ELECTROLYSERS

Introduction

Electrolytic hydrogen is produced by applying electricity to split a pure water source into its component molecules of hydrogen and oxygen. Electrolysers, or more precisely electrolyser stacks, are the primary electrochemical component in an electrolytic hydrogen production system. Electrolyser stacks are the main component within an electrolyser system and are supported by auxiliary components required for functions such as water and electricity supply, cooling and purification. The hydrogen produced from the electrolyser stack is purified through separation and drying processes, whilst oxygen is released into the atmosphere or can be captured or stored to supply other industrial processes.

Electrolyser stacks are comprised of two electrodes (a positively charged anode and a negatively charged cathode) that are separated by an electrolyte, which is the medium responsible for transporting the chemical charges (ions) from one electrode to the other. A variety of electrolyser technologies exist that each present their own opportunities and potential challenges.

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Electrolyser Technologies

Technology	Operating Temperature	System Efficiency
PEM	<100°C	c. 60%
ALK	<100°C	c. 60%
SOE	500-850°C	80-90%

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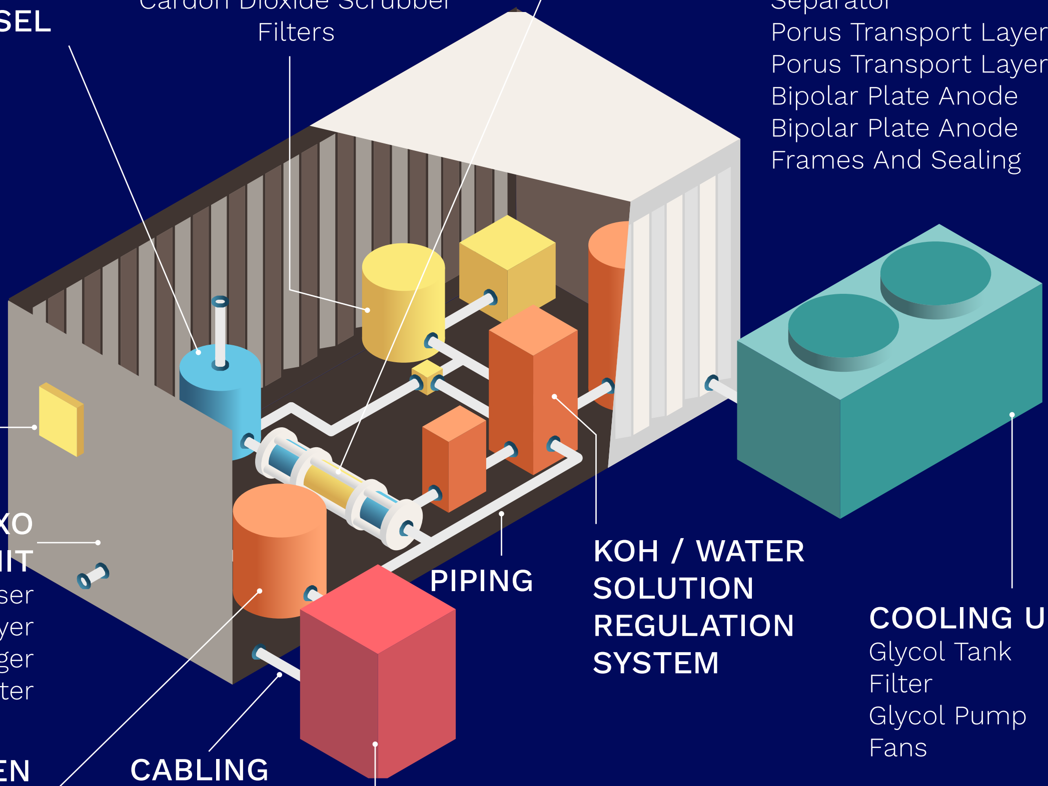
Alkaline Electrolyser

Overview

Alkaline electrolyser stacks consist of two electrodes. The electrolyte is in a liquid form and the electrodes and generated gas are physically separated via a porous inorganic diaphragm, also known as separator.

