Electrolyser Market Overview 2023

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GREEN HYDROGEN SOUTH AFRICA

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RESPONSIBLE INSTITUTIONS

Green Hydrogen South Africa (GH2SA): GH2SA is a multi-stakeholder initiative that promotes South Africa as a leading green hydrogen producer and investment destination of choice. It is led by the Investment and Infrastructure Office (IIO) within the South African Presidency and home of the South African Green Hydrogen Summit (SAGHS).

H2.SA: H2.SA is a project of the German Development Cooperation with South Africa. It is commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH* in close cooperation with The Presidency of South Africa. H2.SA's main objective is to promote a South African green and sustainable hydrogen economy. Working closely with its partners from Government, private sector, and civil society, H2.SA provides expertise, resources, and builds capacity for a secure and sustainable energy future that holds opportunities for all South Africans.

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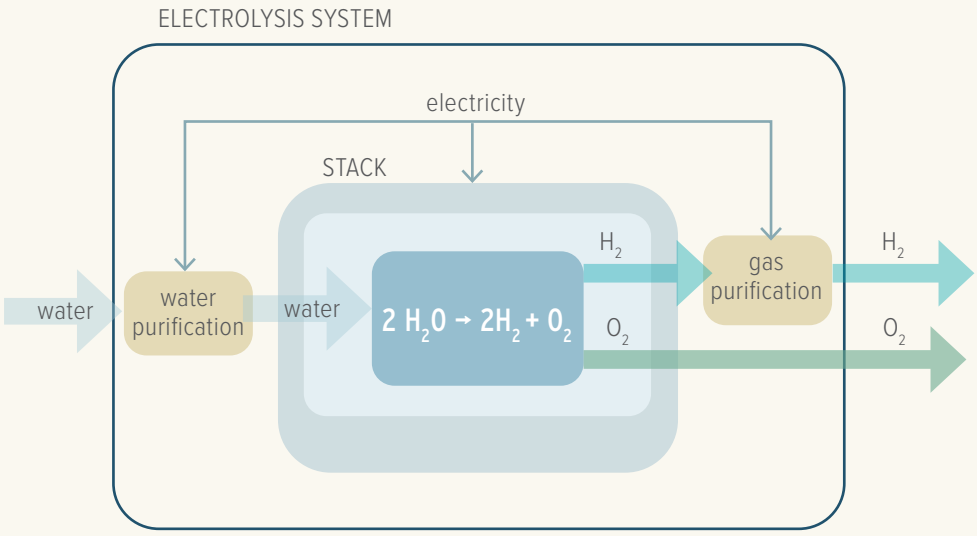
Green Hydrogen and Electrolysers

In the context of a rapidly decreasing global carbon budget and an urgency to identify adequate solutions for decarbonizing the so-called hard-to-abate sectors, the demand for green hydrogen (H2), is steadily increasing.

The term “green hydrogen” refers to H2 produced on the basis of using renewable energy sources via electrolysis; Power to X (PtX) refers to renewable hydrogen-based products such as ammonia and synthetic jet fuels. Many offtakers (e.g. Germany, the EU, Japan) are willing to pay a premium and to sign long-term supply agreements to stimulate the development of the renewable H2/PtX market. Renewable hydrogen also offers domestic use opportunities to countries such as South Africa, which are characterised by favourable solar and wind energy conditions, sufficient mineral resources, and existing hydrogen value chains and industries.

A key component in creating hydrogen is the process of electrolysis, which uses an electrolyser device that converts electrical energy into chemical energy in the form of hydrogen and oxygen, through a process called electrolysis. Electrolysis involves passing an electric current through water, which separates the water molecules into hydrogen and oxygen. The hydrogen and oxygen are then stored in separate containers for later use.



Typical electrolyser layout, adapted from the diagram which appeared in "Marktübersicht Elektrolyseure 2021" Centrales Agrar-Rohstoff Marketing-und Energie-Netzwerk (C.A.R.M.E.N. e.V.)

The basic components of an electrolyser include electrodes, an ion-selective membrane, and a power source. Electrodes serve as the conductive sites for the electric current to pass through the water. The ion-selective membrane separates the hydrogen and oxygen produced during electrolysis, ensuring that only pure hydrogen is collected. The power source supplies the electrical energy needed for the electrolysis process.

Different Types of Electrolysers

There are several different types of electrolysers, each with its own unique characteristics and applications. Some of the most common types of electrolysers include:

- **Alkaline Electrolyser (AEL):** AELs use an aqueous solution of potassium hydroxide as the electrolyte. They are known for their high efficiency, durability, and low cost. AELs are typically used in large-scale hydrogen production.
- **Proton Exchange Membrane Electrolyser (PEMEL):** PEMELs use a thin proton exchange membrane as the ion-selective separator. They are favored for their compact design, fast response time and high flexibility. PEMELs can easily be combined with volatile renewable energy sources, especially in smaller applications.
- **Solid Oxide Electrolyser (SOEL):** SOELs use a solid oxide material as the electrolyte. They operate at very high temperatures and require hot steam as an input instead of liquid water. SOELs have by far the highest efficiency of all types when working in combination with high-temperature industry processes such as steel production.
- **Anion Exchange Membrane Electrolyser (AEMEL):** AEMEL use ion-exchange membranes like PEMEL and operate in a caustic environment like AELs. Theoretically, AEMELs can combine the advantages of both types. Today, they are mostly used in small-scale applications.

Each type of electrolyser has its own advantages and disadvantages, and the choice of electrolyser will depend on the specific requirements of the application. Please note that this section is not intended as a scientific assessment of electrolyser types but rather as a high-level overview of common technologies. Project developers should therefore do in-depth research to identify the most suitable electrolyser type for their specific needs.

Alkaline Electrolyser (AEL)

Advantages:

- **Efficiency**: AELs are known for their high efficiency, making them an efficient choice for large-scale hydrogen production.
- **Durability**: AELs are durable and have a long lifespan, making them a cost-effective choice for long-term hydrogen production.
- **Cost**: AELs are relatively inexpensive to produce and maintain compared to other types of electrolysers, making them a cost-effective choice for large-scale hydrogen production.
- **Maturity**: AELs have been used for decades and are the most mature electrolysis technology.

Disadvantages:

- **Flexibility**: Alkaline stacks cannot be safely operated at low partial loads. This drawback can be omitted when using multiple stacks in larger applications.
- **Plant design**: AEL plants are more complex and difficult to maintain compared to other types of electrolysers, making them less suitable for small-scale or decentralised hydrogen production.
- **Hydrogen purity**: AELs can produce hydrogen with lower purity than other types of electrolysers, making it necessary to purify the hydrogen before it can be used in certain applications.

Overall, AELs are a good choice for large-scale hydrogen production where efficiency, durability, and low cost are important considerations. They are less favourable for small and decentralised application due to their low flexibility and more complex plant design.

