The tide THAT LIFTS all boats

Cover story

Kathy Ayers, Ph.D., Wilhelm Flinder, and Russell Morgan, Nel Hydrogen, outline why electrolyser innovation is for the collective good of the entire hydrogen economy.

The sustainable hydrogen industry faces a deceptively simple problem: it needs to compete with established energy carriers, hence the cost of producing it must come down. The electrolyser sits at the heart of that equation, where the single most powerful lever for reducing the levelised cost of hydrogen (LCOH) is continuous and rigorous research and development (R&D). That effort works across two inseparable dimensions: the electrochemical performance of the stack itself, and the engineering intelligence that determines how stacks are packaged. Advances that either translate directly into lower project costs or energy efficiency – where the interaction between the two is where some of the most significant gains are now being realised.

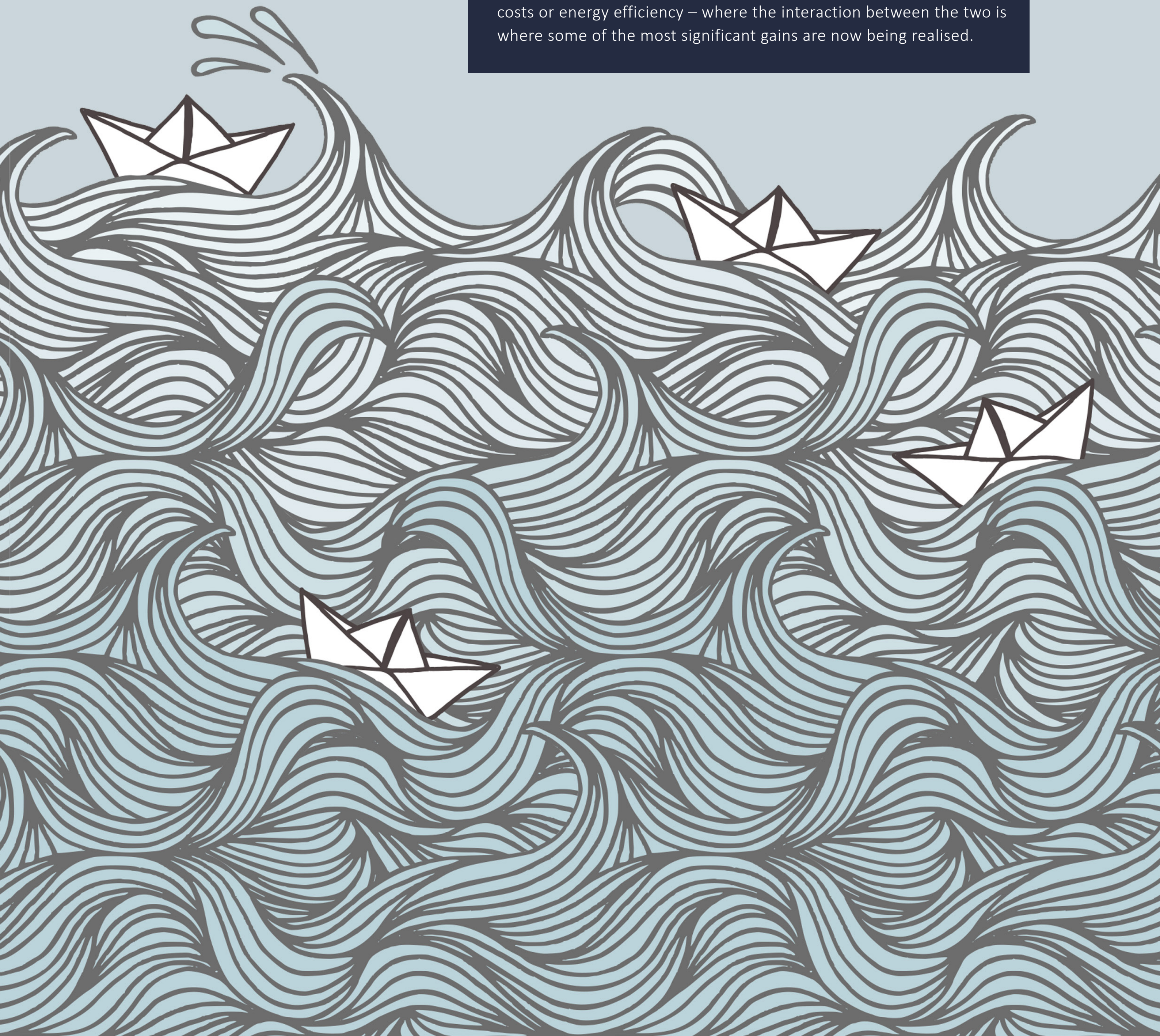

Figure 1. Nel's prototype pressurised electrolyser completed 'first gas' in December 2025.

However, electrolyser R&D is unusual compared with innovation in many other sectors, as the benefits cannot stay behind closed doors. Every meaningful improvement in stack efficiency, every breakthrough in materials science, and every advance in manufacturing technique radiates outward – improving project economics not just for the company that made the discovery, but for the industry at large. R&D in electrolysis is, in the truest sense, for the collective good of the whole hydrogen economy.

This principle has guided nearly a century of work in electrolysis at Nel. Having delivered more than 7000 electrolyser stacks to over 80 countries since 1927, the company has watched its own innovations and advances – as well as those of its competitors – leading the way into an industry that is now on the brink of gigawatt-scale deployment. This article will explore how a next-generation pressurised alkaline electrolyser platform offers another example of how R&D investment is creating value beyond the company that undertakes it.

The compounding effect of efficiency gains

Consider what happens when an electrolyser manufacturer achieves even a modest improvement in energy efficiency. Electricity typically accounts for 50 to 70% of hydrogen production costs in large scale projects. A stack that consumes less power per kilogram of hydrogen produced does not just improve one company's product specification – it resets the baseline for what project developers, financiers, and policymakers consider achievable.