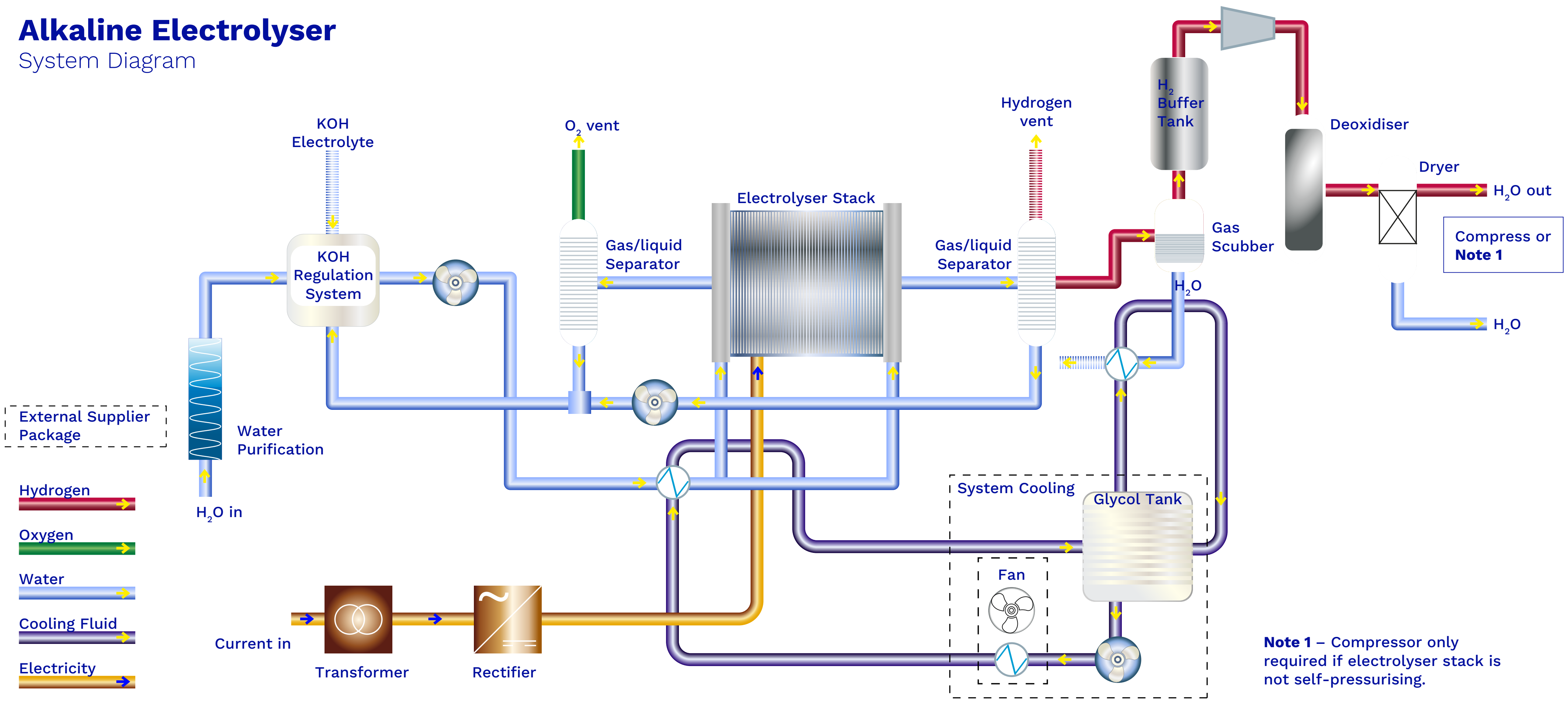
Alkaline electrolysers are the most mature technology, and their long-term stability allows them to be used in industry for the large-scale production of hydrogen for different end uses. Alkaline electrolysers present the simplest stack and system design, which translates to ease of manufacture and is ultimately the cheapest electrolysis technology.

