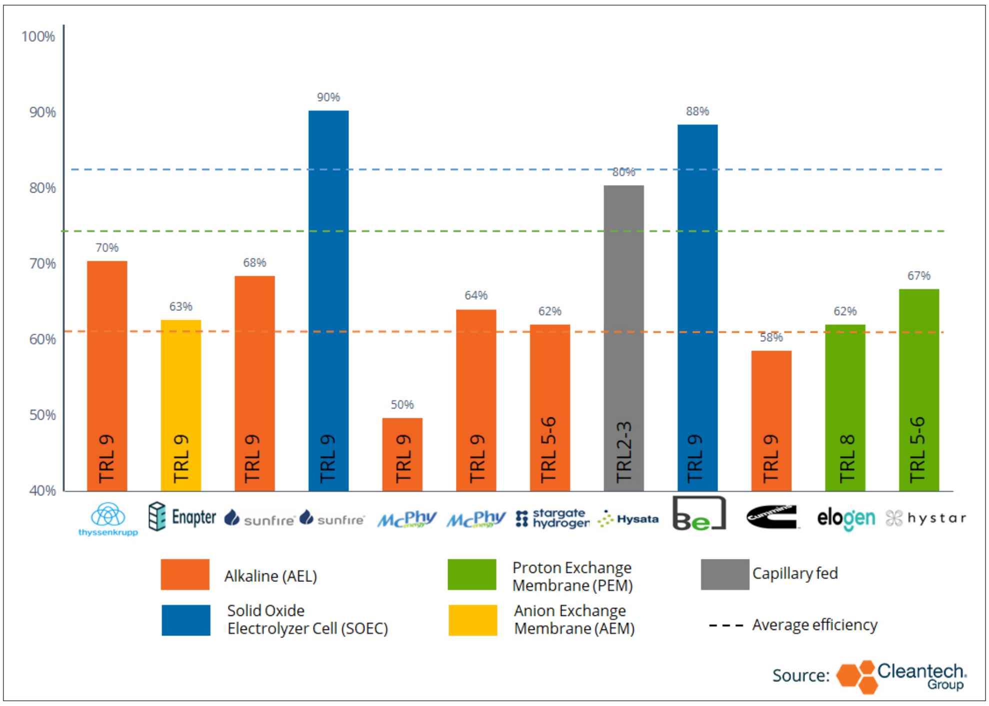
| | AEL | PEM | SOEC | AEM |
|---|---|---|---|---|
| **Advantages** | • Cheap components<br>• High durability<br>• Reduced maintenance costs | • Low partial load<br>• Rapid cycling, flexible<br>• Suitable for grid, res balancing<br>• Better H2 purity compared to AEL | • Efficiency of 80-90%<br>• Low level of minimum load<br>• Low operating costs<br>• Cheap catalysts | • Less prone to corrosion<br>• Reduced potential of electrolyte leakage<br>• High purity of H2<br>• Inexpensive catalysts |
| **Disadvantages** | • Can't couple with renewables<br>• Low start-up time<br>• Low current density and efficiency<br>• Low H2 purity | • Costly catalysts and electrodes<br>• Acidic environment erodes system lifetime<br>• Gradual decline of membrane performance | • Long start-up and break in time<br>• Rapid degradation of components<br>• Low durability, short lifetime<br>• High CAPEX | • High minimum load requirement<br>• Sensitive to CO2 intrusion<br>•Nascent technology |

Source: Oxford Institute of Energy Studies

## Tough Times

Additionally, the triple-digit increase in iridium prices since 2020 has hampered the development of PEM electrolyzers. It doesn't help that the European Union (EU), one of the key hydrogen importing regions, is considering banning fluoropolymers, a key component in alkaline and PEM electrolyzers, which would significantly hamper the development of the green hydrogen market.

Indeed, the last few years have not been kind to electrolyzer developers. The share prices of eight select pure-play hydrogen producers have plummeted by an average of 84% from their




peak in 2021. Yet, industry participants argue that the issues developers are facing are not of technical nature but rather stem from their lack of experience when operating large electrolyzer systems, compounded by supply chain issues, which should resolve in time.

Established players will set the pathway for scaling green hydrogen production, facing the trials and tribulations of implementing new technology. Innovators that are currently trialing new technology and business models are likely to be ready to start scaling up in five years, by which time they will benefit from a well-trodden route to the market.

## Innovation Focuses on Efficiency Improvements in BoP and Stack

The electrolyzer landscape is getting close to saturation, with no shortage of different companies and technologies, which points to consolidation on the horizon. Despite this, there is space in the market for innovation, as newcomers are trying to overcome some of the key challenges of cutting down the use of platinum group metals, ensuring reliability and durability when ramping the system up and down while using variable renewables and improving the efficiency of membranes and BoP.