That single improvement compounds. Project developers can model tighter economics. Lenders become more comfortable with hydrogen offtake agreements. Governments gain confidence that subsidy regimes – whether production tax credits, contracts for difference, or clean hydrogen portfolio standards – are backing technology that will eventually stand on its own.

Nel's existing atmospheric alkaline platform illustrates this incremental compounding in practice: the company has achieved approximately 2% annual reductions in specific energy consumption alongside roughly 8% annual stack cost reductions over recent years. These are not dramatic headlines, but they are the kind of steady gains that push the industry's cost curve down.

The next-generation pressurised alkaline platform is designed to operate at below 50 kWh/kg of hydrogen with a wide load range of 15 to 100%. The system targets a step-change in operating economics, but the broader point is that these efficiency benchmarks – once demonstrated at scale – will become a new standard that every project developer factors into their models. The benchmark changes for everyone, and thus everyone must improve.

Materials science and the supply chain multiplier

Perhaps the clearest example of R&D as shared capital lies in materials science – the catalysts, electrodes, diaphragms, membranes, porous transport layers, and coatings, working in harmony, is defining electrolyser performance. When any manufacturer invests in developing more durable membrane chemistries, reducing precious metal loadings, or engineering better electrode structures, those advances create demand signals that ripple through the entire supply chain.

Component suppliers respond by scaling production, refining their own processes, and competing on both price and quality. The result is a virtuous cycle: as more companies can manufacture catalyst-coated membranes, bipolar plates, or advanced diaphragms at scale, unit costs fall for every original equipment manufacturer (OEM) that sources from them. Individual electrolyser manufacturers may each have proprietary design approaches – their particular cell geometries, manifold configurations, or system architectures – but the underlying materials ecosystem is largely shared.

