

Hydrogen Production and Types of Electrolyzers

Why Alkaline Electrolyzers are the Optimal Solution

Hydrogen Production and Types of Electrolyzers: Why Alkaline Electrolyzers are the Optimal Solution

Hydrogen, one of the most abundant elements in the universe, holds immense potential as a clean energy carrier. It plays a crucial role in achieving a sustainable economy powered by renewable energy sources. Hydrogen can be used as a fuel for vehicles, as a feedstock in chemical and petrochemical industries, or as an energy carrier capable of being converted into heat or electricity. However, its production demands advanced technologies and processes. Among these, water electrolysis stands out as a key method for producing green hydrogen.

This “White Paper” report explores the primary types of electrolyzers—Alkaline Electrolyzers (AEL), Proton Exchange Membrane Electrolyzers (PEM), and Solid Oxide Electrolysis Cells (SOEC). Particular emphasis is placed on alkaline electrolyzers and why they are the optimal solution for large-scale hydrogen production.

1. What is Water Electrolysis?

Water electrolysis is a chemical process that splits water (H_2O) into its fundamental components: hydrogen (H_2) and oxygen (O_2). This process occurs in a device called an electrolyzer, which contains multiple cells. Each cell includes two electrodes (an anode and a cathode) submerged in an electrolyte, an electrically conductive substance. When an electric current is applied, the water molecules dissociate into hydrogen and oxygen.

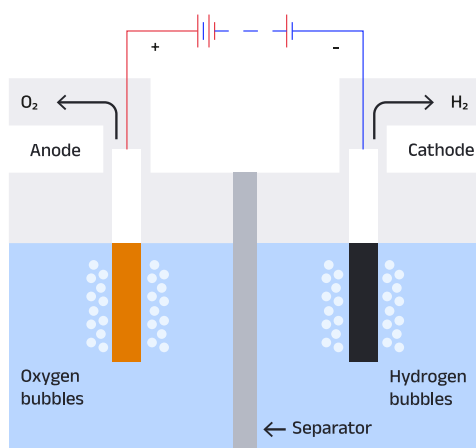


Figure 1: Electrolyzer Cell Diagram

This figure illustrates the core components of a water electrolyzer, including the anode, cathode, electrolyte, and the separation of hydrogen (H_2) and oxygen (O_2).

Own source – Rockfin R & D department

2. Types of Electrolyzers

Electrolyzers are classified into three main categories, each with distinct features and advantages:

1. **Alkaline Electrolyzers (AEL)**
2. **Proton Exchange Membrane Electrolyzers (PEM)**
3. **Solid Oxide Electrolysis Cells (SOEC)**

The selection of a specific type depends on the application's technical and economic requirements.

3. Alkaline Electrolyzers (AELs)

Alkaline electrolyzers are among the most established and widely used technologies for hydrogen production. They operate by splitting water in an alkaline solution, typically potassium hydroxide (KOH) or sodium hydroxide (NaOH). The anode and cathode are separated by a diaphragm or membrane that prevents the mixing of hydrogen and oxygen gases.

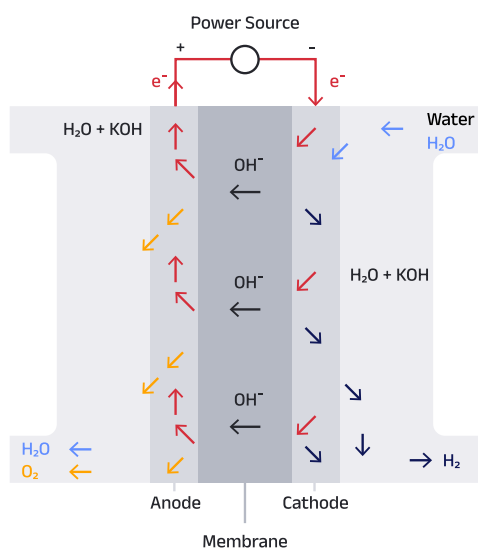


Figure 2: Technical Cross-Section of an Alkaline Electrolyzer

The diagram highlights the internal structure of an alkaline electrolyzer, showing the electrodes, the potassium hydroxide (KOH) electrolyte, and the separator membrane.

