Integrated Solar-Powered Brackish Water Desalination and Green Hydrogen Production System: Design, Modeling, and Techno-Economic Analysis

(Oral)

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ABSTRACT

The growing demand for potable water and clean energy in arid and semi-arid regions, particularly in the MENA region (Middle East and North Africa) and in Morocco, requires the development of integrated and sustainable solutions. This study proposes an innovative system coupling the production of potable water and green hydrogen from brackish water, powered by solar photovoltaic energy. Compared to seawater desalination, which involves high energy consumption, brackish water treatment offers a significant advantage due to its lower energy requirements, making it particularly suitable for inland regions far from coastal areas.

This work aims to design, optimize, and experimentally validate an innovative platform for green hydrogen production from brackish water by integrating four key stages. The first stage involves pretreatment followed by reverse osmosis (RO) desalination powered by solar energy, enabling potable water production with a salt rejection rate of 95–99%. The second stage consists of advanced polishing to produce ultrapure water meeting the stringent requirements of electrolyzers (conductivity < 0.1 µS/cm). The third stage focuses on hydrogen production via water electrolysis using a proton exchange membrane (PEM). Finally, the fourth stage involves hydrogen storage through a hybrid approach combining compressed gas and metal hydrides, coupled with a fuel cell for electricity reconversion.

This concept is particularly relevant for regions such as Aïn Aati Oulmas in Morocco, characterized by the availability of brackish water resources and high solar potential. Other examples include the Souss-Massa plain, where groundwater overexploitation has led to progressive salinization, and the Triffa plain in eastern Morocco, known for its naturally brackish water sources. The integration of desalination, ultrapure water production, electrolysis, and storage within a single platform represents an innovative approach to simultaneously address water scarcity and energy transition challenges in Morocco, which aims to produce 10 million tons of green hydrogen annually by 2050.

In addition, system modeling and techno-economic analysis were carried out using MATLAB/Simulink, incorporating energy performance and capital and operational costs. The economic assessment based on the Levelized Cost of Hydrogen (LCOH) enabled optimization of system operating parameters. The results show that, after optimization, the system achieves a competitive and reasonable hydrogen production cost, confirming the techno-economic feasibility of this solution in the context of MENA regions.

Keywords: Water–Energy Nexus; Solar Desalination; Reverse Osmosis and Photovoltaic System Design; Modeling and Simulation; Experimental Validation; Economic Feasibility; MENA Region.