This dynamic is especially critical for the hydrogen sector today. Unlike mature industries with established supply chains, electrolyser manufacturing is still in its nascent phase, building its supplier base. Every new entrant that can produce high-quality porous transport layers or electrode coatings at volume, adds resilience and competitiveness to the whole industry. The development of Nel's pressurised alkaline technology, for example, required close collaboration with suppliers to develop components that meet the demands of a pressurised cell environment operating at 15 bar. The knowledge generated through that development work – around material behaviour under pressure, sealing technologies, and accelerated lifetime testing – does not remain confined to one product. It expands what the supply chain is capable of delivering to any customer.

Having more companies that can make catalyst, membrane, porous layers, and other critical components at high volumes provides both competition and economies of scale. R&D into components and manufacturing drives down cost for all OEMs.

Figure 2. The new pressurised electrolyser will reduce system CAPEX by 40 - 60%.

Figure 3. Nel will build 1 GW of stack production capacity at its manufacturing facility in Herøya, Norway.

Manufacturing innovation: from laboratory to gigawatt scale

The transition into fully automated, high-volume production lines represents one of the most consequential R&D frontiers in the electrolyser industry. Manufacturing process innovation – how components are coated, assembled, tested, and quality-controlled – determines whether the performance gains achieved in the laboratory can be delivered consistently at scale.

Nel has invested heavily in this area. Its atmospheric alkaline facility at Herøya, Norway, now operates at 1 GW of fully automated annual production capacity, with the potential to expand to 2 GW as market demand warrants. On the proton exchange membrane (PEM) side, a 500 MW automated production line in Wallingford, Connecticut, US, has unlocked substantial stack cost reductions through process and design optimisation. These advances follow substantial investments that reflect a commitment to the industry's future, not just one company's order book.

But manufacturing knowledge does not stay within factory walls. Techniques for high-speed membrane electrode assembly, automated stack conditioning, and inline quality assurance become part of the industry's collective manufacturing know-how. Equipment suppliers, process engineers, and production consultants carry these learnings across organisational boundaries. The scale of investment required to build world-class production capacity means that no single manufacturer will serve the entire market – and the industry is stronger for it.

Nel has been awarded a grant of up to €135 million from the EU Innovation Fund to support industrialisation of its pressurised alkaline platform. The production line will be built in stages at Herøya, with total annual capacity of up to 4 GW when fully realised. This kind of public-private de-risking investment in manufacturing scale-up generates knowledge, tooling, and process capability that inevitably feeds back into the broader industry.

System-level innovation: rethinking the plant

Electrolysis R&D extends well beyond the stack. Some of the most impactful cost reductions come from system-level innovation – rethinking how an electrolyser plant is designed, built, and operated.

Nel's pressurised alkaline platform exemplifies this approach. The system is built around a 25 MW standard

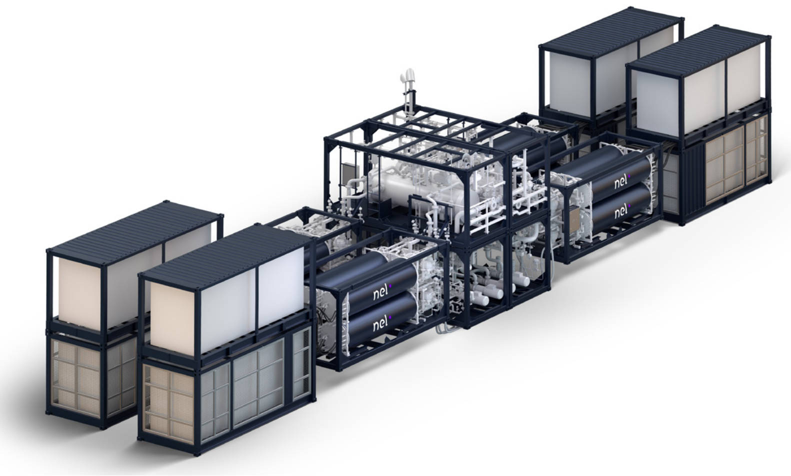

Figure 4. Nel plans to have the capability to deliver 100s of MW in 2027.

setup, installed by standard building blocks, comprising 16 individual 6.25 MW stack modules, four power modules, and a shared gas processing module. The entire system fits within a footprint of approximately 230 m^2 – an 80% reduction compared with an equivalent atmospheric alkaline installation. It is designed for outdoor operation on a flat concrete pad with prefabricated skid-mounted supports, eliminating the need for a purpose-built building. Hydrogen is delivered at 15 bar, reducing or eliminating downstream compression requirements. The modular architecture means that for plants larger than 25 MW, operators simply replicate the building block.