A 3D diagram of an Alkaline electrolyser including all the auxiliary components associated with a complete system is shown here. As well as the electrolyser stack, the system includes key components required to supply the input water and mix it with the potassium hydroxide electrolyte, supply the input electricity, cool the system as required and purify the outputs from the stack.



Alkaline Electrolyser

System Diagram



Note 1 – Compressor only required if electrolyser stack is not self-pressurising.

Component list for an Alkaline Electrolyser

Sub-component	Material(s)	Specs
Anode	Nickel coated perforated stainless steel	Stainless steel, typically 304 or 316. Modified with Ni, e.g. electrodeposition
Cathode	Nickel coated perforated stainless steel	Stainless steel, typically 304 or 316. Modified with Ni, e.g. electrodeposition
Electrolyte	Potassium hydroxide (KOH) 5-7 $molL^{-1}$	Water purity, typically < 5 uS/cm, although often more stringent ASTM Type II used
Separator	Zirfon - ZrO2 (zirconium dioxide) reinforced with PPS (polyphenylene sulphide) mesh	
Porous transport layer anode	Nickel mesh (not always present)	
Porous transport layer cathode	Nickel mesh	
Bipolar plate anode	Nickel-coated stainless steel	Stainless steel, typically 304 or 316. Modified with Ni, e.g. electrodeposition
Bipolar plate cathode	Nickel-coated stainless steel	Stainless steel, typically 304 or 316. Modified with Ni, e.g. electrodeposition
Frames and sealing	Polysulfone, polytetrafluoroethylene, ethylene propylene diene monomer	

