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Proton Exchange Membrane (PEM)

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Overview

- Definition: Water electrolysis uses a solid polymer electrolyte in PEM technology, which splits water molecules into hydrogen and oxygen.
- Sustainability: Supplying clean hydrogen with the aid of renewable electricity.
- Efficiency: Highly efficient with fast response times, thus explaining why it will be important once integrated with fluctuating renewable energy sources.

Definition

- **Electrolysis Process:** Water is split into hydrogen and oxygen using electricity, with the PEM acting as an electrolyte.
- **Materials:** Membranes are typically fabricated with perfluorosulfonic acid polymers.
- **Outputs:** Supplies pure hydrogen ($> 99.99\%$) for fuel cells and industrial applications.

Cost Structure

- Capital Costs: Higher investment in platinum catalysts and high-end membranes increases investment in PEM electrolyzers.
- Operational Costs: Ongoing electricity costs dominate; efficiency offsets operational expenses over time.
- Cost Reduction: One of the inventive uses of catalyst materials includes reducing the platinum content in catalysts. A means of cutting costs overall.

Technology Readiness Level (TRL)

- TRL 7-8: PEM technology is at an almost commercial stage, wherein prototypes were established, and there are already some large-scale deployments.
- Maturity: Already widely adopted in small to medium-scale applications such as hydrogen refueling stations. Challenges include further cost reduction to reach broad use in large-scale hydrogen generation.

Companies



- ITM Power: commercialization of PEM electrolyzers for green hydrogen production.
- NEL Hydrogen: Supplies large-scale PEM systems suitable for industrial use.

Source: (Mendoza & Ibarra, 2023) (Luo et al., 2021) (Ivanov & Dolgui, 2020)

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Public Studies and Research

- Efficiency Gains: Advancements in both electrode and membrane designs have beaten efficiencies above 80%.
- Projected Cost: According to studies, it is believed that with continued innovation, PEM hydrogen could achieve costs below \$2/kg by 2030.
- Environmental Impact: Lifecycle analyses show that PEM produces near-zero-emission fuel when feedstock electricity is renewable.

Process Steps

- Water Inlet: Pure water is fed into the system.
- Electrolysis: Electricity breaks down water into hydrogen at the cathode and oxygen at the anode.
- Collection of Hydrogen: High-purity hydrogen is collected in storage or used instantly.

Benefits

- Fast Response: Suitable for most dynamic renewable energy resources, like wind and solar.
- Purity: Produces hydrogen suitable for critical applications like fuel cells.
- Compact Design: PEM electrolyzers have a smaller footprint than alkaline systems.

Challenges

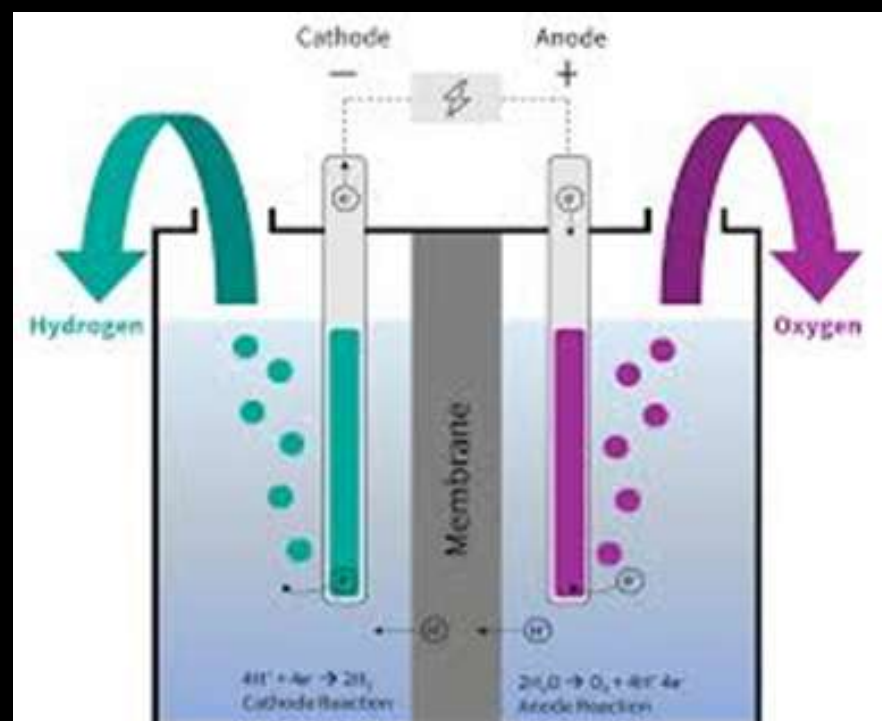
- High Costs: Catalyst and membrane materials are still fairly expensive.
- Durability: High loads can degrade membranes, so longevity innovation is required.
- Water Quality: Ultrapure water is needed for fouling not to set in and the performance to be sustained.

Example Applications

- Chemical Industry: It provides Hydrogen for ammonia production and methanol synthesis.
- Energy Sector: It preserves power-to-gas projects that convert excess renewable energy into Hydrogen for storage or grid balancing.
- Heavy Industry: Hydrogen supplies its raw materials to various processes, one of which is producing steel, thus reducing carbon emissions.

Images

- Efficiency comparison between PEM and other electrolysis technologies. Figure: The PEM electrolyzer was installed within the solar panels.
- Flow Diagram: Electrolysis process whereby water is fed into the system, split into hydrogen, and collected afterward.



Source: (Tufa et al., 2020)

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Summary (I)

- PEM represents a mature technology for high-efficiency hydrogen production.
- The pathways for cost reduction: Material advance and scaling are significant to commercial viability.
- Future role likely to play: Playing a great role in green hydrogen production for energy transition goals.

Summary (II)

- Explore partnerships to expand PEM applications.
- Invest in the search for inexpensive catalysts and membranes.
- Support scaling up PEM Electrolyzers for global green hydrogen demand.