THE ROLE OF INTERCONNECTED POWER SYSTEMS IN ACHIEVING CLEAN HYDROGEN AMBITIONS IN THE MIDDLE EAST

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Overview

The urgent need for decarbonization drives the exploration of clean energy sources and carbon-free fuels, with hydrogen emerging as a key solution. In the Middle East, hydrogen is expected to play a central role in decarbonizing various sectors in a region heavily reliant on fossil fuels for its domestic energy supply while being a global energy exporter. The United Arab Emirates, Oman, Saudi Arabia, and Egypt have already annonced their intentions to become hydrogen producers and/or exporters. During COP26, the UAE announced a goal to capture 25% of the global low-carbon hydrogen market by 2030. Saudi Arabia aims to supply 10% of global hydrogen demand by 2030. Oman has set targets to produce at least one million ton (Mt) of hydrogen from renewables by 2030, up to 3.75 Mt by 2040, and up to 8.5 Mt by 2050. Egypt released its national low-carbon hydrogen strategy in August 2024 which revealed the ambition of the country to represent 5-8% of the worldwide hydrogen market by 2040.

The COP 2028 confirmed the regional interest of transforming its economy to be resilient to the changes on energy transition. Before the energy transition, Middle Eastern economies had a competitive advantage with low-cost access to fossil fuels, facilitating their export across the world. With the energy transition, the advantages take another dimension because the region has advantages for producing clean H2, with the specificity of numerous depleted oil and gas fields facilitating carbon capture and accessible methane for producing low-cost H2 by steam methane reforming. In addition, the high solar potential and proximity to the sea offer good potential for electrolysis development

Previous studies have informed on the economics of hydrogen production in the Middle East (Hasan and Shabaneh 2021 ; Alhadhrami et al. 2024 ; Gado 2024). To the best of our knowledge, no study is yet available on the complementarities between future power systems and hydrogen generation targets in the region and this paper intends to fill this gap. This paper investigates the economic viability of producing hydrogen in the Middle East through an integrated electricity-hydrogen strategy. It focuses on nine countries – the United Arab Emirates, Saudi Arabia, Oman, Egypt, Kuwait, Qatar, Bahrain, Iraq, and Jordan – and includes an hourly representation of their intereconnected power systems. It investigates the economic potential for hydrogen production in this region under a 2050 net-zero scenario for all the countries.

The economic aspects of hydrogen production are assessed, including the cost of production under different scenarios specifcally with various solicitation of the flexibility of the power grid.

Methods

First, the paper reviews the current status of renewable energy developments in the region, ongoing decarbonization efforts, and hydrogen production strategies along with announced targets. This information is then gathered to build scenarios in 2050 horizon that includes national hydrogen generation targets and a publicly sourced representation of the power systems (power generation units, hourly power demand, network capacities between countries).

In order to achieve an economic valuation of the ambition for H2 export 2 scenarios are designed with hydrogen export or with hydrogen dedicated to domestic use. The 2 scenarios assume carbon neutrality of the region in order to ensure exports are done with no regrets of a better internal consumption.

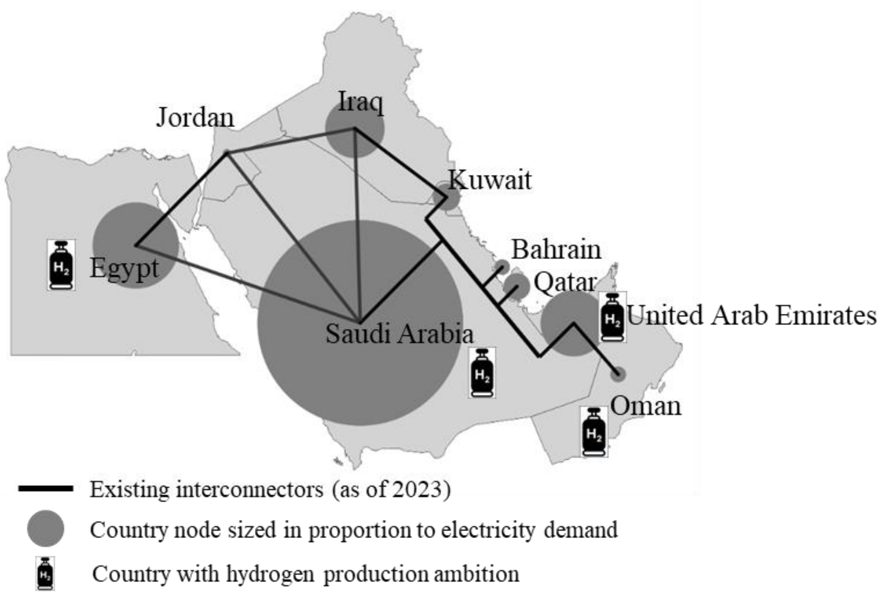

Fig. 1. Illustration of the model and considered region

The model used to investigate hydrogen strategies consists in a detailed power system model of the nine considered countries as illustrated in Fig. 1, expressed as a linear optimization program implemented in PLEXOS. The power model is based on Petitet et al. (2024) and has been extended to include hydrogen production and more time horizons (2040 and 2050). It includes different technologies for hydrogren production, such as steam methane reforming with carbon capture and storage, and electrolysis coupled with wind or solar. First, the model is run to assess the additional generation capacities required given the hydrogen production targets (capacity expansion plan). Second, it is used to simulate the hourly operations of the power systems to the national electricity demand and the electricity demand for hydrogen production.

The model is used to assess different hydrogen strategies.These strategies differ by (i) the ratio of hydrogen from electrolyser process versus carbon capture with steam methane reforming and (ii) the electricity generation assets used for the electricity required for hydrogren production that are either connected to the main national electricity grid, or stand-alone (i.e., not connected to the main grid) and dedicated to the hydrogen facility.

The green hydrogen (coming 100% from renewables); the blue hydrogen (coming from steam methan reforming and carbon capture) and clean hydrogen (coming from a carbon neutral power grid) will therefore be compared.

A simulation with no exchange of electricity between countries is also perfomed for comparison purposes to identify the benefit of the interconnected power grid in the region. For the green hydrogen production, we also test different configuration regarding the load profile of the hydrogen generation facility (e.g., rubbon or flexible demand).

Results and Conclusions

Results suggest that the complemetarities between interconnected power systems in the Middle East and hydrogen strategies can be leveraged to reduce the cost of hydrogen production while meeting national targets. Specifically, for each hydrogen strategy considered, we assess the impacts on the region’s power systems and derive the unit cost of producing hydrogen. The findings reveal that producing green hydrogen from stand-alone dedicated renewable energy sources (i.e., not connected to the main grid) is significantly more expensive than using green electricity supplied by the main national power grid. Moreover, interconnected power systems can further reduce the region’s hydrogen production costs compared to a scenario in which national targets are persued using national isolated power system.

These results lead to several recommendations for policymakers. First, all hydrogen generation options – whether connected to the national power grid or not – should be thoroughly evaluated. In the long-term, once national power grid are fully decarbonized, leveraging the complementarity between the regional interconnected power grid and hydrogen ambitions offers an efficient pathway for hydrogen production. During the transition phase, to support their green hydrogen goals, policymakers can still rely on the national power grid by implementing certification mechanisms for electricity.

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