Proton Exchange Membrane Electrolyser (PEMEL)

Advantages:

- **Response time**: PEMELs have a fast response time, making them suitable for a volatile energy supply.
- **Flexibility**: PEMELs can be operated at low and high current densities making them a good match with variable renewable energy sources.
- **Compact design**: Due to high current densities, PEMELs have a compact design, making them suitable for use in small-scale and decentralised hydrogen production.
- **Hydrogen purity and outlet pressure**: PEMELs produce hydrogen at high purities and at an output pressures of typically 30-40 bars. Depending on the application, gas cleaning and compression stages can be omitted allowing a simpler plant design.

Disadvantages:

- **Cost**: PEMELs use precious materials such as platinum group metals for the electrodes and are thus more expensive than AELs.
- **Durability**: Due to highly acidic conditions in the cell, durability of major components including catalyst layers, membranes and bipolar plates is limited.

Overall, PEMELs are a good choice for applications that require a fast response time and high hydrogen production rate. However, the potentially higher cost should be considered before choosing a PEMEL for a particular application.

Solid Oxide Electrolyser (SOEL)

Advantages:

- **Efficiency**: SOELs have by far the highest electrical efficiency of all electrolysers when supplied with high temperature steam.
- **Co-Electrolysis**: SOELs can perform co-electrolysis of steam and carbon dioxide to produce syngas, making them suitable in the production of carbon-based chemicals and fuels.

Disadvantages:

- **Cost**: SOELs are more expensive than other types of electrolysers.
- **Maturity**: SOELs are still under development and deal with stability issues of components, delamination of different layers and degradation. The lifetime is therefore currently low.
- **Limited range of applications**: SOELs need steam at very high temperatures as an input to be operated in an efficient way. Therefore, applications are limited to industry processes with high temperature waste-heat.

SOELs might become a very good solution for industrial applications using high-temperature heat as well as to produce synthetic fuels, in which co-electrolysis in an advantage. Today, they are still under development and face multiple challenges such as stability issues and low lifetimes.

Anion Exchange Membrane Electrolyser (AEMEL)

Advantages:

- **Potentially low cost**: AEMELs use cheap materials and can theoretically reach high current densities which leads to high potential for low costs.
- **Flexibility**: AEMELs can be safely operated at low and high partial loads, which is an advantage in small-scale applications.

Disadvantages:

- **Maturity**: The development of AEM technology is still in its early stages, and further research is needed to fully optimise its performance and reduce costs.
- **Membrane stability**: The stability of the AEMs can be limited under certain operating conditions, requiring careful monitoring and maintenance.

Overall, AEMELs combine the advantages of AELs and PEMELs and have the potential to become a key technology in the production of hydrogen. However, the challenges associated with membrane stability will need to be addressed in order to fully realise the potential of this technology.

Purpose, Context & Limitations

This market overview seeks to assist project developers with the challenging task of comparing different electrolyser manufacturers and products, in order to select the right electrolyser for their needs. The first section provides an overview of 46 manufacturers and 200 electrolysers. The second section outlines which companies are open to delivering their products to South Africa and to service them there.

Both sections were compiled with significant effort and to the best of our abilities, but they are likely incomplete and may contain minor errors for the following reasons:

- **Section 1: List of Manufacturers** – some manufacturers and/or products may have been missed when compiling this overview. Also, data sheets and even units are not standardised across manufacturers, and product ranges change rapidly, which means that data is quickly outdated.
- **Section 2: Qualitative information** – only about a third of manufacturers responded to GIZ's interview questions about their interest and intended role in the South African market, which limits our insight.

ITEM	EXPLANATION
Type	There are various types of electrolysers, which are defined by the type of separator or the environment in the cell. The most common electrolyser types are proton exchange membrane (PEM), alkaline (AEL), anion exchange membrane (AEM), and solid oxide electrolyser (SOEC).
H2 flow rate [Nm^3/h]	The H2 flow rate indicates the hydrogen output when the electrolyser is operated at nominal/nameplate capacity and is measured in normal cubic meters per hour (Nm^3/h). One normal cubic meter of hydrogen equals roughly 0.09 kilograms (kg).
System power rating [kWel]	The system power rating describes the electricity input needed to operate the electrolyser at nominal/nameplate capacity and is specified in kilowatts of electrical energy (kWel).
Voltage & type (AC/DC)	Electrolysers are typically operated with direct current (DC). If the electrolyser includes a voltage transformer, alternating current (AC) can be connected.
Specific electricity consumption [kWh/Nm^3H2]	This value specifies the electricity consumed to produce hydrogen under nominal/nameplate capacity and is measured in kilowatthours electricity per normal cubic meter of hydrogen (kWh/Nm^3H2). The electricity consumption can be given at stack or at system level, which includes stacks and other parts of the electrolyser such as pumps, power electronics, and gas treating.
System efficiency LHV [%]	The system efficiency is measured in percent (%) and describes the energy content of the hydrogen as the lower heating value (LHV) compared to the electricity which is consumed to produce the hydrogen under nominal/nameplate capacity.
Operational temperature [°C]	The operation temperature describes the temperature in the electrolyser cells, at which the electrolyser should be operated. Lower temperatures lead to a lower efficiencies, higher temperatures to higher degradation. The temperature is typically measured in degrees Celsius (°C).
Operational pressure [bar]	The operation pressure describes the pressure of the hydrogen at the output of the stack and can be increased by a compression system. The pressure is measured in bar (bar).
Dynamic range [% of nominal load]	The dynamic range describes the fraction of the nominal/nameplate capacity at which the electrolyser can be operated in a safe way and is measured in percent (%). PEM electrolysers typically have a higher range than alkaline electrolysers.
Hot stand-by start-up [sec]	The hot stand-by start-up time describes the time the electrolyser needs from stand-by mode to reach the nominal capacity and is measured in seconds (sec).
H2 purity [%]	H2 purity describes the purity of the hydrogen at the output in percent (%). The purity can be increased significantly with a drying system, which is in some cases included in the values given by manufacturers.

ITEM	EXPLANATION
Water consumption [l/Nm³H2]	During electrolysis, when water is split into hydrogen and oxygen, additional losses occur due to evaporation and cooling. The water consumption is given here in liters of water, which is needed to produce one normal cubic meter of hydrogen (l/Nm³H2).
Feed water quality	Electrolysers have high requirements on the feedwater requirements, which can be defined in different ways.
Purification included	This value indicates whether a water purification system is included in the electrolyser or not.
Cooling system	Here, the type of the cooling system is specified if applicable. Water cooling is very effective but leads to additional water demand.
Cooling flow rate [l/min]	The cooling flow rate is only relevant for liquid-cooled electrolysis systems. It indicates the amount of water required (in l/min) to operate the water-based cooling system.
Indicated floor space [m³] or volume [m³]	The size of an electrolyser system can be indicated either by its footprint/the area it covers in square meters (m³) or as the volume in cubic meters (m³) that the system covers.
Ambient temperature condition [°C]	The ambient temperature condition describes under which temperature the system can be operated in a safe way. Here, a minimum and a maximum ambient temperature is given and measured in degrees Celsius (°C).