Innovators like US company Aqua Hydrex, are developing improved alkaline models that optimize the balance of plant (BoP) and eliminate a flowing electrolyte loop that causes corrosion. BoP accounts for roughly 20% of all system costs for alkaline electrolyzers. UK-based Oort Energy is developing technology that reduces hydrogen crossover into the oxygen loop, increasing safety while improving the performance of the membrane. Research from the International Renewable Energy Agency (IRENA) shows that going from a 10 MW/year scale to 1 GW/year allows for a 70% potential cost reduction, while semi-automating stack assembly can yield 90% cost savings. Electric hydrogen from the U.S. is trying to gain an edge with a vertically integrated business model, driving costs down across the value chain, and is going even bigger with 100 GW facilities. Recently, the company announced that it will supply electrolyzer systems for New Fortress Energy in what will be one of the largest green hydrogen facilities in North America.

Cost savings can also come from increased standardization at the system level, which would enable developers to buy off-the-shelf components rather than produce them themselves. In February, classification company DNV launched a joint industry project with 18 industry partners to promote standardization in electrolyzers. Previously, standardization played a key role in decreasing wind and solar PV project costs.

## Solid Oxide Electrolyzers

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**Many innovators have eschewed those models altogether and are working to decarbonize hard-to-abate sectors with solid oxide, which has higher efficiency than any commercial electrolyzer. However, solid oxide electrolyzers operate in the 500–900 °C temperature range, while most other electrolyzers work at ambient temperatures. The specialized application of solid oxide technology is primarily observed in heavy industries such as steel manufacturing, ammonia or chemical production, and refining. In these industries, a crucial aspect to consider is the utilization of waste heat. The incorporation of thermal energy into the functioning of a solid oxide electrolyzer in order to enhance the power supply results in improved electrical efficiency of the equipment and significant reductions in operating expenses**

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In these industries, a crucial aspect to consider is the utilization of waste heat. The incorporation of thermal energy into the functioning of a solid oxide electrolyzer in order to enhance the power supply results in improved electrical efficiency of the equipment and significant reductions in operating expenses. Advanced Ionics, cognizant of the advantage solid-oxide electrolyzers have by using excess heat, has developed a 'symbiotic' electrolyzer that works at as low as 100°C. The company captured $12.5 million in Series A funding in August from heavy-hitters like BP, Mitsubishi Heavy Industries, and Clean Energy Ventures to facilitate the initial deployment of its technology.

## Alkalines Exchange Membrane Electrolyzers

Additionally, anion exchange membrane (AEM) electrolyzer manufacturers like Enapteror Versogenare attempting to circumvent the necessity for noble metals used in PEM at the same efficiency rate. This process demonstrates efficacy even when implemented on a smaller scale, rendering it appropriate for decentralized applications. Sunfire, notable for syngas and multiple electrolyzer types, partnered with Frauhofer IFAM and Canadian materials producer Ionomr Innovations to research how to scale AEM to an industrial level. US AEM innovator Verdagy is looking to gain an edge by using higher current densities, which will help improve electrolyser efficiency and stability.

Despite gaining significant interest from venture capitalists, it is unlikely that the technology readiness level (TRL) of this particular type will reach the levels of PEM or alkaline until the latter part of the 2020s. However, it appears to be the type to keep an eye on, as even electrode innovators like Sungreen $H_2$ of Singapore are developing their own class of AEM electrolyzers for the future market.

## Other Developments

Further down the scale of TRL, there are promising signs of electrolyzer innovation. Hysata, an Australian developer of an electrolyzer that feeds water into the system using a capillary separator between the electrodes, recently received over $20 million in government funding to build and test a 5-MW system. By eliminating all the main sources of electrical resistance in the unit, the company boasts a theoretical efficiency of 95% compared to the average 75% of electrolyzers on the market. Other innovators are pursuing membranelessel ectrolyzer technology that uses sea water, likes HYp. The company intends to take its electrolyzer out of the R&D lab to pilot in the US in 2024. Seawater as an input remains a topic of interest down to the university level, as researchers from Shenzhen University and Nanjing Tech University are studying ways to create electrolyzers that perform at the same rates as conventional alkaline without a separate desalination process. SHYp faces competition from Ohmium/Aquastill, Torvex Energy and membraneless electrolyzer producer $CPH_2$.

While the question of who reaches price parity for grey hydrogen first remains to be seen, global market dynamics are showing a consensus that electrification is not enough and we need affordable green hydrogen to reduce carbon emissions in hard-to-abate sectors. While the jury is still out on exactly which end-user markets will successfully adopt green hydrogen, it is clear that it can displace the 94 tons of grey hydrogen that are being used across industries globally. Electrolyzers are a key component in making this possible.