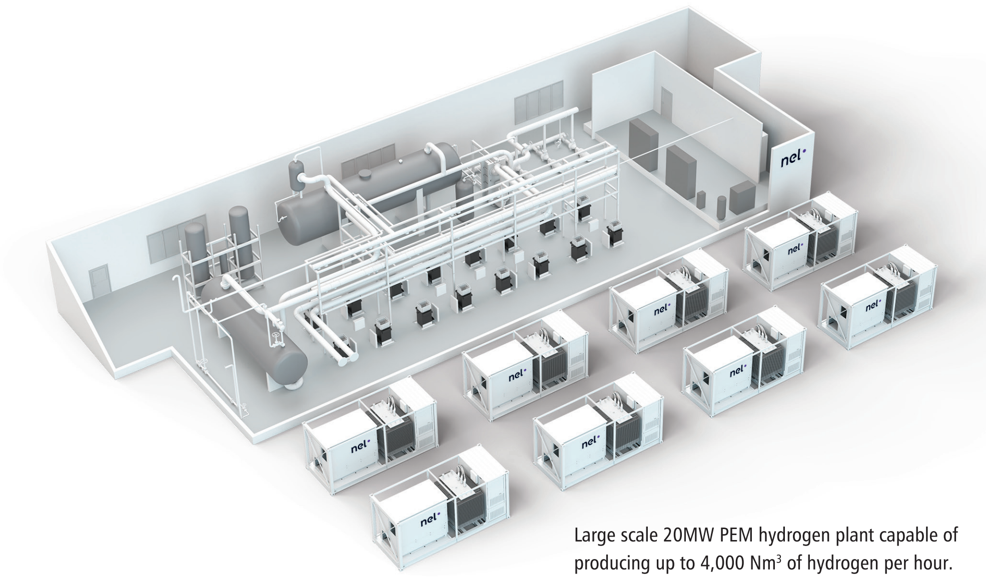
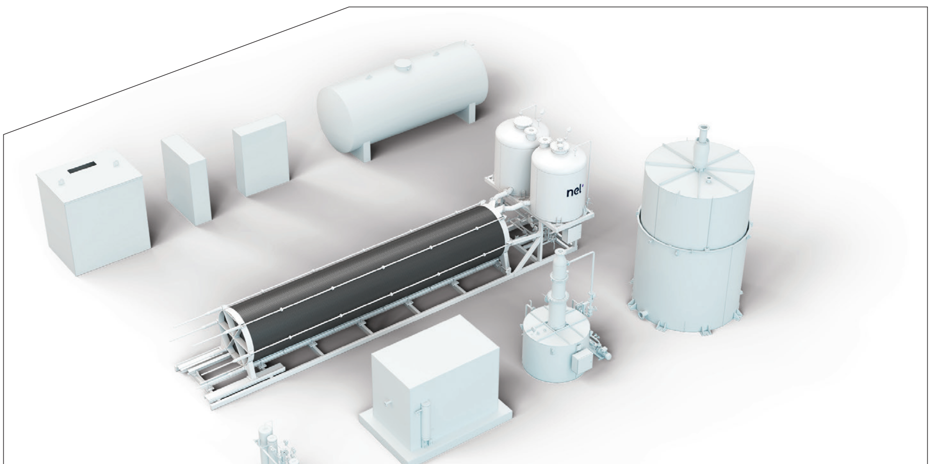
Green hydrogen for the steel industry – requirements for success

Slowly but surely, momentum is building to upscale H_2 production via electrolysis, with goals to increase renewable energy sources, and reduce costs. By **Lynn Gorman***



Large scale 20MW PEM hydrogen plant capable of producing up to 4,000 Nm³ of hydrogen per hour.

Containerized PEM electrolyser capable of producing up to 500 Nm³ of hydrogen per hour.



Single unit alkaline electrolyser capable of producing up to 485 Nm³ of hydrogen per hour.

The steel industry is realigning future investment from the legacy steelmaking technologies of the BF and the BOF to the current preferred technology of the EAF. As such, steelmaking is on track to become significantly greener, and the plants will become smaller, cleaner, and consume less energy. Today, the steel industry releases 7% of the world's CO_2. According to a report by Wood Mackenzie, the steel industry's carbon emissions are expected to fall by 30% by 2050 compared to 2021 levels. The European steel industry has already cut its CO_2 emissions and energy use by half since 1960, and aims to achieve further cuts of 80-95% by 2050 compared to 1990 levels. Because of the enormous installed equipment base and the long life of steel production plants, the evolution to a greener steel industry may be a slower one compared to some other industries such as power generation, semiconductor, and automotive. However, the steel industry is indeed positioning itself for a cleaner future and has demonstrated notable efforts on the decarbonization journey.

