GOING GREEN

Filip Smeets, Nel Hydrogen, explores how renewable hydrogen electrolysis production can reduce costs and boost capacities.

Large-scale ammonia production, as most readers of *World Fertilizer* know already, is primarily based on the Haber-Bosch process, which was invented by the German chemist and Nobel laureate Fritz Haber in the early 20th century. Most agree, considering the global pressures to reduce energy consumption targets by 2050, that the 'grey' or 'brown' Haber-Bosch process is unsustainable today. More than 235 million t of ammonia – crucial for modern agriculture – are produced globally at a cost of 1 – 2% of the world's energy consumption. This large scale of ammonia production also emits approximately 450 million tpy of carbon dioxide (CO_2) and represents approximately 1% of all human emissions, more than any other industrial chemical reaction. The upside is the private and public stakeholders in energy, mobility and chemical markets are tackling the biggest CO_2 offenders first. So, when – not if – there is good progress on producing ammonia with a significantly lower carbon footprint, then there will be an impressive dent in greenhouse gas emissions on a global scale. Renewable hydrogen, produced via the water-based electrolysis process, is a viable pathway to sustainable ammonia production, and there are advances being made and encouraging news to report surrounding these initiatives.

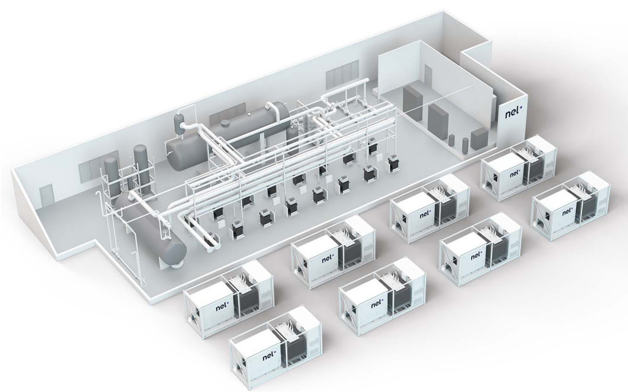

Figure 1. 20 MW PEM electrolyser designed to produce 4920 Nm^2/hr of green hydrogen at an ammonia plant in Spain.

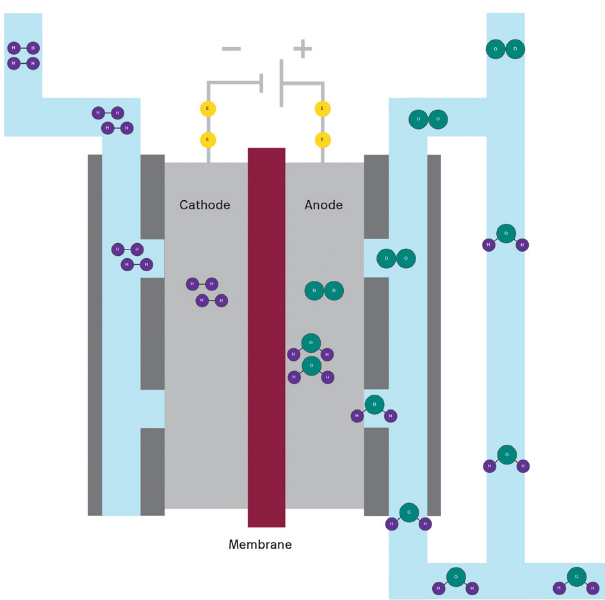

Figure 2. Electrolysers generate hydrogen by splitting water and releasing only oxygen as a byproduct.

Hydrogen's role in producing ammonia for fertilizer manufacturing is just one of hundreds of current and forthcoming uses of hydrogen. Ammonia, however, is uniquely interesting. It is a high-density carrier of hydrogen energy, allowing the exportation of hydrogen and thereby cost-effective energy. Furthermore, it is relatively easy to 'crack' the ammonia to liberate hydrogen at the point of use for a variety of applications. Also easing the cost is the fact that there is a massive ammonia distribution infrastructure already in place. There are gas pipelines in many regions around the world, and global transport of ammonia by truck tanker, by rail and by ship is something that is already done today. Most importantly, it enables economies to achieve decarbonisation for the energy, mobility and industrial sectors, and this is what is driving much of the current interest in 'green' ammonia. For example, energy-rich countries can export ammonia (and thus its hydrogen travel companion) to energy-poor nations, where they can release the hydrogen out of the ammonia and use it to foster other sectors of the new hydrogen economy. This scenario is happening already in places such as Australia, which is exporting ammonia/hydrogen to help countries such as Japan achieve hydrogen-fuelled supply chains and markets.