It is worth being explicit about the mechanics here. The pressurised alkaline stack carries a higher unit cost than its atmospheric alkaline counterpart – a reflection of the additional engineering required to operate reliably at 15 bar. However, eliminating the purpose-built building, reducing civil works to a flat concrete slab, and enabling standardised outdoor installation with prefabricated skid-mounted modules, contributes to a system-level CAPEX decline by 40 to 60% compared with current atmospheric alkaline solutions. Packaging, in other words, is not a cosmetic consideration – it is a primary cost lever, and one that is often underappreciated in discussions of electrolyser economics. The design principles that make this possible – standardisation, modularisation, outdoor installation, prefabrication, plug-and-play – are not proprietary concepts. They represent an emerging industry consensus around how large scale hydrogen production facilities should be engineered. Every manufacturer that adopts these principles contributes to a more predictable, bankable project model for developers and financiers alike.

The 16-stack architecture also enables a level of operational redundancy that strengthens the case for hydrogen in industrial applications: operators can take individual stacks offline for maintenance or replacement without stopping production. Combined with a wide operating range of 15 to 100% load and rapid ramp-up and ramp-down capability, the system is designed to pair effectively with variable renewable energy sources – a critical requirement as green hydrogen projects increasingly couple directly with wind and solar assets.

The way ahead

The current generation of alkaline and PEM electrolysers continues to improve incrementally. But the industry is also investing in step-change technologies: next-generation pressurised alkaline and PEM systems, and emerging platforms such as anion exchange membrane (AEM) and solid oxide electrolysis (SOEC) that could open entirely new application spaces. Nel's own technology roadmap spans both its current atmospheric alkaline and PEM platforms and next-generation systems, including the pressurised alkaline platform now moving toward a commercial pilot with Norwegian Hydrogen at Rjukan, Norway, with completion expected in 2027.

These next-generation platforms build on decades of collective industry learning – from the atmospheric alkaline systems that have operated reliably since the mid-20th century to the PEM platforms that proved themselves in demanding applications from submarine life support to semiconductor manufacturing. The companies pursuing these technologies are not starting from zero. They are standing on shared foundations of materials science, electrochemistry, and systems engineering that the entire industry has helped to build.

Industry forecasts from the Hydrogen Council and McKinsey project approximately 8 million tpy of clean hydrogen demand by 2030 where existing policy frameworks already enable a positive business case, with a further 13 million tpy unlockable through targeted infrastructure investment and continued cost reductions.[1] R&D is the mechanism that closes that gap. And the nature of electrolyser innovation means that when any company closes it, the whole industry benefits.

An industry that wins together

The hydrogen economy will not be built by any single company. It requires a healthy, competitive ecosystem of manufacturers, suppliers, developers, and integrators – all pushing the boundaries of what electrolysis technology can achieve. R&D is the shared foundation on which that ecosystem rests.

Every efficiency improvement compounds across the industry. Every materials breakthrough expands the supply chain for all. Every manufacturing innovation raises the bar for what can be produced at scale. And every standard developed makes it easier for the next project to reach final investment decision.

The question is not whether electrolyser R&D benefits the company that undertakes it – of course it does. The more important truth is that it benefits everyone. In an industry working to decarbonise some of the hardest-to-abate sectors of the global economy, that is not a side effect. It is the point.

Reference

1. 'Global Hydrogen Compass 2025', Hydrogen Council, McKinsey & Co., (September 2025).