The iron and steel industry knows where the technology gaps are, what the market realities are, and what the cost inhibitors are, enabling stakeholders to turn the stumbling blocks into practical solutions. There are pilot projects well underway

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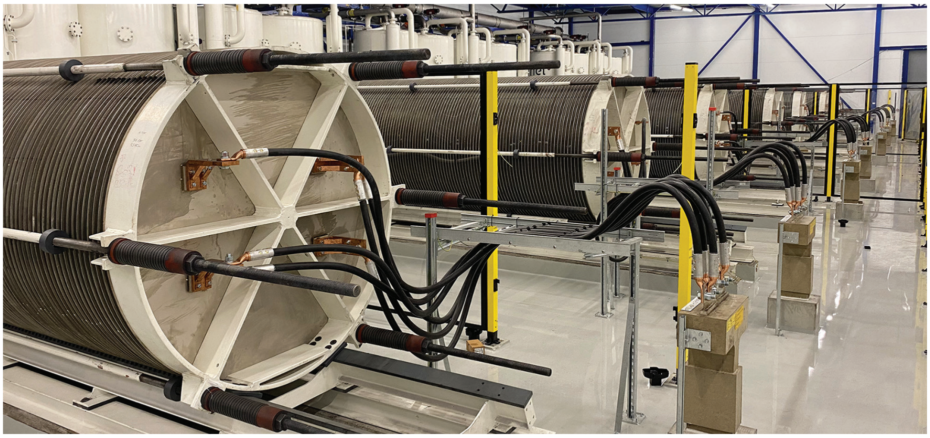
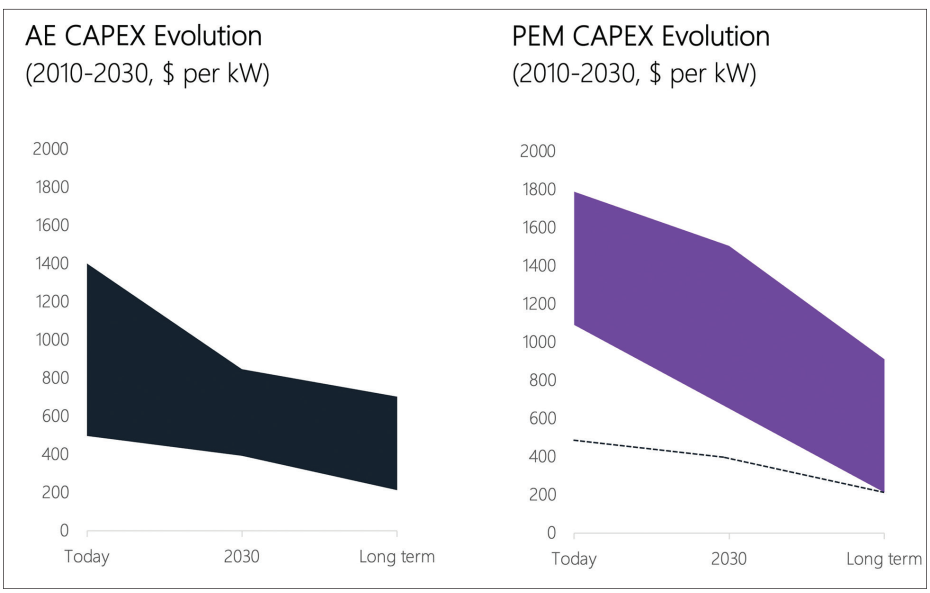


Nel Hydrogen 20MW alkaline water electrolysis plant at Ovako's facility in Hofors, Sweden, capable of producing up to 3,380 Nm3 of hydrogen per hour.

Fuel	LHV BTU/MCF*	LHV BTU/lb	Flame speed m/sec	CO_2 emissions (lb CO_2/MMBTU)
Hydrogen	290,000	51,635	2.933	0
Methane (NG)	964,000	21,504	0.374	117
Carbon Monoxide	323,400	4,366		576
Coal		12,468		200+

MCF = 1,000's of (standard) cubic feet of gas

Hydrogen versus other steel industry fuels – BTU content, density, and flame speed.



These graphs illustrate the lower CAPEX slope comparing alkaline electrolysers with PEM electrolysers over time. Note that both technologies will result in $300 per kiloWatt CAPEX for hydrogen generation by 2030.

worldwide, and demonstration facilities in northern Europe that serve as teaching models for the optimal systems to employ, strategic partnerships to nurture, and are providing the data the steel industry has been seeking.

Steel is the most recycled manufactured product in the world. EAF steel plants primarily use scrap steel to make new steel, yet they must add additional iron molecules to the process, such as DRI (direct reduced iron), sponge iron, or HBI (hot briquetted iron), to augment recycled steel in EAF production. EAF iron feedstock produced in a shaft furnace to complement scrap steel made from ore is using a CO (carbon monoxide)-hydrogen blend currently made from natural gas or coal. The near-term solution for a greener steel industry is replacing natural gas and/or coal used for producing iron units with zero carbon hydrogen as the reducing gas for EAF feedstock preparation. Clean steelmaking may ultimately use hydrogen-derived DRI and hydrogen-enhanced electric arc furnaces with near-zero CO_2 emissions per ton of steel. However, to reach that level requires massive production of green hydrogen at a cost that's acceptable to steelmakers.

David Wolff, director of industrial product sales at Nel Hydrogen, cited several requirements for green hydrogen to contribute to the steel industry successfully.