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
ELOGEN (former ArevaH2Gen)	France	Market ready	E200	PEM	200	1 000	400V AC	4.4	4.9	61.22	30	5	100		>99.9	2	Tap water	Optional			44.51	-20	40	See online
			E500	PEM	500	2 500	400V AC	4.4	4.9	61.22	30	5	100		>99.9	2	Tap water	Optional			<75	-20	40	See online
			E1000	PEM	1 000	5 000	400V AC	4.4	4.85	61.86	30	5	100		>99.9	2	Tap water	Optional			<150	-20	40	See online
			Modular Open Power System	PEM	<4 000	<20 000	400V AC	4.4	4.85	61.86	30	5	100		>99.9	2	Tap water	Optional			<30m²/MW	-20	40	See online
			Multi-MW Systems	PEM	>2 000	>10 000	400V AC	4.3	4.8	62.50	30	0.1	100		>99.9	<2	Tap water	Optional			<31.25m²/MW	-20	40	See online
NEL ASA (took over PROTON ONSITE from the US for small PEMEL: C-, H-, M- and S-Series)	Norway	Market ready	H-Series H2	PEM	2	14.6	480V AC (50hz) or 380 - 415V AC (60hz)		7.3	41.10	15/30	0	100		100	0.92	Minimum 0.1µS/cm Best 1µS/cm	No	Liquid	45	1.46	5	50	See online
			H-Series H4	PEM	4	28	480V AC (50hz) or 380 - 415V AC (60hz)		7	42.86	15/30	0	100		100	0.92	Minimum 0.1µS/cm Best 1µS/cm	No	Liquid	68	1.46	5	50	See online
			H-Series H6	PEM	6	40.8	480V AC (50hz) or 380 - 415V AC (60hz)		6.8	44.12	15/30	0	100		100	0.92	Minimum 0.1µS/cm Best 1µS/cm	No	Liquid	87	1.46	5	50	See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
NEL ASA (took over PROTON ONSITE from the US for small PEMEL: C-, H-, M- and S-Series)	Norway	Market ready	C-Series C10	PEM	10	62	480V AC (50hz) or 380 - 415V AC (60hz)		6.2	48.39	30	0	100		100	0.9	Minimum 0.1µS/cm Best 1µS/cm	No	Liquid	76	5.01	5	40	See online
			C-Series C20	PEM	20	120	480V AC (50hz) or 380 - 415V AC (60hz)		6	50	30	0	100		100	0.9	Minimum 0.1µS/cm Best 1µS/cm	No	Liquid	114	5.01	5	40	See online
			C-Series C30	PEM	30	174	480V AC (50hz) or 380 - 415V AC (60hz)		5.8	51.72	30	0	100		100	0.9	Minimum 0.1µS/cm Best 1µS/cm	No	Liquid	167	5.01	5	40	See online
			M-Series M100	PEM	104	550	10kV and 20kV		5.3	56.60	30	10	100	10	100	0.89	Minimum 0.1µS/cm Best 1µS/cm	No			16.96	10	40	See online
			M-Series M200	PEM	209	1 100	10kV and 20kV		5.3	56.60	30	10	100	10	100	0.9	Minimum 0.1µS/cm Best 1µS/cm	No			16.96	10	40	See online
			M-Series M400	PEM	417	2 200	10kV and 20kV		5.3	56.60	30	10	100	10	100	0.9	Minimum 0.1µS/cm Best 1µS/cm	No			19.19	10	40	See online
			M-Series M2000	PEM	1 968	8 856			4.5	66.67	30	10	100		100	0.9						10	40	See online
			M-Series M3000	PEM	2 952	13 284			4.5	66.67	30	10	100		100	0.9						10	40	See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
NEL ASA (took over PROTON ONSITE from the US for small PEMEL: C-, H-, M- and S-Series)	Norway	Market ready	M-Series M4000	PEM	3 936	17 712			4.5	66.67	30	10	100		100	0.9						10	40	See online
			M-Series M5000	PEM	4 920	22 140			4.5	66.67	30	10	100		100	0.9						10	40	See online
			M-Series MC250	PEM	246	1 250	6.6 - 30kV	4.5	5.08	59.04	30	10	100	15	100	1.44	Tap water	Yes	Liquid		41.59	-20	40	See online
			M-Series MC500	PEM	492	2 500	6.6 - 30kV	4.5	5.08	59.04	30	10	100	15	100	1.44	Tap water	Yes	Liquid		55.46	-20	40	See online
			S-Series S10	PEM	0.27	1.65	208 - 240V AC		6.1	49.18	13.8	0	100		100	0.96	Minimum 0.1µS/cm Best 1µS/cm	No	Air		0.77	5	40	See online
			S-Series S20	PEM	0.53	3.23	208 - 240V AC		6.1	49.18	13.8	0	100		100	0.9	Minimum 0.1µS/cm Best 1µS/cm	No	Air		0.77	5	40	See online
			S-Series S40	PEM	1.05	6.41	208 - 240V AC		6.1	49.18	13.8	0	100		100	0.9	Minimum 0.1µS/cm Best 1µS/cm	No	Air		0.77	5	40	See online
			A-Series A150	A	50 - 150			3.8 - 4.4		73.17	1 - 200	15	100		99.99	1					150	2	40	See online
			A-Series A300	A	150 - 300			3.8 - 4.4		73.17	1 - 200	15	100		99.99	1					200	2	40	See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
NEL ASA (took over PROTON ONSITE from the US for small PEMEL: C-, H-, M- and S-Series)	Norway	Market ready	A-Series A485	A	300 - 485			3.8 - 4.4		73.17	1 - 200	15	100		99.99	1					225	2	40	See online
			A-Series A1000	A	600 - 970			3.8 - 4.4		73.17	1 - 200	15	100		99.99	1					350	2	40	See online
			A-Series A3880	A	2 400 - 3 880			3.8 - 4.4		73.17	1 - 200	15	100		99.99	1					770	2	40	See online
Cummins (Hydrogenics cooperation with SINoPEC in China)	United States of America	Market ready	HySTAT 10	A	10	50	400V AC		5.03	59.63	10	40	100		100	1.6	Tap water	Yes			14.86	-20	40	See online
			HySTAT 15	A	15	75	400V AC		5.03	59.63	10	40	100		100	1.6	Tap water	Yes			14.86	-20	40	See online
			HySTAT 30	A	30	151	400V AC		5.03	59.63	10	40 (optional: 20)	100		100	1.6	Tap water	Yes			14.86	-20	40	See online
			HySTAT 60	A	60	311	400V AC		5.03	59.63	10	40 (optional: 12)	100		100	1.6	Tap water	Yes			29.72	-20	40	See online
			HySTAT 70	A	70	383	400V AC		5.03	59.63	10	40 (optional: 12)	100		100	1.6	Tap water	Yes			29.72	-20	40	See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
Cummins (Hydrogenics cooperation with SINoPEC in China)	United States of America	Market ready	HySTAT 100	A	100	515	400V AC		5.03	59.63	10	40 (optional: 6)	100		100	1.6	Tap water	Yes			29.72	-20	40	See online
			HyLyzer 200	PEM	200	1 033	6 - 36kV AC	3.95	4.95	60.61	30	5	100		100	1.35	Tap water	Yes			44.58	-20	40	See online
			HyLyzer 250	PEM	250	1 291	6 - 36kV AC	3.95	4.95	60.61	30	5	100		100	1.35	Tap water	Yes			44.58	-20	40	See online
			HyLyzer 400	PEM	400	2 065	6 - 36kV AC	3.95	4.86	61.73	30	5	100		100	1.35	Tap water	Yes			59.44	-20	40	See online
			HyLyzer 500	PEM	500	2 588	6 - 36kV AC	3.95	4.86	61.73	30	5	100		100	1.35	Tap water	Yes			59.44	-20	40	See online
			HyLyzer 1000	PEM	1 000	5 175	4.1 - 30kV AC	4.3	4.59	65.36	30	5	100		100			No	Liquid	2 500	30.57	5	40	See online
Rolls Royce MTU (Hoeller Electrolyzers GmbH)	Germany	Limited production	Prometheus S	PEM	16	76	372V DC		4.8	62.50							0.1µS/cm	No						
			Prometheus M	PEM	68	325	496.5V DC		4.8	62.50							0.1µS/cm	No						
			Prometheus L	PEM	295	1 400	662V DC		4.7	63.83							0.1µS/cm	No						
HydrogenPro (Tianjin Mainland Hydrogen Equipment Co. Ltd. (THE))	China	Market ready	FDQ5	A	2 - 8				4.9	61.22	50	40	100		99.9							5	50	See online

