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Green hydrogen production potential in the UAE using solar PV system

Yaser Al Swailmeen[1,a], Tareq Salameh[1,b], Abdul-Kadir Hamid[2,c], Mousa Hussein[3,d*]

[1]Sustainable and Renewable Energy Engineering Department, University of Sharjah, Sharjah, UAE

[2]Electrical Engineering Department, University of Sharjah, Sharjah, UAE

[3]Electrical Engineering Department, United Arab Emirates University, Al Ain, UAE

[a]U22102284@sharjah.ac.ae, [b]tsalameh@sharjah.ac.ae, [c]AKHAMID@sharjah.ac.ae, [d]mihussein@uaeu.ac.ae

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Abstract. This study explores the potential of green hydrogen production in the United Arab Emirates (UAE) using solar photovoltaic (PV) systems, aligning with the nation's commitment to sustainable energy. By integrating solar PV stations with various electrolyzer types, the research evaluates the UAE's capacity to become a global leader in green hydrogen production. The findings highlight significant production potential, with detailed analyses of electrolyzer specifications, solar PV optimization, and strategic energy scenarios, positioning the UAE at the forefront of renewable energy innovation.

Introduction

Amid global demands for sustainable energy, green hydrogen, produced via water electrolysis powered by renewable sources, emerges as a key solution for decarbonization [1,2]. The UAE, traditionally reliant on fossil fuels, is transitioning toward cleaner energy alternatives to balance economic growth with environmental responsibility [3-5]. Leveraging its abundant solar resources, the UAE aims to harness green hydrogen to support sectors like transportation and industry [6], aligning with its vision for energy independence and reduced carbon emissions [7-11]. This study estimates the UAE's green hydrogen production potential using solar PV systems, emphasizing its role in a sustainable energy future.

System and Analysis

The proposed green hydrogen production system comprises two main components: a solar PV station to generate electricity and an electrolyzer to split water into hydrogen and oxygen. The electrolysis process is described by the reaction [12]:

$$H_2O\ (l) + \text{Electricity} \rightarrow H_2\ (g) + \tfrac{1}{2}\ O_2\ (g) \quad (1)$$

Key electrolyzer types analyzed include Alkaline, Proton Exchange Membrane (PEM), and Anion Exchange Membrane (AEM), with efficiencies of 66.10%, 64.63%, and 67.86%, respectively. The solid oxide electrolyzer was excluded due to its high operating temperature requirements (>500°C) [13-15].

Solar PV panels, optimized for maximum energy output, are crystalline silicon, ground-based, and tilted at an optimal angle of 25°, determined through simulations to maximize annual energy yield. Factors such as solar irradiance, ambient temperature, terrain, and losses (3.5% from dirt/soiling and 7.5% from shading and conversion) were considered. The UAE's total area was adjusted to exclude urban, agricultural, forest, and water areas, with a coefficient accounting for land-use limitations. Two scenarios were evaluated: one where all solar PV electricity is used for

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hydrogen production, and another where excess electricity, after meeting the UAE's 2021 consumption of 122.39 billion kWh (equivalent to 4.18 Mt of hydrogen), is utilized.

Results and Discussion

The UAE's high solar irradiance ensures substantial PV power potential across the country. Simulations determined that a 25° tilt angle for solar PV panels yields the highest annual energy output, closely aligned with the UAE's latitude. The maximum green hydrogen production potential was estimated at 416.94 Mt, 407.68 Mt, and 428.05 Mt per year for Alkaline, PEM, and AEM electrolyzers, respectively, when all solar electricity is dedicated to hydrogen production. In the excess energy scenario, production slightly decreases to 414.18 Mt, 404.97 Mt, and 425.21 Mt per year for the respective electrolyzers, reflecting practical integration with national energy demands. These results highlight the UAE's capacity to leverage its solar resources for large-scale green hydrogen production, positioning it as a global leader in sustainable energy. The analysis accounts for environmental and technical factors, ensuring robust estimates. Visualizations, including maps and charts, illustrate the UAE's uniform PV potential and comparative hydrogen yields across electrolyzer types. Spatial variation exists across the UAE, with Abu Dhabi and Dubai showing the highest, and northern emirates exhibit slightly lower solar PV–based hydrogen potential due to superior irradiance and land availability. Declining PV and electrolyzer CAPEX enhances the economic attractiveness of large-scale green hydrogen production.

Conclusion and Future Work

The study highlights the UAE’s strong potential for green hydrogen production using solar PV, supporting its sustainability goals. High production estimates confirm the viability of green hydrogen as a clean energy alternative. Future research will focus on emirate-level variations and extend to the wider GCC region. Improved datasets and collaboration will refine results and advance sustainable energy solutions. A sensitivity analysis is planned to assess robustness.

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