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Electrolyser Case Studies

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Intelligence Report

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1. INTRODUCTION TO ELECTROLYSIS

Electrolysis is a process in which electricity, including from renewable sources, is used to split water (H2O) into its component molecules -- hydrogen (H2) and oxygen (O2) -- in systems known as **electrolysers.** Direct current electrolysis was discovered by English scientists William Nicholson and Anthony Carlisle in 1800, thus establishing the scientific field of electrochemistry. Initially, and for a long time, this process dominated the field of industrial hydrogen production, before being displaced by the more cost-effective steam reforming thanks to the increasing adoption of natural gas. Nowadays, electrolysis is resurfacing as the world focuses on a greener future. Companies increasingly rely on electrolysis to produce hydrogen with zero greenhouse gas emissions, depending on the source of electricity used.

Electrolysers contain an anode and a cathode that are separated by an electrolyte. There are three main types of electrolysers based on the electrolyte material involved -- polymer electrolyte membrane (PEM), alkaline and solid-oxide (SOEC) electrolysers. In addition, there is the much less mature (lab-scale) technology called anion exchange membrane (AEM).

Types of electrolysers

PEM

The electrolyte in a PEM electrolyser is a solid speciality plastic material. In this type of systems, on the anode side water reacts to form oxygen and positively charged hydrogen ions, or protons, which then move across the PEM to the cathode side and combine with electrons from the external circuit to form hydrogen gas.

ALKALINE

Alkaline electrolysers include “cells” that consist of an anode, cathode and membrane, and are typically assembled in stacks.
The system uses a liquid electrolyte solution such as potassium hydroxide (KOH) or sodium hydroxide (NAOH), and water.
By applying current on the cell stack, the hydroxide ions (OH-) move from the cathode to the anode of each cell. This leads to the production of hydrogen gas bubbles at the cathode and oxygen gas on the anode side.

SOLID OXIDE (SOEC)

SOEC electrolysers are a less mature technology that uses a solid ceramic material as the electrolyte. In these systems, water on the cathode side combines with electrons from the external circuit to form hydrogen gas and negatively charged oxygen ions. Then, these oxygen ions pass through the solid ceramic membrane and react on the anode side to form oxygen gas and generate electrons for the external circuit.

AEM

On paper, AEM combines the simplicity and efficiency of a PEM electrolyser with the less harsh environment in which alkaline electrolysers operate, but enables the use of non-noble catalysts and titanium-free components. It is the latest of the main technologies to be developed and as such is still dealing with unstable lifetime profiles caused by chemical and mechanical stability issues.

This report provides an inexhaustive list of key electrolyser suppliers from around the world in alphabetical order. It gives examples for manufacturers of all of the above-mentioned technologies.

2. KEY SECTOR PLAYERS

At present, the financing aspect of developing hydrogen projects depends on the type of project and the sector it originates from. For instance, projects developed in the private sector, primarily in energy, chemicals and refining, are mostly the seed of large and well-known sponsors that, Pavlovic says, are leaders in their field and benefit from privileged access to the capital markets. These are still pilot projects, being developed for internal use by an investor often looking to gain know-how in the field and prepare for a future in which they could secure state aid for larger developments.

The other currently popular type of projects is in the mobility sector, where financing is mostly public and comes in the form of grants from the state or, for example, the European Union (EU). Public-private partnerships are common there.

Bloom Energy

Bloom Energy, the San Jose, California-based developer of a flexible platform for 24/7 onsite power based on solid oxide fuel cell technology, in July 2020 announced plans to enter the commercial hydrogen market through the introduction of fuel cell and eletrolyser offerings. Later that year, together with partner SK Engineering and Construction (SK E&C), it won a competitive Request for Proposal (RFP) under the RE100 programme to supply solid-oxide fuel cells powered by 100% hydrogen and electrolysers to an industrial complex in Changwon, Korea.

