Power to X: Design of a unit of green hydrogen production and Its Derivatives

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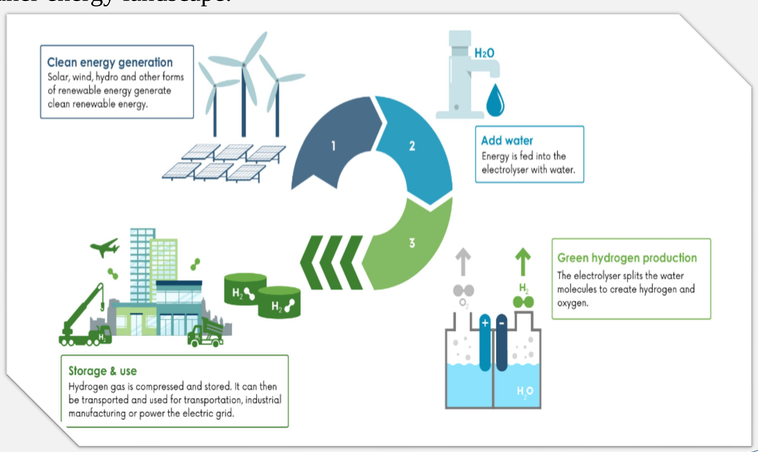
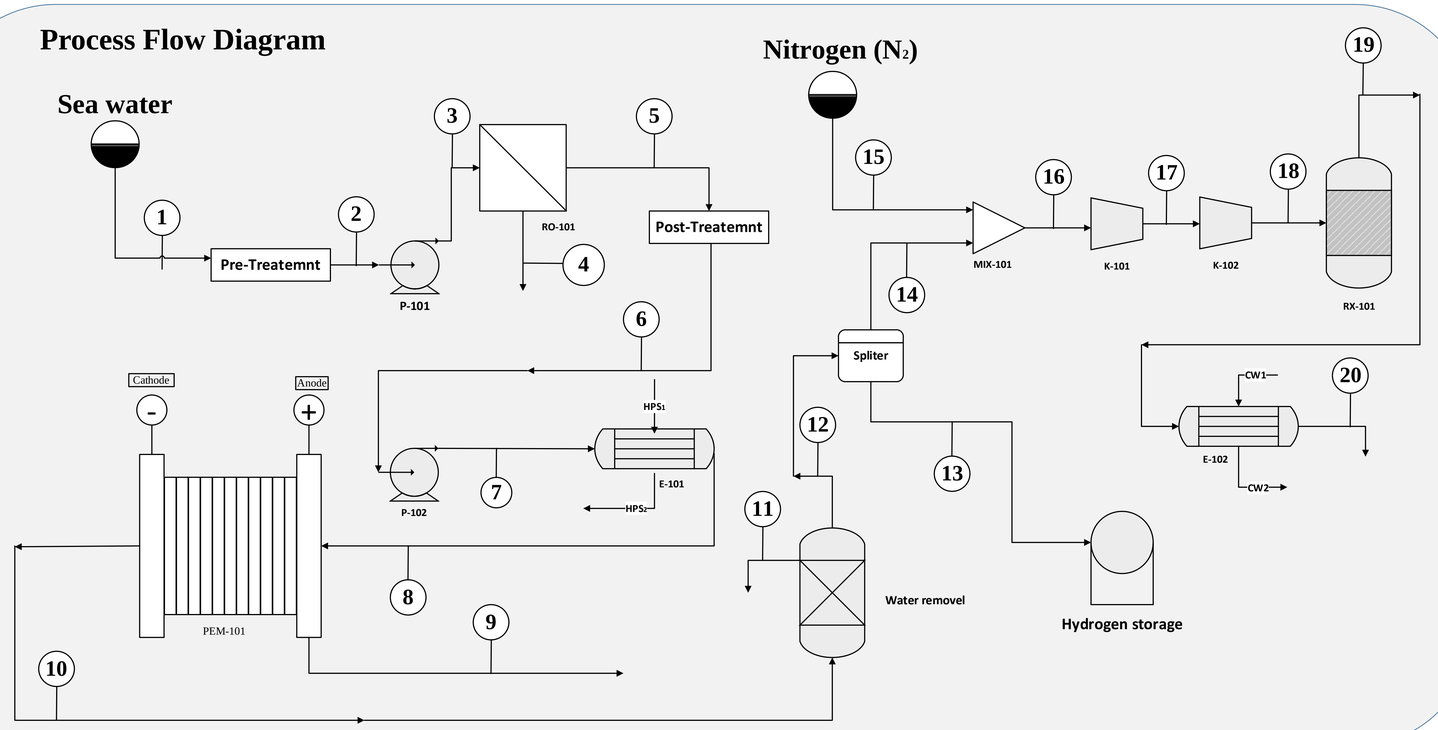
Introduction