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Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
HydrogenPro (Tianjin Mainland Hydrogen Equipment Co. Ltd. (THE))	China	Market ready	FDQ10	A	8 - 20				4.8	62.50	50	40	100		99.9							5	50	See online
			FDQ20	A	20 - 40				4.7	63.83	50	40	100		99.9							5	50	See online
			FDQ60	A	40 - 80				4.6	65.22	50	40	100		99.9							5	50	See online
			FDQ100	A	80 - 150				4.5	66.67	40	40	100		99.9							5	50	See online
			FDQ400	A	150 - 400				4.4	68.18	30	40	100		99.9							5	50	See online
			FDQ800	A	400 - 1 000				4.4	68.18	30	40	100		99.9							5	50	See online
			SPE	PEM	0.4 - 10						70				99.99									See online
Siemens Energy (Air Liquide)	Germany	Market ready	Silyzer 300	PEM	3 783	17 500			4	75		5	100	60	100	0.9	Tap water	Yes			112.5			See online
			Silyzer 200	PEM	225	1 250	DC		4.62	65	35			10	99.9	1.51	Tap water	Yes			19.53			See online
Plug Power Inc. (previously Plug Power)	United States of America	Market ready	EX-426D	PEM	200	1 000	400V AC	4.48	5	60	40			30	100	1.17					29.3	-20	40	See online
			EX-2125D	PEM	1 000	5 000	11 - 33kV AC	4.48	5	60	40			30	100	1.17					87.9	-20	40	See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
Plug Power Inc. (previously Plug Power)	United States of America	Market ready	EX-4250D	PEM	2 000	10 000	11 - 33kV AC	4.48	5	60	40			30	100	1.17					117.2	-20	40	See online
Sunfire GmbH (through acquisition of IHT Industrie Haute Technology S.A.)		Limited production		SO	750	2 680	AC	3.3	3.6	83.33	0	5	100	600	99.99						300	-20	40	See online
		Market ready		A	2 230	10 000	AC		4.7	63.83	30	20	100		99.6	0.85					450	5	40	See online
Enapter	Germany	Market ready	EL4.0	AEM	5	2.4	230V AC		4.8	62.5	35				99.9		20µS/cm	No			0.3	5	45	See online
			AEM Multicore	AEM	210	1 008	400V AC		4.8	62.5	35	3	105		99.9		20µS/cm	No			29.7			See online
John Cockerill (applying Chinese Jingli electrolysers)	Belgium	Market ready	DQ100	A	100	500	3.3 - 20kV	4.38	5	60	30	40	100		99.8	1.45	Tap water				36			See online
			DQ500	A	500	2 500	3.3 - 20kV	4.15	5	60	30	40	100		99.8	0.92	<1µS/cm	No			300			See online
			DQ1000	A	1 000	5 000	3.3 - 20kV	4.3	5	60	30	40	100		99.8	0.92	0.1µS/cm	No			400			See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
ITM Power	United Kingdom	Market ready	HGAS 1SP	PEM	122	707	400V AC		5.78	51.9	20				99.99	2.25					37.01	-20	40	
			HGAS 3SP	PEM	401	2 070	11kV AC		5.17	58.05	30				99.99	2.25					37.01	-20	40	See online
			3MEP CUBE	PEM	401	2 000	11kV AC		5	60.08	30				99.99	2.25								See online
Thyssenkrupp Nucera (former Thyssenkrupp Uhde Chlorine Engineers in cooperation with deNora)	Germany	Market ready	20 MW module	A	4 000	18 000	DC		4.5	66.67	30	10			99.9									See online
McPhy Energy S.A.	France	Market ready	Piel Baby	A	0.4	3					1				100									See online
			Piel P	A	1 - 1.6	6 - 9					1 - 2.5				100									See online
			Piel M	A	2.4 - 4.4	14 - 26					1 - 2.5				100									See online
			Piel H	A	3 - 10	18 - 60					4 - 8				100									See online
			Mc Lyzer 10-30	A	10	50		4.5	5	60	30													See online
			Mc Lyzer 20-30	A	20	100		4.5	5	60	30													See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
McPhy Energy S.A.	France	Market ready	Mc Lyzer 100-30	A	100	500		4.5	5	60	30													See online
			Mc Lyzer 200-30	A	200	1 000		4.5	5	60	30													See online
			Mc Lyzer 400-30	A	400	2 000		4.5	5	60	30													See online
			Mc Lyzer 800-30	A	800	4 000		4.5	5	60	30													See online
GENVIA (Schlumberger)	France	Early stage		SO																				See online
LONGi Green Energy TechNology Co. Ltd.	China	Market ready	LHy-A800	A	800	4 000		4.15	5	60	16	25	115		100						260	5	40	See online
			LHy-A1000	A	1 000	5 000		4.15	5	60	16	25	115		100						260	5	40	See online
			LHy-A1500	A	1 500	7.5		4.15	5	60	16	25	115		100						280	5	40	See online
Hystar	Norway	Limited production	Vega 200	PEM	226	900		4.1	4.5	66.67	4	25	110	10	99.97						29.72	-20	40	See online
			Vega 400	PEM	452	1 900		4.1	4.5	66.67	4	25	110	10	99.97						59.44	-20	40	See online
			Vega 900	PEM	905	3 700		4.1	4.5	66.67	4	25	110	10	99.97						59.44	-20	40	See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
Hystar	Norway	Limited production	Mira 300	PEM	314	1 400		4.4	4.9	61.22	4	15	100	10	99.97						29.72	-20	40	See online
			Mira 600	PEM	627	2 800		4.4	4.9	61.22	4	15	100	10	99.97						29.72	-20	40	See online
			Mira 1200	PEM	1 255	5 500		4.4	4.9	61.22	4	15	100	10	99.97						59.44	-20	40	See online
NextHydrogen	Canada	Early stage		A																				
AVX/KUMATEC Hydrogen GmbH & Co. KG	Germany	Limited production	50	PEM	10	50	400V AC	5	7	42.86	40	20	100		100	1	Tap water	Yes			7.43	-20	35	See online
			100	PEM	20	100	400V AC	5	6	50	40	20	100		100	1	Tap water	Yes			7.43	-20	35	See online
			200	PEM	40	200	400V AC	5	6	50	40	20	100		100	1	Tap water	Yes			14.86	-20	35	See online
			300	PEM	60	300	400V AC	5	6	50	40	20	100		100	1	Tap water	Yes			14.86	-20	35	See online
			400	PEM	80	400	400V AC	5	6	50	40	20	100		100	1	Tap water	Yes			14.86	-20	35	See online
			450	PEM	90	450	400V AC	5	5.89	50.94	40	20	100		100	1.06	Tap water	Yes			14.86	-20	35	See online
			600	PEM	120	600	400V AC	5	5.67	52.94	40	20	100		100	1.04	Tap water	Yes			29.72	-20	35	See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
AVX/KUMATEC Hydrogen GmbH & Co. KG	Germany	Limited production	750	PEM	150	750	400V AC	5	5.67	52.94	40	20	100		100	1	Tap water	Yes			29.72	-20	35	See online
			900	PEM	180	900	400V AC	5	5.67	52.94	40	20	100		100	1.06	Tap water	Yes			29.72	-20	35	See online
Green-H2-Systems (GHS)	Denmark	Limited production	HyProvide A-Series	A	90	469.8	400V AC	4.31	5.21	57.55	28				100	0.94	5µS/cm	No			14.86	-20	35	See online
			HyProvide X-Series	A	1 200	1 000	10kV AC		4.99	60.14	35				100	0.85	5µS/cm	No			48.99	-20	40	See online
Hydrogen InNovation GmbH (outsourced from HIAT GmbH)	Germany	Limited production	PURIFIER 40	PEM	1.2	6.2			5.17	58.06	40										0.02			
			CUSTOMIZER 40	PEM	2.8	15			5.36	56.00	40										0.04			See online
			SUPPLIER 40	PEM	7.6	40.5			5.33	56.30	40										0.09			See online
			STORAGER 40	PEM	20.3	102			5.03	59.71	40										0.24			See online
			PURIFIER 100	PEM	0.8	3.7			4.63	64.86	100										0.02			See online
			CUSTOMIZER 100	PEM	1.9	8.8			4.63	64.77	100										0.04			See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
Hydrogen InNovation GmbH (outsourced from HIAT GmbH)	Germany	Limited production	SUPPLIER 100	PEM	4.8	23.9			4.98	60.25	100										0.07			See online
Elcogen A.S.	Estonia	Limited production	E3000	SO	3	9.6	143 - 214V		3.2	0.94	1										0.04			See online
Sylfen	France	Early stage		SO																				See online
Himenergo (former Uralhimmash)	Russia	Market ready	BEU 125	A	125						10				99.7									
			BEU 250	A	250						10				99.7									
Hymeth	Denmark	Early stage	HYAEON	A																				See onlne
GraForce GmbH	Germany	Early stage	Dirt water plasmalysis		5 - 100						2				98						29.54			See online
H2B2 Electrolysis Technologies	Spain	Limited production	EL0.5N	PEM	0.5	3.2	400V AC	4.7	6.5	46.15	1 - 20	10	100	1	99.9	1	0.1µS/cm	No	Air		1.44	5	45	See online
			EL1N	PEM	1	6.3	400V AC	4.7	6.3	47.62	1 - 21	10	100	1	99.9	1	0.1µS/cm	No	Air		1.44	5	45	See online
			EL2N	PEM	2	12	400V AC	4.7	6	50.00	1 - 22	10	100	1	99.9	1	0.1µS/cm	No	Air		1.44	5	45	See online
			EL10N	PEM	10.05	53.2	400V AC	4.7	5.3	56.60	15 - 40	10	100	1	99.9	1	0.1µS/cm	No	Air		7.43	5	45	See online