Exactly a year after unveiling the initial plan, Bloom Energy introduced the so-called Bloom Electrolyser, claiming that it is 15%-45% more efficient than any other product on the market at the time. It is a solid-oxide electrolyser that operates at high temperatures and has the capability to leverage both electricity and hear to produce hydrogen. The Bloom Electrolyser has the potential to use up to 45% less electricity when integrated with external heat sources than low-temperature PEM and alkaline electrolysers, the company claims.

The product's specifications can be seen in the table in the next page

PRODUCT STREAMS	
Nominal H2 Flow (kg/h)	7.8 per 360 kW module
Hydrogen outlet pressure (barg)	0-0.05 barg
Hydrogen outlet temperature (°C)	130-180 C
Hydrogen purity (wt %)	99.99% after drying
Gas4climate (2020)	
Efficiency (kWh/kg)	46 kWh/kg - 39 kWh/kg (with external steam - 120°C supply)
Nominal electrical power consumption (MWel)	360 kW
Voltage	480 V
Frequency	60 Hz
OPERATING CONDITIONS	
Nominal water flow (kg/h)	102.78
Stack life	5 years
Hot startup time	6 mins
Flexibility (% of nominal load)	20-100%
PHYSICAL ATTRIBUTES AND ENVIRONMENT	
Weight	6 tonnes
Dimensions (feet)	15'1"x3'7"x6'10" (LxWxH)

According to Bloom Energy, its facilities in Sunnyvale, California and Newark, Delaware are currently capable of manufacturing 500 MW of electrolysers and will expand to 1 GW within a year (as of July 2021).

Bloom Energy expects to begin commercial shipments of its electrolyser in the autumn of 2022.

Cummins Inc

While starting the development of its fuel cell capabilities over 20 years ago, diesel and alternative fuel engines manufacturer Cummins entered the hydrogen economy in September 2019 by taking control of hydrogen fuel cells and electrolyser technology maker Hydrogenics Corporation at an enterprise value of about USD 290 million. Cummins now holds an 81% stake in that company, while Air Liquide SA of France owns the remainder.

Following the acquisition, Cummins has both fuel cell and hydrogen generation from electrolysis capabilities. Cummins currently offers two different types of electrolysers: the HyLYZER PEM electrolyser, which is better suited for large-scale hydrogen production; and the HySTAT alkaline electrolyser, which is well-suited for small- to medium-scale hydrogen production.

The following table shows the technical specifications for the largest units of both electrolyser types.

Model	HySTAT - 100	HyLYZER - 4000
Technology	Alkaline	PEM
Hydrogen production	100 Nm3 /h (215 kg/day)	4,000 Nm3 /h (8,630 kg/day)
H2 delivery pressure	10 barg (145 psig) without a compressor	30 barg (435 psig) without a compressor
H2 quality max impurities	99.998% O2 < 2 ppm, N2 < 12 ppm (higher purities optional); Atm. Dew point:-75°C	99.99% dry basis, gas is fully saturated with water O2 < 100 ppm Optional > 99.998% with hydrogen purification system
Technical specifications		
Operating range	40-100% (optional 6-100%)	5-125%
DC power consumption at stack	--	40 to 50 kWh/kg, 48 at nominal load (3.6 to 4.5 kWh/Nm3, 4.3 at nominal load)
System specific consumption*	55-60 kWh/kg	≤ 51 kWh/kg
Rectifier input and specifications	3 X 400 VAC ± 10% 50/60 Hz	4.1 to 30 kV 50/60 Hz, 23 MVA 97% efficiency
Installed power	800 kVA	150 kVA (estimated)
Total footprint (including maintenance area)	15.5 m x 5.8 m (~ 89 m2)	Electrolyser dimensions (estimated) = 10 m x 15 m (34 x 50 ft) Rectifier dimensions (estimated) = 10 x 15 m (34 x 50 ft)
Installation environment	Outdoors -20°C to 40°C / -4°F to 104°F	Indoors 5°C to 40°C / 41°F to 104°F

Elogen

Elogen is a French PEM electrolysis expert that offers containerised electrolysers up to 10 MW and modular high-power electrolysis systems of tens or even hundreds of megawatts for mobility applications, power-to-gas, power-to-power and industry.

The table below gives specifics about some of the company's largest offerings.