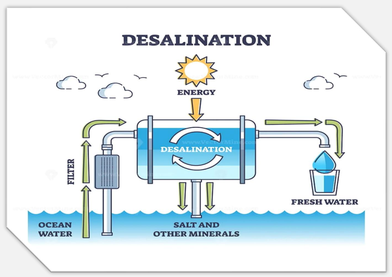
This project studies the implementation of a green hydrogen production unit in KSA, supporting Vision 2030's sustainability goals and aiming to achieve zero carbon emissions. Powered by renewable energy, the process begins with seawater desalination through reverse osmosis (RO) to provide water for electrolysis. Using a Polymer Electrolyte Membrane (PEM) electrolyzer, produced high-purity hydrogen (99.99%) is stored or converted into green ammonia via the Haber-Bosch process. The project aims to produce 100,000 tons/year of hydrogen, contributing significantly to a cleaner energy landscape.



Process Flow Diagram



Desalination Process



Feed volumetric flow rate

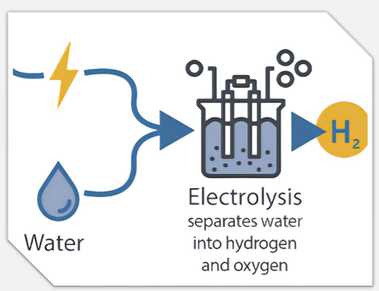
$$Q_F = 0.2484 \left(\frac{\mathrm{m}^3}{\mathrm{s}}\right)$$

Product volumetric flow rate

$$Q_P = 0.1863 \left(\frac{\mathrm{m}^3}{\mathrm{s}}\right)$$

Energy for RO system: $Q = 1.49$ MW

Hydrogen production



$$2H_2O \rightarrow O_2 + 4H^{+} + 4e^{-}$$

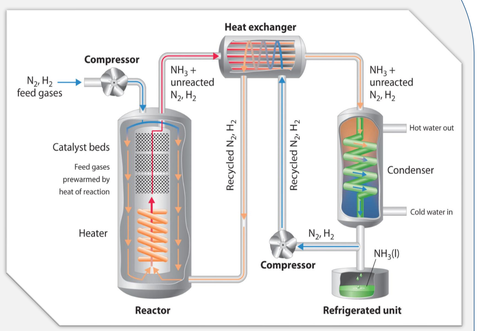
$$4H^{+} + 4e^{-} \rightarrow 2H_2$$

$$\boldsymbol{m_{H2O\ in}} = 185.7 \left(\frac{\mathrm{Kg}}{\mathrm{s}}\right)$$

$$\boldsymbol{m_{H2\ out}} = 3.17 \left(\frac{\mathrm{Kg}}{\mathrm{s}}\right)$$

Energy for PEM electrolyzer: $Q = 581.1$ MW

Ammonia production



$$N_2 + 3\,H_2 \leftrightarrow 2\,NH_3$$

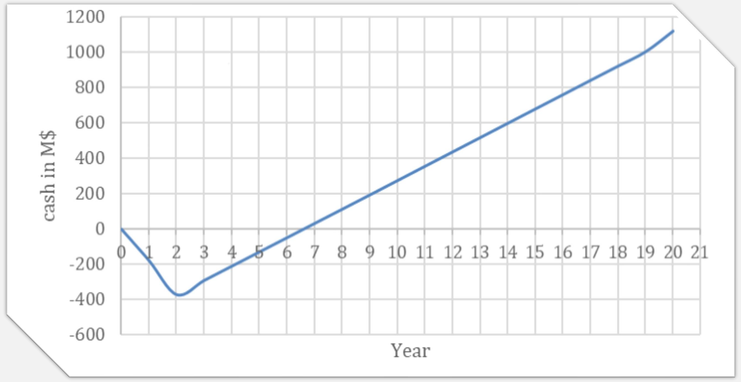
$$\boldsymbol{m_{H2}} = 1.9 \left(\frac{\mathrm{Kg}}{\mathrm{s}}\right)$$

$$\boldsymbol{m_{N2}} = 10.1 \left(\frac{\mathrm{Kg}}{\mathrm{s}}\right)$$

$$\boldsymbol{m_{NH3}} = 633.4 \left(\frac{\mathrm{Kg}}{\mathrm{s}}\right)$$

Energy for reactor: $Q = 30.2$ MW

Cumulative cash flow diagram (CCFD)



The economic analysis shows that the plant's total cost of manufacturing (COM) is approximately $389.18 million per year, while annual revenue from green ammonia and hydrogen sales is $481.63 million. After accounting for various costs, the plant achieves a profit of $1.12 billion over its 20-year lifespan, with a payback period of 6 years and 4 months. This demonstrates the plant's financial viability, offering a solid return on investment while supporting sustainable energy production through green ammonia and hydrogen.