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Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
H2B2 Electrolysis Technologies	Spain	Limited production	EL20N	PEM	20	106.6	400V AC	4.7	5.2	57.69	15 - 40	10	100	1	99.9	1	0.1µS/cm	No	Air		14.86	5	45	See online
			EL30N	PEM	31.7	164.8	400V AC	4.7	5.2	57.69	15 - 40	10	100	1	99.9	1	0.1µS/cm	No	Air		14.86	5	45	See online
			EL60N	PEM	63.3	329.2	400V AC	4.7	5.2	57.69	15 - 40	10	100	1	99.9	1	0.1µS/cm	No	Air		14.86	5	45	See online
			EL100N	PEM	100	515	400V AC	4.7	5.1	58.82	15 - 40	10	100	1	99.9	1	0.1µS/cm	No	Air		29.72	5	45	See online
			EL200N	PEM	200	1 030	400V AC	4.7	5.1	58.82	15 - 40	10	100	1	99.9	1	0.1µS/cm	No	Air		29.72	5	45	See online
			EL400N	PEM	400	2 060	400V AC	4.7	5.1	58.82	15 - 40	10	100	1	99.9	1	0.1µS/cm	No	Air		29.72	5	45	See online
			EL600N	PEM	600	3 100	400V AC	4.7	5.1	58.82	15 - 40	10	100	1	99.9	1	0.1µS/cm	No	Air		59.44	5	45	See online
			EL800N	PEM	800	4 130	400V AC	4.7	5.1	58.82	15 - 40	10	100	1	99.9	1	0.1µS/cm	No	Air		59.44	5	45	See online
PERIC Hydrogen TechNologies Co. Ltd.		Market ready	CNDQ5-15	A	5 - 15						15				100									See online
			KCDQ5-100	A	5 - 100										100						29.72			See online
			CDQ16-CDQ1000	A	20 - 2 000				4.3	69.77					99.8									See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Opera-tional pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consump-tion [l/Nm³H2]	Feed water quality	Purifi-cation included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient tempera-ture condition [°C]		Website
								Stack	System			From	To								Area	From	To	
PERIC Hydrogen TechNologies Co. Ltd.	China	Market ready	Micro H2 generator	PEM	0.02 - 0.06																			See online
			SDQ-0.01~200Nm³/h	PEM	0.01 - 300							0	100											See online
HyGear	Netherlands	Limited production	Hy.GEN-E 10	A	10	50			5	60	3 - 30	20	100	2 700	99.9	2	0.1µS/cm	No	Liquid	200	29.72	5	50	See online
			Hy.GEN-E 50	A	50	260			5.2	57.69	3 - 18	50	100	2 100	99.9	1.2	0.1µS/cm	No	Liquid	333.3	29.72	5	50	See online
			Hy.GEN-E 100	A	100	520			5.2	57.69	3 - 18	50	100	1 800	99.9	1.2	0.1µS/cm	No	Liquid	500	29.72	5	50	See online
			Hy.GEN-E 150	A	150	780			5.2	57.69	3 - 18	50	100	1 800	99.9	1.2	0.1µS/cm	No	Liquid	666.67		5	50	See online
			Hy.GEN-E 250	A	250	1 300			5.2	57.69	3 - 18	50	100	1 800	99.9	0.88	0.1µS/cm	No	Liquid	733.33		5	50	See online
H-TEC Systems GmbH	Germany	Limited production	ME 450	PEM	210	1 000	400V AC		4.8	62.50	20 - 30	20	100	30	99.9	1.24	Tap water	Yes			29.72	-20	40	See online
			2 MW HCS	PEM	420	2 000			4.8	62.50	15 - 30	20	100	30	99.9	1.44	Tap water	Yes			55.08	-20	40	See online
			4 MW HCS	PEM	840	4 000			4.8	62.50	15 - 30	20	100	30	99.9	1.44	Tap water	Yes			110.16	-20	40	
			10 MW HCS	PEM	2 100	10 000			4.80	62.50	15 - 30	20	100	30	99.9	1.44	Tap water	Yes			275.4	-20	40	