PEM Electrolyser

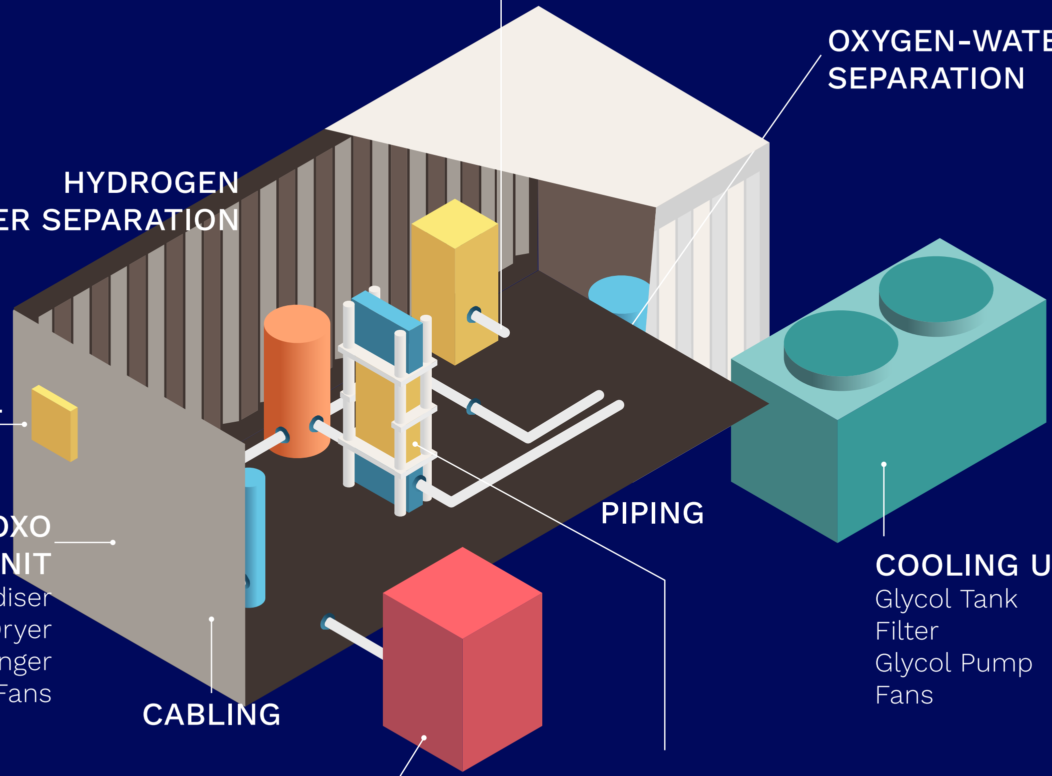
Overview

A 3D diagram of an PEM electrolyser including all the auxiliary components associated with a complete system is shown here

Similar to Alkaline electrolysis, a PEM electrolyser stack consists of two electrodes, however, in this case they are separated by a solid polymer electrolyte, which is responsible for transporting ions from anode to cathode whilst physically separating the generated hydrogen and oxygen gas.