Own source – Rockfin R & D department

Advantages of Alkaline Electrolyzers

Cost-Effectiveness:

Alkaline electrolyzers use readily available and inexpensive materials, such as nickel-based catalysts and stainless steel electrodes, avoiding costly elements like platinum and iridium required for PEM electrolyzers.

Durability:

Their robust design ensures long service life, significantly reducing maintenance and replacement costs.

Proven Technology:

With decades of development, the design and operation of alkaline electrolyzers are well-understood, making them a reliable choice for industrial applications.

High Energy Efficiency:

Alkaline electrolyzers achieve energy efficiencies between 60–80%, comparable to other technologies, and operate effectively over a wide power range.

Scalability:

They are adaptable for applications ranging from small-scale laboratory setups to large industrial hydrogen production plants.

Disadvantages of Alkaline Electrolyzers

Lower Current Density:

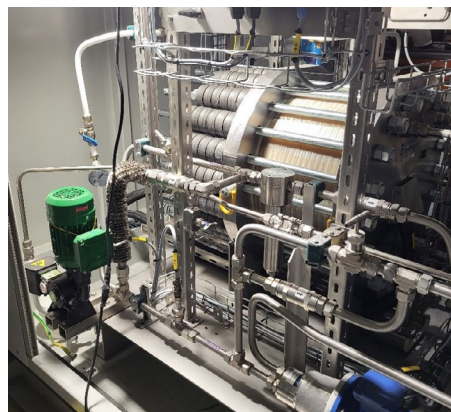
Compared to PEM electrolyzers, alkaline systems operate at lower current densities, requiring larger setups for equivalent hydrogen production.

Slow Start-Up:

AELs have longer start-up times and reduced efficiency during rapid load changes.



Picture 1: Rockfin S.A. Alkaline Water Electrolyzer HyVentive



Picture 2: Rockfin S.A. Alkaline Water Electrolyzer- inside view

4. Proton Exchange Membrane (PEM) Electrolyzers

PEM electrolyzers use a proton-conductive membrane to separate hydrogen and oxygen. The electrodes are coated with precious metal catalysts, such as platinum, which enhance the efficiency but increase production costs.

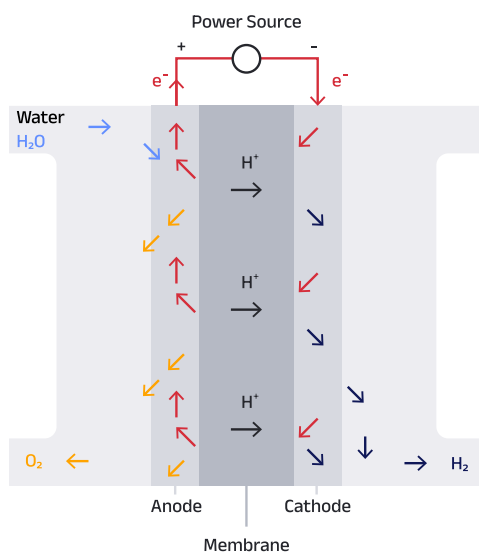


Figure 3: Schematic of a Proton Exchange Membrane (PEM) Electrolyzer

This schematic demonstrates the operation of a PEM electrolyzer, emphasising the proton-conductive membrane, catalytic electrodes, and the hydrogen and oxygen outputs.

Own source – Rockfin R & D department

Advantages of PEM Electrolyzers

High Current Density:

They produce more hydrogen per unit area of the electrode, enabling compact designs.

Rapid Response:

PEM systems respond quickly to changes in load, making them ideal for dynamic applications like renewable energy integration.

Compact and Lightweight:

These electrolyzers are suitable for mobile applications or locations with limited space.

No Liquid Electrolyte:

PEM electrolyzers use ultra-pure water instead of liquid electrolytes, simplifying maintenance.