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
Ostermeier	Germany	Limited production	ELM.10	PEM	0.22		AC				15				99.95	1	<1µS/cm	No						See online
			ELM.30	PEM	0.66		AC				15				99.95	1	<1µS/cm	No						See online
			ELM.50	PEM	1.1		AC				15				99.95	1	<1µS/cm	No						See online
iph Hähn GmbH	Germany	Limited production	EL 8 - V1. EL 1	PEM	0.3 - 1	9.1																		See online
			EL 8 - V1. EL 3	PEM	0.9 - 3	22.1																		See online
			EL 8 - V1. EL 8	PEM	2.4 - 8	61.1																		See online
			EL 8 - V1. EL 20	PEM	6 - 20	156																		See online
			EL 8 - V1. EL 40	PEM	12 - 40	315															14.86			See online
			EL 8 - V1. EL 80	PEM	24 - 80	624															29.72			See online
			EL 8 - V1. EL 160	PEM	48 - 160	1 248															29.72			See online
Haldor Topsoe A/S	Denmark	Limited production	H_2 SOEC 100 MW	SO	32	100 000	6 - 24kV		3.13	96	2	10	100		100	0.84					8 400			See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
Yangzhou Zhongdian Hydrogen Production Equipment Co. Ltd.	China	Limited production	CHE-1000	A	1	6	380 - 440V AC	4.6	6	50	10				100	1			Liquid	8.33	1.93			See online
			CHE-2500	A	2.5	15	380 - 440V AC	4.6	0	0	10				100	1			Liquid	33.33	1.93			See online
			CHE-5000	A	5	30	380 - 440V AC	4.6	6	50	10				100	1			Liquid	41.67	1.93			See online
			CHE-10000	A	10	60	380 - 440V AC	4.6	6	50	10				100	1			Liquid	90	1.93			See online
			CHE-15000	A	15	90	380 - 440V AC	4.6	6	50	10				100	1			Liquid	125	2.8			See online
			CHE-20000	A	20	120	380 - 440V AC	4.6	6	50	10				100	1			Liquid	158.33	2.8			See online
			SDQ-10	A	10		380 - 440V AC	4.5		66.67	1 532				99.8	1			Liquid	31.67				See online
			SDQ-30	A	30		380 - 440V AC	4.3		69.77	15 - 20				99.8	1			Liquid	50				See online
			SDQ-50	A	50		380 - 440V AC	4.3		69.77	15 - 20				99.8	1			Liquid	70				See online
			SDQ-100	A	100		380 - 440V AC	4.3		69.77	15 - 20				99.8	1			Liquid	250				See online
			SDQ-200	A	200		380 - 440V AC	4.3		69.77	15 - 20				99.8	1			Liquid	466.67				See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
Yangzhou Zhongdian hydrogen production equipment Co. Ltd.	China	Limited production	SDQ-300	A	300		380 - 440V AC	4.3		69.77	15 - 20				99.8	1			Liquid	800				See online
			SDQ-400	A	400		380 - 440V AC	4.3		69.77	15 - 20				99.8	1			Liquid	1 016.67				See online
			SDQ-500	A	500		380 - 440V AC	4.3		69.77	15 - 20				99.8	1			Liquid	1 266.67				See online
			SDQ-600	A	600		380 - 440V AC	4.3		69.77	15 - 20				99.8	1			Liquid	1 533.33				See online
			SDQ-700	A	700		380 - 440V AC	4.3		69.77	15 - 20				99.8	1			Liquid	1 833.33				See online
			SDQ-800	A	800		380 - 440V AC	4.3		69.77	15 - 20				99.8	1			Liquid	2 000				See online
			SDQ-900	A	900		380 - 440V AC	4.3		69.77	15 - 20				99.8	1			Liquid	2 333.33				See online
			SDQ-1000	A	1 000		380 - 440V AC	4.3		69.77	15 - 20				99.8	1			Liquid	2 500				See online
Shandong Saikesaisi Hydrogen Energy Co. Ltd.	China	Limited production	QL200	PEM	0.18	2	110 - 220V AC		11.11	27	4				100						0.21			
			QL300	PEM	0.02	0.15	110 - 220V AC		8.07	37.2	4				100						0.1			
			QL500	PEM	0.03	0.2	110 - 220V AC		6.53	45.9	4				100						0.1			