Specifications	Elyte 260	Open Power	Multi MW Systems
Hydrogen Production			
H2 flow rate [Nm3/h]	260	Min. 500	Min. 2 000
Oxygen Production			
O2 flow rate [Nm3/h]	130	Min. 250	Min. 1 000
Operating range			
Hydrogen production [%]	2-100	0.1-100	0.1-100
Power input [%]	2-100	0.1-100	0.1-100
Feeding Water			
Consumption [l/Nm3 H2]	< 2	< 2	< 2
Installed Power			
Electrolysis [kW]	1 300	Min. 2 500	Min. 10 000
Power [kVA]	1 680	Min. 3 200	Min. 13 000
Specific Energy consumption			
Stack consumption [kWh/Nm3 H2]	4.3	4.5	4.3
System consumption [kWh/Nm3 H2]	4.9	5.0	4.8
Footprint			
Dimensions	--	< 30 m2 /MWel	< 31.25 m2 /MWel

All of the company's PEM electrolyser development and production capabilities are accommodated at its Les Ulis headquarters near Paris. There, Elogen has a 1,200-square-metre production area for stack and electrolyser assembly and certification. As of the fourth quarter of 2021, the firm has the capacity to manufacture 160 stacks and 40 electrolysers per year. The complex also house laboratories with 10 test benches.

Enapter

Enapter is the only company in this list that manufactures AEM electrolysers. Its plug-and-play solution is modular and can produce hydrogen at any scale by stacking units to achieve the required production rate, from kilowatts to megawatts range. The company says that up to 70 electrolysers can be stacked in a 20-foot container to create the AEM Cluster that is suitable for larger refueling stations and industrial use.

Below you can see more information about Enapter's Electrolyser EL 2.1.

Production rate	500 NL/hr
Hydrogen output purity	35 bar: ~ 99.9% (Impurities: ~ 1000 ppm H_2O) 8 bar: > 1500 ppm H_2O
Output pressure	Up to 35 barg
Nominal power consumption per Nm^3 of H_2 produced (beginning of life)	4.8 kWh/Nm^3
Operative power consumption	2400 W
Stand-by power consumption	15 W
Power supply	200-240 V, 50/60 Hz
Ambient operative temperature range	5°C to 45°C
Ambient operative humidity range	Up to 95% humidity, non-condensing
Water consumption	~400 ml/hr
Maximum water input conductivity	20 µS/cm at 25°C
Water input pressure range	1 - 4 barg

Enapter says that its electrolyser can be deployed in a variety of applications including: electricity storage, power-to-heat, power-to-gas, industrial solutions, mobility solutions and research. It refers to its AEM offering as "a PEM 2.0 technology."

The company, which is listed on the Frankfurt Stock Exchange, has offices in Italy, Thailand, Germany and Russia. At present, it is carrying out serial production in Italy, but in October 2020 it unveiled plans to build its first mass-production facility in North Rhine-Westphalia, Germany. The "Enapter Campus" will feature both a production centre and R&D facilities. The company will be able to manufacture more than 100,000 AEM electrolyser modules per year there, relying on renewable energy generated by on-site solar arrays and hydrogen storage systems, as well as on Saerbeck municipality's existing solar, wind and biomass power output.

Enapter commenced construction work on the EUR-105-million complex in September 2021 with the objective of initiating production in the fourth quarter of 2022. First deliveries to its customers from mass-production are planned for 2023.

In early November, Enapter reported receiving the first order for the AEM Multicore electrolyser, a containerized system designed for megawatt-class green hydrogen production. The delivery is scheduled for June 2023.

Green Hydrogen Systems

Danish firm Green Hydrogen Systems (GHS) aims to eventually build one of the largest alkaline electrolysis factories in Europe. Its HyProvide line of alkaline electrolysers are available in 30, 60 or 90 Nm³/h versions and are fully upgradable. The units can operate standalone or in clusters up to multi-megawatt scale. GHS says that its A-Series enables the clustering of units to scale from 15 Nm³/1.4 kg to more than 3,330 Nm³/300 kg of hydrogen per hour.