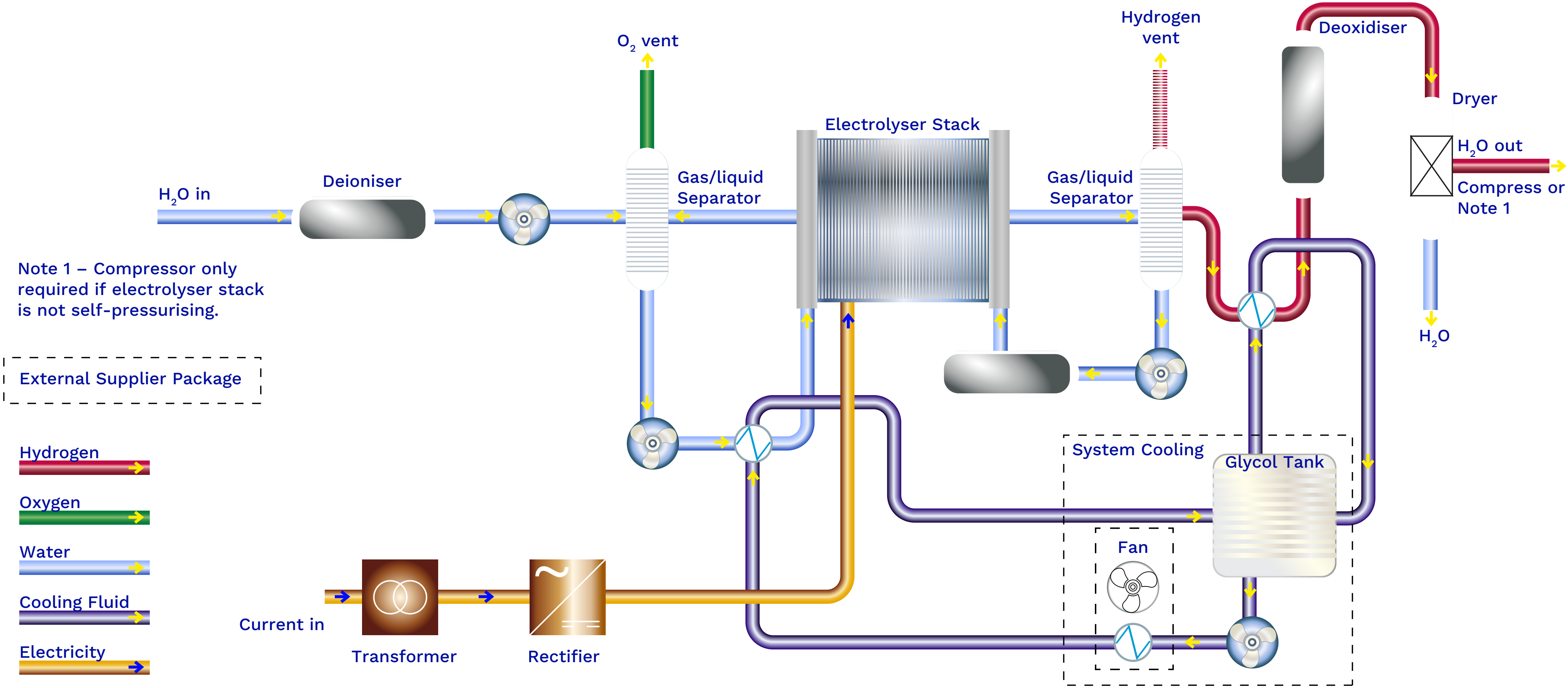
PEM electrolysers can ramp hydrogen production up and down to meet a variable demand. This flexible demand response makes the PEM electrolyser particularly suitable for intermittent renewable energy applications, including curtailed electricity consumption. For many hydrogen projects currently in development, PEM electrolysers are emerging as a favoured technology.