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
Shandong Saikesaisi Hydrogen Energy Co. Ltd.	China	Limited production	QL1000	PEM	0.06	0.5	110 - 220V AC		8.17	36.72	4				100						0.18			
Asahi Kasei Corp.	Japan	Limited production	Aqualyzer	A	2 000	10 000			5	60														
MVS Engineering	India	Limited production	MVS bipolar electrolyser	A	5 - 500				4.8	62.5	15				99.5				Liquid					See online
EMK	South Korea	Market ready	EHG 203A	A	20	140	220, 380, 440V AC		7	42.86	9.9				99.5		<10µS/cm	No			27			See online
			EHG 403A	A	40	280	220, 380, 440V AC		7	42.86	9.9				99.5		<10µS/cm	No			36			See online
			EHG 603A	A	60	420	220, 380, 440V AC		7	42.86	9.9				99.5		<10µS/cm	No			45			See online
			EHG 803A	A	80	480	220, 380, 440V AC		7	42.86	9.9				99.5		<10µS/cm	No			45			See online
Elchemtech	South Korea	Limited production	H2GEN 50	PEM	5	25			5	60	9				99.95									See online
			H2GEN 100	PEM	10	50			5	60	9				99.95									See online
			H2GEN 200	PEM	20	100			5	60	9				99.95									See online
			H2GEN 400	PEM	40	200			5	60	9				99.95									See online
			H2GEN 1000	PEM	100	500			5	60	9				99.95									See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Operational pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consumption [l/Nm³H2]	Feed water quality	Purification included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient temperature condition [°C]		Website
								Stack	System			From	To								Area	From	To	
Elchemtech	South Korea	Limited production	H2GEN 2000	PEM	200	1 000			5	60	9				99.95									See online
Hitachi-Zosen Corporation	Japan	Market ready	Hydrospring-1		1		200V AC		5	60	8 - 8.5				99.9	3	1µS/cm	No			1.98	5	40	See online
			Hydrospring-5		5	25	200V AC		5	60	8 - 8.5				99.9	3	1µS/cm	No			3.12	5	40	See online
			Hydrospring-10		10	50	400V AC		5	60	8 - 8.5				99.9	3	1µS/cm	No			9.6	5	40	See online
			Hydrospring-50		50	250	6.6kV AC		5	60	8 - 8.5				99.9	3	1µS/cm	No			22.5	5	40	See online
			Hydrospring-100		100	500	6.6kV AC		5	60	8 - 8.5				99.9	3	1µS/cm	No			29.77	5	40	See online
			Hydrospring-200		200	1 000	6.6kV AC		5	60	8 - 8.5				99.9	3	1µS/cm	No			29.77	5	40	See online
Versogen	United States of America	Early stage		AEM																				
IMI Critical Engineering	United Kingdom	Early stage		PEM																				
CERES	United Kingdom	Early stage		SO																				
Toshiba	Japan	Early stage		SO																				
Bloom Energy	United States of America	Early stage		SO																				
FuelCell Energy	United States of America	Limited production	SOEC	SO	278.15	1 100	480V		3.94	76.21	1				99.9		1µS/cm				29.62			See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Company name	Country	Market readiness	Name	Type	H2 flow rate [Nm³/h]	System power rating [kW]	Voltage and type (AC/DC)	Specific electricity consumption [kWh/Nm³H2]		System efficiency LHV [%]	Opera-tional pressure [bar]	Dynamic range [% of full load]		Hot stand-by start-up [sec]	H2-purity [%]	Water consump-tion [l/Nm³H2]	Feed water quality	Purifi-cation included	Cooling system	Cooling flow rate [l/min]	Indicated floor space [m²] or volume [m³]	Ambient tempera-ture condition [°C]		Website
								Stack	System			From	To								Area	From	To	
Hyter	Italy	Market Ready	Rigel M2	AEM	2	11	400V AC	4.2	5.2	70	25	3	105	240	99.9	0.8	ASTM II	Optional			4	-5	45	See online
			Rigel [...]	AEM	[...]		400V AC	4.2	5.2	70	25	3	105	240	99.9	0.8	ASTM II	Optional				-5	45	See online
			Rigel V24	AEM	24	120	400V AC	4.2	5.2	70	25	3	105	240	99.9	0.8	ASTM II	Optional			11.2	-5	45	See online
		Limited Production	Sirius [...]	AEM	[...]		690V AC	4.2	4.9	75	20	3	105	240	99.9	0.8	ASTM II	Optional				-5	45	See online
			Sirius Q200	AEM	200	1050	690V AC	4.2	4.9	75	20	3	105	240	99.9	0.8	ASTM II	Optional			30.5 - 53	-5	45	See online

TYPE: Proton Exchange Membrane (PEM) Alkaline (A) Solid Oxide (SO) Anion Exchange Membrane (AEM)

Electrolyser manufacturer feedback

The above electrolyser market overview comprises a large number of companies and products; however, not all of them are available in South Africa. In order to understand the potential engagement of international electrolyser manufacturers in South Africa, and to assist South African project developers in identifying potential suppliers, we posed several key questions to the manufacturers about their business strategies.

Not all manufacturers gave feedback, but the following information provides a snapshot of their interest and intention to do business in South Africa.

1. Do you already sell electrolyser hardware in South Africa or are you considering entering the market?

Most companies, including **Elogen, Hydrogenpro ASA, Hyter, PERIC Hydrogen Technologies, Ostermeier Hydrogen Solutions,** and **Hi-Tec Systems**, have not engaged in the South African market and do not have local offices or a sales representative, but have indicated that they are open to opportunities to participate in projects in South Africa.

Hoeller Electrolyzer GmbH would be interested in supplying products to South Africa, based on the assumption that EU certified systems are acceptable and that they find a suitable partner.

John Cockerill Industry/Renewables Hydrogen has representatives in South Africa, but they are not dedicated to the hydrogen business and the company has not planned any expansion into South Africa.

Norwegian manufacturer **Hystar** has not yet sold electrolysers in South Africa and does not have representatives in the country. They aim to be a leading global electrolyser manufacturer, and as such are considering collaboration with system integrators in South Africa. They can then supply stacks from their facility in Norway and assemble containerised systems in South Africa. On very short term (delivery in 2023 or 2024), full turnkey, containerised electrolyser systems could likely be shipped from their facilities in Europe to the South African market. Hystar can offer turnkey, containerised solutions of from 1 – 6MW. Multiples of these units can also be supplied, and deliveries of up to 20MW are possible within 2024. The delivery time of these units would be in the range of 12 – 18 months. From 2025, Hystar can deliver larger plant solutions (50MW to 500MW) in collaboration with EPC companies.

Most manufacturers are more focused on their own local and regional markets. For instance, **GraForce** has focused its technology start-up activities in Germany, Austria and Switzerland, but is diversifying to international markets.

Yangzhou Zhongdian is interested in the South African market, but they need more information to understand and enter the market. Yangzhou Zhongdian provides containerised hydrogen production equipment for overseas customers, only requiring to connect water and electricity to work, which reduces the overseas installation and commissioning workload. The company also provides hydrogen production kits to facilitate the expansion of the same project and to fully match the needs of the project.

2. Are you interested in supplying components such as stacks or full hydrogen systems?

Most companies do not plan to supply components to South Africa, and prefer to supply fully integrated or turnkey systems.

Hoeller Electrolyzer GmbH focuses on stacks, and would ideally enter a new market with a partner that has already integrated a Hoeller stack into one of their systems.

Hydrogenpro ASA mainly delivers components such as stacks and gas separators which are their core products. Other components can be delivered on a case-to-case basis.