The table below includes the HyProvide A-Series specifications.

	A30	A60	A90
Hydrogen production rate (Nm³/hour | kg/hour)	30 | 2.7	60 | 5.4	90 | 8.1
Hydrogen pressure (bar)	35	35	35
Hydrogen purity (%)	>99.998	>99.998	>99.998
Hydrogen dew point (°C)	-70	-70	-70
Oxygen purity (%)	>99	>99	>99
Maximum stack power consumption (kW) BOL-EOL*	125 - 150	250 - 300	390 - 450
Maximum stack voltage max. (DC)	120	250	250
Stack current at 100% load (A)	1200	1200	1800

* BOL - Beginning of life; EOL - End of life

GHS says its electrolysers are suitable for refueling stations, industrial sites, Power-to-X applications and some special projects, including grid stabilisation. Last year, the company's solutions were chosen by big names in the renewable energy industry such as Ørsted A/S and Siemens Gamesa Renewable Energy SA.

As part of a consortium, the company will be working on a 6-MW module for a 100-MW green electrolysis project in GreenLab, Denmark.

In June, the company debuted on Nasdaq Copenhagen and a month later its board approved the planned second expansion phase of its combined manufacturing, R&D and office facilities in Kolding, Denmark. The project will increase the firm's current annual electrolyser production capacity from 75 MW to 400 MW by 2023. In subsequent phases, the complex could expand to 1,000 MW.

Haldor Topsoe

Another Danish company, Haldor Topsoe, focuses on the solid oxide technology. The firm is a provider of energy-efficient technologies, catalysts, services and hardware used in the production of chemicals and fuels. It already offers technologies for traditional natural-gas-based hydrogen production with the option of carbon capture, as well as solid oxide electrolyser cells, which, it claims, deliver up to 30% more green hydrogen from the same amount of renewable electricity when compared to PEM and alkaline electrolysers.

In early March 2021, Haldor Topsoe announced its intention to build a 500-MW production plant for industrial-scale solid oxide electrolysers, with the potential to expand its annual capacity to 5,000 MW in the future. The company noted that this facility will be the largest of its kind.

The project is currently under development. According to the company's half-year financial report, the facility should become operational in 2024.

"With Topsoe's SOEC electrolyser, more than 90% of the renewable electricity that enters the electrolyser is preserved in the green hydrogen it produces. This is significantly more efficient than the other available technologies in the market," CEO Roeland Baan commented when announcing the plan.

At the start of June 2021, the company announced the establishment of a new green hydrogen organization that is fully dedicated to stepping up all aspects of its business within electrolysis.

Topsoe's technology will be used in a number of projects including the 100-MW Aquamarine project in Germany and the Helios project in the NEOM economic zone in Saudi Arabia.

Hoeller

Hoeller Electrolyzer GmbH is a Germany-based developer of PEM electrolysers. The company says its ultimate goal is to deliver green hydrogen at less than EUR 4 per kg.

Hoeller's Prometheus series of electrolysis stacks can be used in a wide range of applications, including for fuel and long-term storage, in refineries and for emergency power supply. The company's 1.4-MW Prometheus L electrolyser can produce 295 Nm3 per hour or 635 kg per day. Its largest stack, though, is one of 1.5 MW.

"We will offer larger modules with multiple stacks for larger projects as well. A 3-MW module is already in development," said chief financial officer Matthias Kramer.

The company is also a member of the German Hyplant 100 project to define the layout of large-scale electrolysers.

Presently, Hoeller is able to manufacture up to 250 units per year and plans further expansions from 2024 onwards, the CFO noted.

ITM Power

UK-based company ITM Power is a 20-year-old manufacturer of integrated hydrogen energy solutions utilising PEM electrolysers. Its offerings, which range in size from 600 kW to 2 MW, include the HGas1SP (0.65 MW), HGas2SP (1.26 MW), HGas3SP (2 MW) and HGasXMW systems.