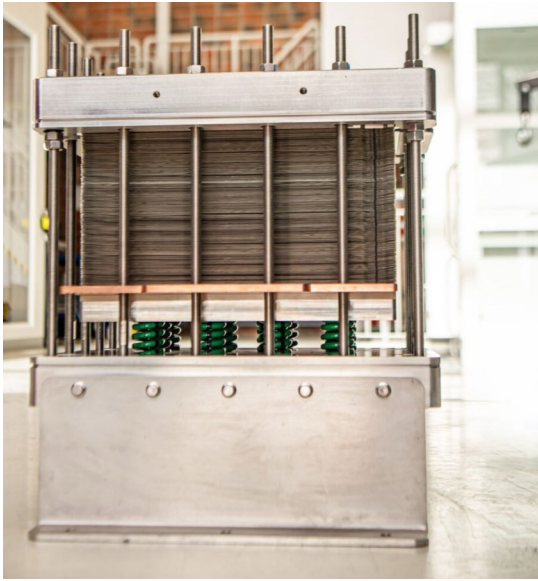
Disadvantages of PEM Electrolyzers

High Production Costs:

High production costs due to the use of precious metals and specialised membranes.

Shorter Lifespan:

Shorter lifespan due to material degradation under operating conditions.



Picture 3: Example of PEM Electrolyzer
Source: Hystar AS



Picture 4: Hydrogen generator PEM technology at the assembly line in Rockfin S.A.

5. Solid Oxide Electrolysis Cells (SOECs)

SOECs represent a cutting-edge technology that operates at high temperatures (600–1000 °C) using ceramic materials as oxygen ion conductors.

Solid Oxide Technology enables in a reverse mode so called rSOE and the system could be used as an Electrolyzer and a Fuel Cell

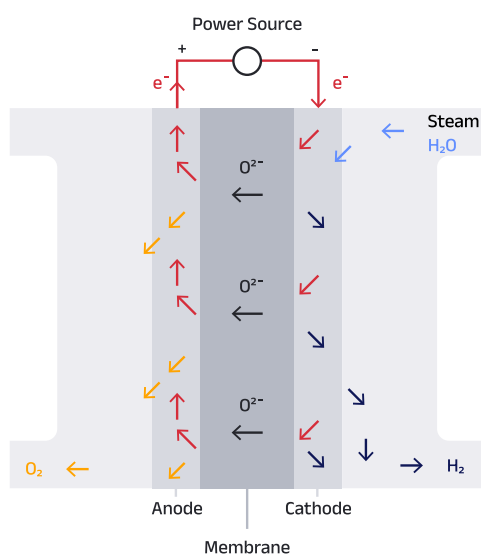


Figure 4: Solid Oxide Electrolysis Cell (SOEC) System Diagram

The figure depicts an SOEC system, showcasing its high-temperature operation, ceramic oxygen-ion conductive materials, and integration with industrial heat sources.

Own source – Rockfin R & D department

Advantages of SOEC Electrolyzers

Exceptional Efficiency:

High temperatures reduce electricity requirements, and waste heat from industrial processes can further improve efficiency.

Integration with Industrial Heat Sources:

SOECs can integrate with systems that generate waste heat, enhancing overall system efficiency.

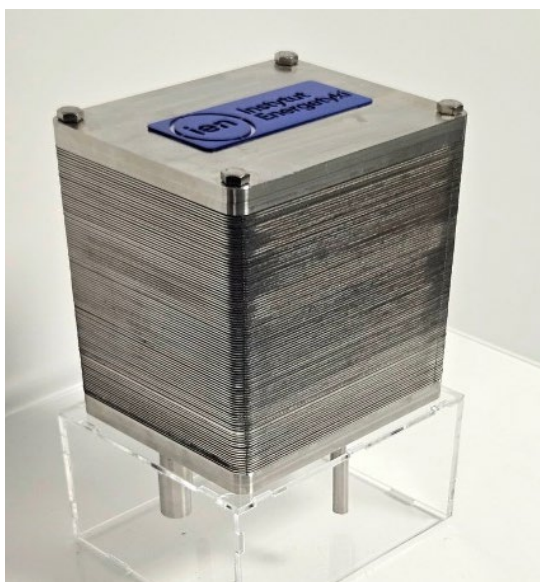
Disadvantages of SOEC Electrolyzers

High Operational Costs:

High operational costs due to expensive materials and manufacturing processes.