The following companies provide full systems or turnkey solutions:

Elogen is operating at large scale, and prefers to deliver complete systems (1MW, 2.5MW and 5MW are the standard unit sizes). In the medium- to long-term, components can be provided. Elogen's focus is on green hydrogen with electrolysers, using PEMEL technology.

Sunfire GmbH is focused on full systems.

Hyter supplies a full-assembled generator, customisable according to any specific needs. With the support of their holding company, the Pietro Fiorentini group, they manufacture and deliver integrated solutions with blending units, meters, storage, and piping.

John Cockerill Industry/Renewables Hydrogen supplies full hydrogen systems all over the world. They have production facilities in China with a capacity of 500MW (expanding to 1GW in 2023) and new facility in Europe with a capacity of 350MW by the end of 2023.

Thyssenkrupp Uhde Chlorine Engineers GmbH focuses on pre-fabricated skids, which can be assembled on site to electrolysis modules, including stacks. The EPC scope would be complemented via partners, although it is not currently part of their business model. They can offer balance of plant as water treatment and compression.

Hystar can provide both electrolyser stacks and full turnkey, plug and play containerised systems. In the short term, Hystar would prefer to offer turnkey, containerised solutions in the size range of 1 – 6MW.

Kyros Hydrogen Solutions products comprise turnkey systems. Sales of single components is currently not foreseen by the company.

GraForce manufactures the GraForce Plasmalyzer – a complex product which is better produced in complete units. It differs from a typical water electrolyser by splitting hydrogen from the ammonia contained in sewage water with hydrogen and purified water as products.

PERIC Hydrogen Technologies prefers to supply full hydrogen systems, with cell stack, gas-lye treator and other facilities of hydrogen generation systems with their independent IP rights.

H-TEC SYSTEMS GmbH supplies only full hydrogen systems. **Ostermeier Hydrogen Solutions GmbH** aims to supply complete systems or components to the market, and would have to rely on a reliable local partner.

Yangzhou Zhongdian would like to provide hydrogen production electrolysers or full sets of hydrogen production equipment.

3. Are you willing to offer maintenance of electrolysis hardware in South Africa?

Many companies were undecided about offering maintenance, especially since they had no current projects in the region. However, **Thyssenkrupp Uhde Chlorine Engineers GmbH** offers services and maintenance worldwide. **Hyter** indicated its willingness to establish a local presence, provided that the market proved to be valuable.

Hystar offers long-term service agreements for all markets including South Africa. Various options of these agreements can be selected, ranging from basic annual maintenance, to extended warranty schemes where everything is taken care of by Hystar. The latter includes unscheduled maintenance and stack replacement. This offers enhanced security for the buyer and can provide local actors with high confidence related to the long-term success and prosperity of the project.

GraForce indicated that maintenance could be feasible as their systems could also be serviced remotely, i.e. with support from Germany.

PERIC Hydrogen Technologies offers operation and maintenance training for clients directly when they dispatch their site engineers to do the commissioning after delivery; however, they do not offer further equipment maintenance.

4. Are you interested in entering the South African market?

Elogen and **Hyter** indicated interest in potential- and emerging hydrogen markets and will follow developments in South Africa closely.

Thyssenkrupp Uhde Chlorine Engineers GmbH through Thyssenkrupp Nucera (NCA) offers electrolysis equipment, plants, and services worldwide, including South Africa. The NCA entity has no office in South Africa, but could leverage the Thyssenkrupp network and infrastructure.

GraForce is willing to engage in South Africa as it believes that water purification combined with hydrogen production could be an interesting market segment.

Hystar could consider everything from industrial offtake opportunities (hydrogen as feedstock into ammonia/fertiliser production, refineries, mining, metals), to transportation (including compression, storage, and re-fueling). They collaborate with subcontractors on the compression, storage, and refuelling auxiliaries for transportation cases. Hystar is not focused on a single market but designs customised solutions upon request.

Companies such as **Hoeller Electrolyzer GmbH, Yangzhou Zhongdian** and **John Cockerill Industry/Renewables Hydrogen**, are not currently focused on southern Africa.

5. If you enter the South African market, how do you intend to cooperate with local partners?

Several companies such as **Elogen, Hoeller Electrolyzer GmbH, GraForce, Hydrogenpro ASA, Ostermeier Hydrogen Solutions GmbH**, and **Yangzhou Zhongdian** have indicated a willingness to consider cooperating with local partners and possibly offering maintenance services in South Africa in the future, especially if they develop projects in the region. Others might only consider expanding to promising markets in the mid- or long term, but indicted an interest in establishing local partnerships because of the distance between South Africa and their headquarters.

John Cockerill Industry/Renewables Hydrogen indicated that partnerships in South Africa had not yet been considered. They felt that due to the distance between South Africa and Europe, a partnership would be helpful for developing and maintaining business. If they decide to be active in South Africa, they will consider local staff or partners for functions such as maintenance services.

Thyssenkrupp Uhde Chlorine Engineers GmbH indicated that whether a partnership is pursued or not depends on the scope, competency, and desired partnership model of the other party.

Hystar would consider working with system integrators and EPC companies to help with system assembly of containerised systems and with the design of large plants. They could also help with installation and commissioning. Hystar's scope of supply would mainly be stack modules, control and safety systems.

PERIC Hydrogen Technologies would consider cooperating with local partners, if the market was large enough in scale. They may also consider offering maintenance services in South Africa involving training local engineers to execute technical support.

6. What strategic considerations do you have, if you enter the South African market?

In summary, most companies had different value offerings and indicated that they would consider entering the South African market provided market conditions were positive.

Hydrogenpro ASA's business model is focused on large scale (20+MW) hydrogen projects and, as such, they will monitor market developments closely.

Hyter is a young company, recently acquired by Pietro Fiorentini group and structured and financed to be a highly competitive company in the field. They are expecting exponential growth, but their technology, the AEMWE, is promising although still in its early commercial stage.

John Cockerill Industry/Renewables Hydrogen indicated that the workload to serve the European Market is quite high, so entry into the South African market seems unrealistic in the near future. However, the African continent is a very promising market for H2-production and storage. For John Cockerill to become a market player, it will be important for them to learn about the South African Hydrogen Strategy and other policy developments.

Thyssenkrupp Uhde Chlorine Engineers GmbH would consider the localisation of their supply chain and partnering with local players, but this depends on the individual market outlook, the corresponding expected market volumes, and the local investment conditions.

GraForce indicated that they are monitoring the regulatory environment in South Africa, specifically whether CO_2-free hydrogen from methane is defined as green hydrogen.

PERIC Hydrogen Technologies could sell their equipment to South Africa through a local company, or sign a non-exclusive cooperation agreement and pay commission to the partner as their representative in South Africa.

Ostermeier Hydrogen Solutions GmbH believe that a strong local partner is always mandatory. At the same time, value creation should happen locally, as far as possible.