	HGas2SP	HGas3SP	HGasXMW	Green H2
Number of stacks	1	2	3	15
Power supply	400 V AC, 3 Phase, 50 Hz	11 kV AC, 3 Phase, 50 Hz	11 kV AC, 3 Phase, 50 Hz	11 kV AC, 3 Phase, 50 Hz
Control	PLC	PLC	PLC	PLC or DCS
Hydrogen generation pressure (barg)	20	20	20 now / 30 from 2022	20
Hydrogen purity	Up to 99.999% (ISO standard)	Up to 99.999% (ISO standard)	Up to 99.999% (ISO standard)	Up to 99.999% (ISO standard)
Maximum hydrogen production appx (kg/h)*	11	22	36	4,050
Input power at maximum appx (kW)	700	1,390	2,350	10,070

*In the case of HGasXMW, the maximum is for 24 hours.

The latter is the company's modular system for large-scale hydrogen production and is based on modules of three stacks. Each three-stack module, rated at about 2 MW, is built on a skid frame suitable to be housed indoors. Based on the requirements of the customer, an HGasXMW system

installation could include a number of 2-MW modules. ITM Power notes that this product is suitable for: various hydrogen fuel stations; refineries; facilities for methanation, renewable ammonia and renewable methanol; decarbonising heat; and grid balancing.

The previous table includes specifics for each of the four products.

Speaking to the authors of this report, James Collins, head of investor relations at ITM Power, disclosed that the company is working on an even larger electrolyser system. According to him, the largest unit that the company would make is of 5 MW. Anything larger would not fit in a shipping container, he noted.

In January 2021, ITM Power initiated production at its first Gigafactory at Bessemer Park in Sheffield, the UK. The complex, officially opened in August 2021, has an annual production capacity of 1,000 MW and, at the time, was considered to be the largest in the world.

In November 2021, the company agreed to acquire a site in Tinsley, Sheffield, where it plans to build a second automated factory with an annual production capacity of 1.5 GW by end-2023. The project will establish a template for ITM Power's first international facility of 2.5 GW, it said. This means that by the end of 2024, the company expects to have a total annual electrolyser production capacity of 5 GW.

The company, which counts Linde Plc and Snam SpA as shareholders, has supplied electrolyser systems for some notable projects such as REFHYNE and HyDeploy.

John Cockerill

John Cockerill is a mechanical engineering group based in Belgium with activities in energy, defense, industry, environment and the provision of services. When it comes to the segment of green hydrogen, the group invests in the production, storage and distribution of this type of energy carrier, including in the manufacture of electrolysers and hydrogen refueling stations.

John Cockerill estimates that in 2020 its 56% joint venture Cockerill Jingli Hydrogen delivered 20% of the large-capacity hydrogen electrolysers sold in the world.

Below you can find information about John Cockerill's DQ1000 electrolyser. It is a 5-MW stack that is easily duplicable to reach large-scale plants.

H2 gas production	
Nominal H2 flow	1000 Nm³/h (2136 kg/day)
Flow range	40% - 100%
Delivery pressure	30 bar (g) without compression
H2 purity before purification system	99.8%
H2 purity after purification system	99.999% suitable for fuel cell application
Electrical requirements	
Plant power consumption (AC)	5000 kW
Stack consumption (DC)	4.16 – 4.66 kWh/Nm³ H2
Electrical converter power factor	≥ 95%
Primary voltage	3.3 – 20 kV (typical 10 kV) (optional up to 34 kV)
Feed water and electrolyte	
Water conductivity required	< 1 µS/cm (demineralization process available in option)
Demineralized water consumption	0.92 l/Nm³ H2
Electrolyte	30% KOH aqueous solution
Dimensions & weight	
Plant footprint	Approx. 400 m²
Stack dimensions (LxWxH)	6.9 m x 2.2 m x 2.2 m
Stack weight	58 000 kg

The group's offerings go beyond 5 MW, as well. It has supplied a 6-MW electrolyser for the 2022 Winter Olympics to feed buses in the Olympic village and two 6.5-MW units to another customer.

While the current portfolio of the group is based on pressurised alkaline electrolysers, John Cockerill is open to other technologies in future developments, Roland Hequet, the hydrogen team's vice president of strategy and origination, told the authors of the report.