Ramping up hydrogen production capacity to meet fast-growing demand

All the makers of electrolysers – the equipment that makes low carbon hydrogen by using electricity to split water into hydrogen and oxygen – are readying themselves to meet the anticipated, fast-growing demand for clean hydrogen for emerging applications. As just one example, Nel Hydrogen's ammonia connection began with its founding in the early 1900s, when the company built large alkaline electrolyser plants to produce the hydrogen feed stocks for ammonia production in Norway. Fast forward 100 years, the company still builds alkaline electrolysers in Norway and now produces proton exchange membrane (PEM) electrolysers in the US. Regarding its effort to increase production capacity, the company is currently at 500 MW/yr with the completion of a new plant, and then will grow up to 2000 MW/yr with subsequent planned expansions. In the US, it is planning to increase its production for PEM systems from 50 MW/yr as demand increases.

Alkaline electrolysis is a mature technology that still adopts enhancements in each new generation of the product line. By comparison, PEM technology is a newer technology with potential for significant technological innovation and cost reduction in the future. There are certain operating scenarios in which a hybrid approach works best – customers can use a combination of alkaline and PEM electrolysers, depending on the need, the reliability of the energy source and other considerations.

Green ammonia pilot programmes underway

As already established, ammonia producers are among the largest industrial users of hydrogen, and the transition from grey and brown to 'blue' and green ammonia is being studied at newly-launched pilot programmes. For instance, Nel has announced a collaboration with Haldor Topsoe for delivery of end-to-end green ammonia and methanol solutions. Additionally, there is a green fertilizer project underway with Yara.

Case study: Spain

Another recently funded pilot programme surrounds a utility customer in Spain for green ammonia production. The Spain project is the largest PEM electrolyser plant that the company has delivered. Each of the 16 PEM cell stacks is a 1.25 MW cell stack to achieve a total 20 MW input capacity. A trend among the company's ammonia customers is that they are asking for more than just the green hydrogen piece of the project; they want to be able to bundle the whole solution going from renewable energy to hydrogen to green ammonia. These kinds of collaborations can be seen as real-world test cases to gain engineering expertise and process knowledge to provide a full solution for future commercial green ammonia projects.

Case study: Minnesota, US

Another US pilot project is being led by the University of Minnesota, where the institution has onsite wind electricity production for an entirely green process end-to-end. The zero-carbon wind resources drive the Habor-Bosch process and uses green hydrogen electrolysis to make green ammonia.

This project will inform the company as to how to properly scale the Haber-Bosch process and the electrolyser process for distributed ammonia production, as it is still currently a challenge. To make this proven idea practical, usable and cost-effective, it is of paramount importance to create the right size ammonia plant, taking into consideration the available resources in that region, and then serving the local markets that are matched in size.

Cost comparison with other green systems

The capital costs associated with a tank of ammonia are very low compared to, for example, batteries. In addition, it scales up or down well and the chemical can be stored for long durations. The conclusion that can be drawn is that ammonia as a hydrogen carrier is very efficient, as low-cost transportation and storage technologies already exist. It can be directly used as a fuel, and combustion and safety measures for ammonia are well understood. Furthermore, carbon capture and sequestration (CCS) from a blue ammonia production plant is still a feasible option in the near term. On the journey to green, however, carbon free ammonia needs to be a significant contributor to the overall H_2@Scale initiative that is being driven by the US Department of Energy.

It is already proven that renewable ammonia production will directly benefit from electrolysis technology cost improvements. Ammonia can play a really important role, both as a life-sustaining commodity and an efficient energy carrier. Nel believes distributed ammonia production can be located in areas with both high renewable energy resources and high fertilizer demand, such as in the upper Midwest in the US where there is a good wind resource, high fertilizer usage and reduced transport requirements.

Relevant to the role that hydrogen costs play into green ammonia costs, in 2021 Nel announced a green hydrogen cost target of US$1.50/kg by 2025. There is belief that there is a viable pathway to achieve this cost target, based on the company's understanding of the various energy markets, its own CAPEX cost models, market demands and incentives in the public sectors.

Conclusion

The application of green hydrogen from renewably powered electrolysis will be an important contributor to the decarbonisation of ammonia production. As a major emitter of CO_2 emissions, the ammonia production process will absolutely need to be a significant focus of climate change initiatives in the industrial sector. In addition, green ammonia offers an additional opportunity to store and transport renewable energy as a hydrogen carrier. The infrastructure for storing and moving ammonia over long distances, including through pipelines, already exists and can be expanded at a low relative cost compared to other bulk hydrogen infrastructure approaches.

Ultimately, green ammonia will play a dual role in offering both decarbonised fertilizer and renewable energy storage solutions in support of international climate change objectives. The development of green ammonia business cases will require lower costs for large-scale electrolyser plants, and perhaps some market-based incentives and mandates for the near term, but there is no doubt that renewable electrolysis technology offers a unique opportunity to address these objectives. WF