PEM electrolysers are less expensive that alkaline electrolysers at present, however their design is more compact.



PEM Electrolyser

System Diagram



Component list for a PEM electrolyser

Sub-component	Material(s)	Specs
Anode	Iridium and Iridium oxide	Finely dispersed or coated on titanium or alternative supports materials
Cathode	Platinum nanoparticles on carbon black	
Electrolyte	PFSA Membranes	
Separator	PFSA Membranes	
Porous transport layer anode	Platinum coated sintered porous titanium	Thin Pt coating on titanium felt, applied using advanced coating techniques, e.g. PVD
Porous transport layer cathode	Sintered porous titanium or carbon cloth	
Bipolar plate anode	Platinum-coated titanium	
Bipolar plate cathode	Gold-coated titanium	
Frames and sealing	PTFE, PSU, ETFE, EPDM	

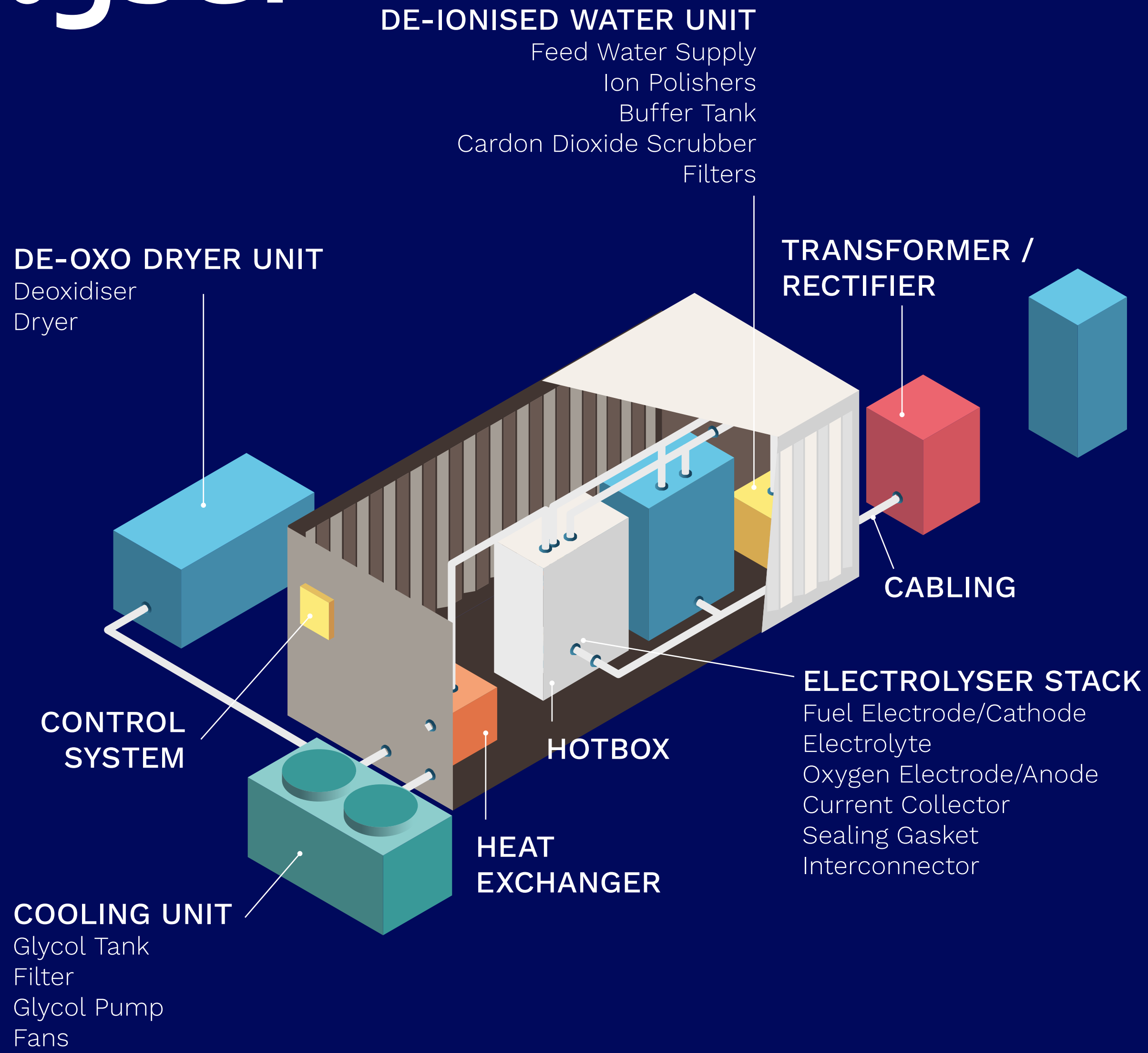
SO Electrolyser

Overview

SOEs differ from PEM and Alkaline electrolysers as they utilise heat to make hydrogen from steam. SOE electrolyser stacks are made from a mix of ceramics and metal that can handle very high temperatures of >500°C.