At present, John Cockerill has a workshop in China with an electrolyser production capacity of 350 MW, to be increased to 500 MW in a second phase. Meanwhile in Europe, the group plans a new 200-MW factory in France that will be expanded to 1 GW in the subsequent years. Hequet pointed out that the group will seek to establish other workshops by 2023 in order to accompany its growth.

McPhy Energy SA

France's McPhy is another notable company in the field of hydrogen production and distribution equipment, with a speciality in the design, production and integration of high-pressure alkaline electrolysers and hydrogen stations. The company offers the Piel & McLyzer Small Line ranges of electrolysers for light industrial applications, as well as the Augmented McLyzer range of electrolysers for the 20 MW and 100 MW models and beyond.

The McLyzer range includes both small and large lines of electrolysers. The high-capacity electrolysers in that offering can generate hydrogen in large volumes for heavy industries and/or continuous applications. McPhy says that the McLyzer range is especially adapted for Power-to-Gas and industrial hydrogen applications.

The table below contains more information about the larger models in the McLyzer range.

Models	Pressure (barg)	Rated output of H2 (Nm^3/h)	Power Class	Specific DC consumption at rated output (kWh/Nm^3)
McLyzer 100-30	30	100	0.5 MW	4.5
McLyzer 200-30	30	200	1 MW	4.5
McLyzer 400-30	30	400	2 MW	4.5
McLyzer 800-30 (core-module Augmented McLyzer)	30	800	4 MW	4.5

So far, McLyzer electrolysers have been used in a number of mobility projects in combination with McFilling hydrogen stations, projects in the refining, steel-work and chemistry industries, as well as in the field of Power-to-Gas, including the Jupiter 1000 demo in France. The latter project utilises one 0.5-MW alkaline electrolyser and one PEM electrolyser of 0.5 MW to form a 1-MW configuration.

Nel ASA

Norway-based Nel describes itself as a dedicated hydrogen company that delivers solutions covering the entire value chain from hydrogen production technologies to hydrogen fueling stations. The company says it is the largest electrolyser manufacturer in the world based on 2020 revenue figures.

In 2017, Nel acquired Connecticut-based sector player Proton Energy Systems Inc, also known as Proton OnSite, for an enterprise value of USD 70 million. That is when Nel added PEM electrolysers to its product offering.

When it comes to hydrogen production, the company now offers a number of different systems incorporating either alkaline or PEM electrolysers. Nel's A Series electrolysers use an atmospheric alkaline method for splitting water, while its M, C, H and S Series utilise the PEM technology. Units from the A, C and M Series can be containerised to facilitate deployment and setup.

The table below includes information about the largest of Nel's electrolysers within its A and M Series.

	A3880	M5000
Net Production Rate	2,400-3,880 Nm^3/h	4,920 Nm^3/h
Production Capacity Dynamic Range	3.75-100% of flow range	10-100% (Input Mode); 10-100% (H_2 Demand Mode)
Power Consumption at Stack1	3.8-4.4 kWh/ Nm^3	4.53 kWh/ Nm^3
H_2 Purity (with Optional Purification)	99.99-99.999 %	99.9995%
O_2-Content in H_2	< 2 ppm v	< 1 ppm v
H_2O-Content in H_2	< 2 ppm v	< 5 ppm v
Delivery Pressure	1-200 barg	30 barg (435 psig)
Ambient Temperature	5-35º C	10-40º C
Electrolyte	25% KOH aqueous solution	Proton Exchange Membrane

According to information from the company's third-quarter financial report released in October 2021, it manufactures PEM electrolysers at its Wallingford facility in the US with an annual production capacity of more than 50 MW, and alkaline electrolysers at the Herøya site in Norway totaling 500 MW. The latter site could be expanded to 2 GW.

The company has set itself a target of producing green hydrogen at USD 1.5 per kg by 2025.

Plug Power

Plug Power Inc is a US-based provider of clean hydrogen solutions that made the news in January 2021, when it agreed a USD-1.5-billion investment from South Korean industrial conglomerate SK Group. The latter eventually completed a capital investment of USD 1.6 billion in February to secure a 9.6% stake in the US company.