"The volume of hydrogen that the steel industry could use – both in iron production as a reducing gas and in steelmaking as a heating fuel source – exceeds the current capacity of electrolytic hydrogen generation by orders of magnitude," said Wolff. "There simply aren't enough electrolysers right now, however new electrolyser equipment manufacturing plants will be coming online by 2025, and likely just in time for the steel industry to benefit."

Competitive market realities will also affect the steel industry's transition to green hydrogen. Other market sectors, for example sustainable aviation fuel, green ammonia, and hydrogen fueling, are moving more quickly, and making larger investments in hydrogen electrolysis for their needs than the steel industry. As such, these 'first movers' are first in line to procure electrolysers.

These more active market sectors are creating enough demand so that new electrolyser manufacturing plants are being built, which will aid the steel industry as its evolution continues and its demand for electrolysers increases. For instance, Nel is building a new electrolyser equipment manufacturing plant near Detroit, Michigan, USA. When fully developed, the Michigan plant alone will have a production capacity of up to 4GW of alkaline and proton exchange membrane (PEM) electrolysers.

Alkaline electrolysis and PEM electrolysis are the two types of electrolysis systems that are generally considered commercially mature right now. There are other types in development which also show promise. Alkaline technology has historically been used for large capacity hydrogen plants. Alkaline cell stacks cost fewer capital dollars on a per kW basis because they do not use precious metals as catalysts as PEM does, and alkaline equipment has reduced in cost to a great extent, having been commercially deployed for almost a century. Alkaline electrolysis is being used at green steel projects in Sweden such as Ovako (see article about this project in Steel Times International September 2023 issue); HYBRIT, a joint venture between SSAB, LKAB, Vattenfall; and H_2 Green Steel.

Conversely, PEM electrolysers are compact, and can ramp up quickly to cope with variable energy sources or changing hydrogen demand. They can be supplied to make a range of hydrogen production from pounds per day to hundreds of tons per day. PEM electrolysers have been working in the field commercially for about 50 years. According to Wolff, PEM is well suited to small footprint applications and offers simple, straightforward equipment that does not require downstream compression or gas purification.

Electrolysis begins with the electrolyser's cell stack. That's the core of the electrolyser, akin to the chip in a computer or the engine in a truck. Each cell stack is made up of many electrolytic cells, each of which is an electrochemical reactor. Add water, an electrolyte and DC power, and the cell stack creates hydrogen and byproduct oxygen. Cell stacks can be arrayed to increase production in a number of different configurations.

Ironmaking and steelmaking sites are typically large; most of them are expected to accommodate multiple electrolyser 'trains' to accommodate generation in the 100MW to 500MW range that might be required at full scale. There's also the concept being explored to establish separate green hydrogen generation plants – complete with co-located off-grid renewables, companion storage facilities, and transport fleets to deliver the green hydrogen to various nearby iron and steel locations. For example, the Hy Stor Mississippi Clean Hydrogen Hub project features underground salt caverns for storage. Hy Stor's goal is to develop a green hydrogen generation, storage, and transportation hub in the USA. The first phase of the project is expected to be commissioned in 2025.

Another stumbling block to a green steel industry is, of course, cost. Water electrolysis runs on electricity, and electricity is the largest contributor of hydrogen cost when deploying water electrolysis on a large scale.

"Both CAPEX and OPEX must decline," said Wolff. "Progress is being made on that front as we scale up electrolysis and clean energy plants, but it takes time to make that progress and there are few shortcuts." Wolff used the analogy of the electric vehicle market, citing that it has taken about 10 years for EV costs to come down to the point where mainstream consumers are buying them.

Many markets right now need steady, predictable, high-quality electricity. One potential scenario for green hydrogen electrolysis in the steel industry is to close-couple the electrolysis plant with a solar array or with a wind farm – meaning the electrolysers operate directly off of those renewables with no costly grid in between. This may speed short-term progress toward cost-effective green hydrogen. Longer term, according to Wolff, it makes more sense for electrolysis to be a valuable grid participant, enabling enhanced energy usage and lower costs for all.

Green steel is a premium product. When the private sector users of steel demand greener steel, such as the automakers, and the public sector incentivizes it – as the Inflation Reduction Act in the US will do once the guidelines are known – the investment in green hydrogen generation equipment is expected to grow to serve the steel industry.

Certain regions are using carrot and stick approaches to inspire innovation. Carbon pricing is a powerful incentive for lower carbon steel in Europe but has not been used to strongly influence behaviour elsewhere.

"Having to pay a tax for every pound of CO_2 released could go a long way to incentivizing the investment into these new clean technologies for the steel industry," said Wolff. "That, combined with earning a premium price for greener steel, for example in a car, will help pay for the steel company's investment."

Wolff suggests that we in the steel industry should be striving to take on the projects today that specifically revolve around using hydrogen as the reducing gas in ironmaking and replacing the gray hydrogen in steelmaking with green. This will give the industry experience of operating electrolysis plants and will make a measurable difference in the carbon intensity of the steel. ■

At Ovako's facility in Hofors, Sweden, steel can be heated prior to rolling with hydrogen produced through water electrolysis and green electricity to reduce the facility's carbon emissions.