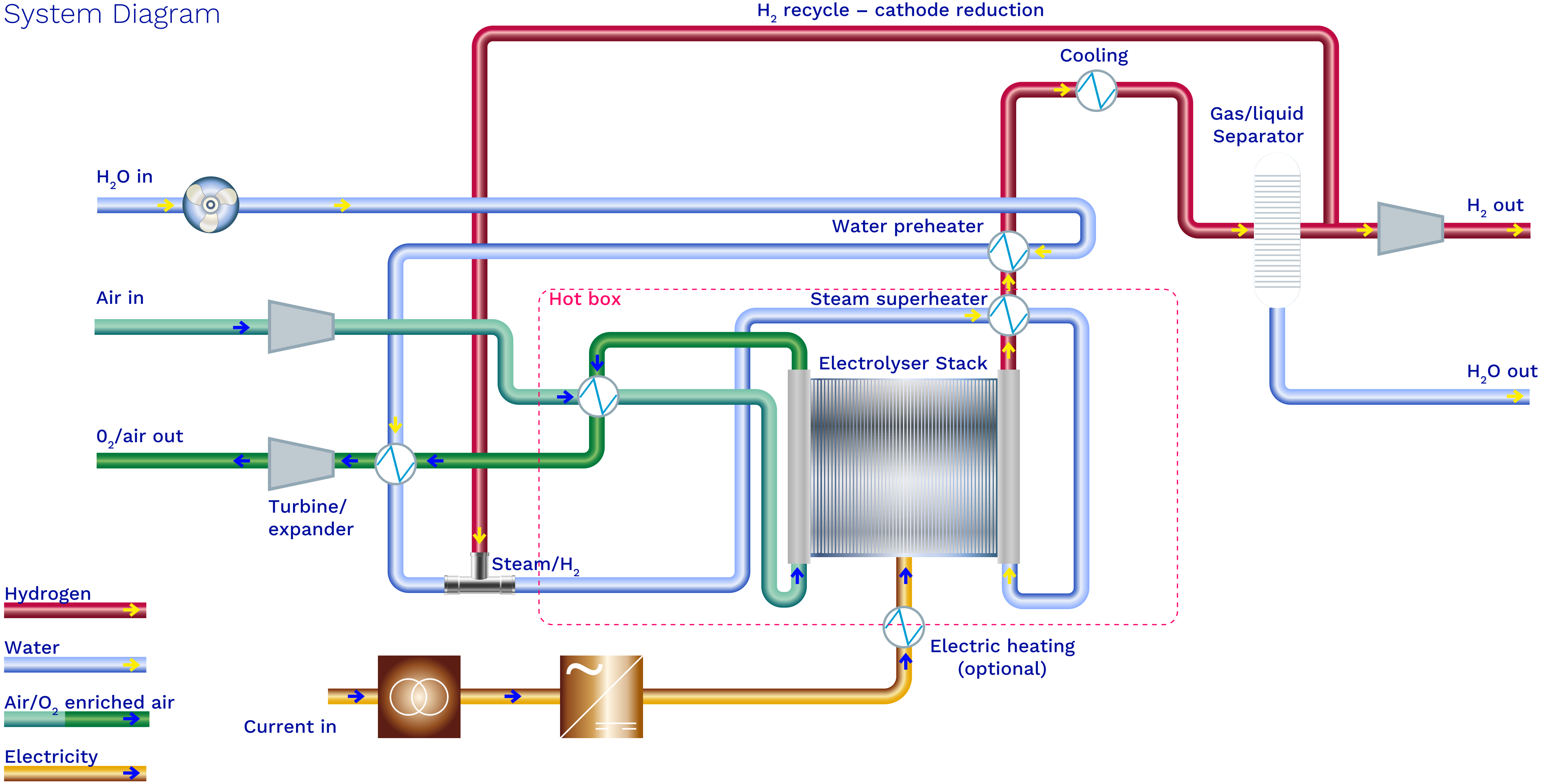
SOEs are best placed where there is a waste heat source available (e.g. nuclear or industrial facilities) as it can utilise this heat to reduce the electrical requirement to produce hydrogen. The main advantage of SOEs is their high system efficiency of 80-90%, if waste heat can be used. There is also an opportunity to capture and use the excess heat from electrolysis to improve efficiency further. However, SOEs are not able to ramp up and down very quickly due to the high temperatures involved, therefore are better suited to base load requirements.

A 3D diagram of an SO electrolyser including all the auxiliary components associated with a complete system is shown here. As well as the electrolyser stack, the system includes key components required to supply the input water and mix it with the potassium hydroxide electrolyte, supply the input electricity, cool the system as required and purify the outputs from the stack.



SO Electrolyser

System Diagram



Component list for a Solid Oxide Electrolyser

Sub-component	Material(s)	Specs
Fuel electrode/ Cathode	Nickel (Oxide) (Ni/NiO) + YSZ	Typically submicron to several micron particle size. Minimum 40 vol% Ni for electronic percolation
Electrolyte	Yttria-Stabilised Zirconia (YSZ)	Typically submicron particle size powders or dense sintered substrates
Oxygen electrode/ Anode	Perovskite materials, typically Lanthanum Strontium Cobalt Ferrite (LSCF) or Lanthanum Strontium Manganite (LSM)	Typically submicron particle size powders. Chemical composition can vary
Current collector	Silver/gold/platinum/nickel mesh	
Sealing gasket	Mica/thermiculite/glass-ceramics	
Interconnector	Stainless steel, or specialist alloys, possibly with coatings to reduce Cr evaporation	Examples: AISI430, AISI316, Crofer APU 22, Crofer 22H, Ducralloy, CFY, CrFe5, etc. Coatings typically (Mn,Co)-spinel based

With thanks to:

Scottish Enterprise

Atrium Court
50 Waterloo Street
Glasgow
G2 6HQ

www.scottish-enterprise.com