Plug Power is a supplier of hydrogen and various fuel cell solutions that also manufactures PEM electrolysers. More specifically, the company offers the GenFuel stacks in two versions of 1 MW and 5 MW per unit. The larger system provides on-site hydrogen for markets such as heavy industry, e-mobility, renewable energy and energy storage.

Below you can see the product specifications for the two GenFuel versions.

	GenFuel 1 MW	GenFuel 5 MW
Electrical input	480 VAC, 60 Hz (USA) / 400 VAC, 50 Hz (EU)	--
AC power requirements	--	5.2 kWh/Nm³ @ full capacity / 200 kWh standby (0% flow, system on)
Ambient temperature	--	-20°C to +40°C
Hydrogen production	200 Nm³/hr / 425 kg per day	100 to 1,000 Nm³ /hr (9 to 90 kg/hr)
Hydrogen quality/purity	Up to 99.999%	99.999%
Hydrogen pressure	40 barg	Up to 40 barg
Startup time	30 seconds (warm start) / <5 minutes (cold start)	30 seconds (warm start) / 5 minutes (cold start)
Average Stack Efficiency	49.9 kWh/kg	49.9 kWh/kg

Plug Power is aggressively expanding all around the world. In November 2021, the company opened the Plug Power Innovation Center, a green hydrogen and fuel cell Gigafactory in Rochester, New York, that also has the capacity to produce 500 MW of electrolysers per year.

Just in the month of October, Plug Power announced three partnerships in South Korea, Australia and Europe that involve the construction of electrolyser production facilities. The company has set up one joint venture with SK E&S to build a Gigafactory in a key metropolitan area in South Korea by 2024, another with Fortescue Future Industries (FFI) in Australia to build an 2-GW electrolyser production plant in Queensland, and a green hydrogen partnership with Lhyfe in Europe that includes plans for a 1-GW production site.

At its third annual Plug Symposium held in mid-October, the company made projections for electrolyser sales of over 100 MW by 2022.

Siemens Energy

Siemens Energy is another large company that manufactures and provides electrolysers as it continues to drive the development of a hydrogen economy.

In February 2021, Siemens Energy announced an electrolysis and hydrogen technology partnership with Air Liquide. The two signed a memorandum of understanding (MoU) that outlines a plan to combine their expertise in PEM electrolysis, focusing on the co-creation of large industrial-scale hydrogen projects, preparing for the mass fabrication of electrolysers in Europe, and on research and development (R&D) activities to co-develop next generation electrolysers.

Siemens has created the Silyzer product family, a fully-CO2-free PEM electrolysis system that runs on wind and solar power to produce hydrogen. The Silyzer 300 is what Siemens says is the most powerful product line in the double-digit megawatt range of its PEM electrolysis portfolio. More details about the product are available in the table below.

Silyzer 300	
Hydrogen production	100 – 2,000 kg per hour
Plant efficiency	> 75,5%
Startup time	< 1 minute
Dynamics	0 – 100% in 10% / s
Minimum load	≥ 5%
Water consumption (DI)	10 l per kg hydrogen
Hydrogen quality	Ultra high purity 5.0

Stiesdal

Stiesdal A/S is a Danish cleantech firm that develops floating offshore wind foundations, energy storage technology, Power-to-X technology and pyrolysis plants for atmospheric carbon capture and storage (CCS) and biofuel production. The company has a unit called Stiesdal PtX Technologies A/S that is dedicated to the application of renewable electricity across all sectors through its HydroGen electrolyser.

This product is based on conventional alkaline electrolysis but its electrode stack system is of a novel design that integrates cooling and gas separation.

Depending on the configuration, the electrolyser can be supplied with a very small unit footprint, down to 10 square metres per MW for the 2X unit and to 5 sq m per MW for the 10X unit.

The first commercially available unit is presented with a rating of 2 MW-3 MW, while the next-generation unit will exceed 10 MW.