Shorter Lifespan:

Shorter lifespans due to material degradation at extreme temperatures.
See picture 3: Solid Oxide Electrolysis



Picture 5: Example of SOEC Electrolyzer

Source: The Institute of Power Engineering
- National Research Institute



Picture 6: Solid Oxide Cells based on MHI technology at Rockfin S.A. factory

6. Why Alkaline Electrolyzers are the Optimal Solution

Despite advancements in PEM and SOEC technologies, alkaline electrolyzers remain the optimal choice for many applications, particularly in large-scale hydrogen production. Key reasons include:

Economic Viability:

Lower upfront and operational costs make AELs accessible to industries with tight budgets.

Longevity and Reliability:

Their robust construction ensures long-term operation with minimal degradation, reducing lifecycle costs.

Established Technology:

Decades of use in industrial applications provide a proven track record of performance and reliability.

Scalability:

AELs are highly scalable and can be customised to meet diverse production requirements, from small pilot projects to expansive hydrogen production facilities.

7. Conclusion

The choice of electrolyzer depends on specific application requirements. While PEM and SOEC technologies offer advantages in niche scenarios, alkaline electrolyzers remain the most versatile and cost-effective solution. Their affordability, proven reliability, and scalability make them indispensable for the growth of the global hydrogen economy.

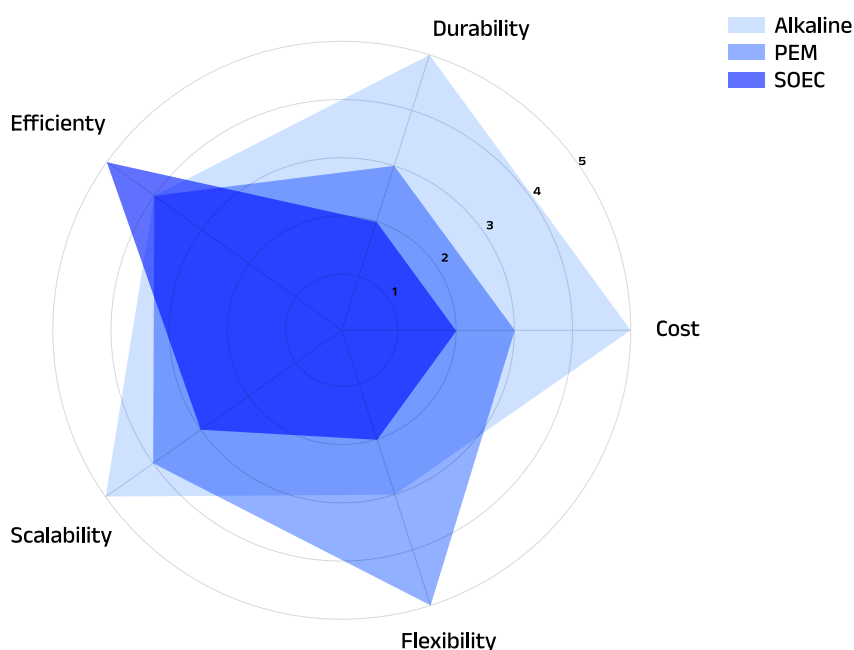


Figure 5: Performance of each type of Electrolysers – AEL, PEM, SOEC

Own source – Rockfin R & D department

This radar chart illustrates the performance of each type across multiple categories, while the bar charts focus on cost, efficiency, and durability.

As research and innovation continue, alkaline electrolyzers will likely see further advancements, solidifying their role as a cornerstone in the transition to a hydrogen-based energy system.

Disclaimer and Acknowledgement

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