The company, backed by PensionDanmark, has said that an initial demo project will be installed in early 2022.

In October 2021, it was announced that Reliance New Energy Solar Ltd (RNESL), part of Indian conglomerate Reliance Industries Limited, intends to build a "giga factory" in the state of Gujarat for the production of hydrogen electrolysers using Stiesdal's technology.

Sunfire

Sunfire GmbH is a German manufacturer of industrial electrolysers based on both alkaline and SOEC technologies. Its systems are modular in design so that the output can be adapted to the demand. The company offers alkaline electrolysers with a minimum power of 10 MW and SOEC electrolysers with a minimum power of 3 MW.

Dresden-based Sunfire says that pressurised alkaline electrolysis is the most mature, reliable and cost-effective technology currently available. The firm added high-pressure alkaline water electrolysis to its portfolio in January 2021 when it took over Swiss sector player IHT Industrie Haute Technology SA.

The table below includes the technical data for the company's HyLink Alkaline electrolyser.

Hydrogen production	
Net production rate	2,230 Nm3 /h
Production capacity dynamic range	20 % ... 100 %
Delivery pressure	30 bar (g) without additional compression
Hydrogen purity	> 99.6 % before gas cleaning**
Operation temperature	up to 85 °C
Power input and electrical efficiency	
Stack power rating (DC)	10,000 kW
Specific power consumption at system level (AC)	4.7 kWh/Nm3
System electrical efficiency*	64 %

Feedstock	
Demineralized water consumption	1.9 m³/h
Electrolyte	30 % KOH aqueous solution
Other specs	
Proven system runtime	> 20 years
Stack lifetime	> 90,000 h
Footprint* **	~ 450 m2
Ambient temperature	5 °C ... 40 °C

* Lower heating value of hydrogen referred to AC power input
** up to 99.999 % after gas cleaning
*** Average space requirement for a 10 MW system comprising all auxiliary systems

In October 2021, the company announced its intention to build a large-scale alkaline electrolyser production site with an annual capacity of 500 MW in Germany by 2023. The idea is to expand that facility to more than 1 GW in the future.

When it comes to the SOEC technology, Sunfire operates the largest such electrolyser at the Salzgitter Flachstahl iron and steel mill and will start a multi-megawatt system at the Neste refinery in Rotterdam next year. CEO Nils Aldag believes that SOEC will be the preferred electrolysis technology in various industries due to its efficiency.

“We are currently preparing for upscaling by designing our SOEC electrolysers for industrialisation and developing manufacturing processes,” a company representative told the authors of this report.

“It is highly attractive for Sunfire to both offer high and low temperature electrolysis. This allows us to equip our customers with the most suitable technology for each application. In addition, we can even offer hybrid electrolysis plants that take advantage of the individual, complementary benefits of both technologies. Sunfire is currently the only company in the world to offer this package,” said Laura Ziegler, manager communications.

ThyssenKrupp

Germany-based industrial group ThyssenKrupp is best known as a steel manufacturing major, but is also an engineering company with interest in energy storage systems. In this particular field, ThyssenKrupp is developing redox flow battery and hydrogen electrolysis technologies.

Through ThyssenKrupp Uhde Chlorine Engineers, the group is developing its own advanced alkaline water electrolysis technology. It offers electrolysers in prefabricated skid-mounted modules that can be added up to several hundred megawatts up to gigawatt scale.

Below you can find technical specifications for the company's 20-MW electrolyser unit.

20 MW module	
Design capacity H2	4000 Nm³/h
Power consumption (DC) at start up	4.5 kWh/Nm³
Water (demineralized) consumption	<1l/Nm³ H2
Standard operation window	10% - 100%
H2 product quality at electrolyzer outlet	> 99.9% purity (dry basis)
H2 product quality after treatment (optional)	as required by customer, up to 99.999%
H2 product pressure at electrolyzer outlet	~300 mbar
Operating temperature	up to 90°C

The company says that presently it can deliver 1 GW of electrolysis cells per year and is looking forward to expanding to a 5-GW supply chain. It has concluded that global transport chains operate efficiently only at gigawatt scale.

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