[*Assessing Hydrogen Economy Development in Egypt: Evaluation of Sustainable Hydrogen Production Technologies Using FAHP Analysis*]

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Overview

The concept of a hydrogen economy has garnered significant attention in recent years as a potential option for transitioning away from fossil fuels and toward a more sustainable energy system (Edwards et al., 2008; Falcone et al., 2021; Griffiths et al., 2021). Hydrogen, the most abundant element in the universe, can serve as a clean energy carrier that uses in a variety of applications, including transportation, electricity generation, and industrial processes. In addition, hydrogen can store excess renewable energy to stabilize and buffer the power grid. Moreover, it serves as a feedstock in the production of various chemicals, such as ammonia and methanol, which can substitute for fossil-based feedstocks (Falcone et al., 2021).

According to the International Renewable Energy Agency (IRENA), Egypt has the potential to become a major player in the hydrogen energy market due to its abundant renewable energy resources (such as solar and wind) and its established infrastructure for natural gas production and distribution (IRENA, 2018). In July 2020, The Egyptian prime minister issued a decision (number 2516/2020) that stipulates the formation of a working group to study the importance of hydrogen technology, including the generation and use of hydrogen in Egypt; the committee is formed under the chairmanship of the minister of electricity and renewable energy (MoERE) and the membership of twelve representatives from the various concerned ministries

Identifying the current viable HPT is essential to promote the development of the hydrogen economy. Since this study aims to evaluate the different HPT in the development of a hydrogen economy in Egypt, the authors considered only the technologies that have a high potential to produce hydrogen on a large and commercial scale. In order to support the policy maker and decision-making for developing hydrogen strategies and practices in Egypt. Based on experts' suggestions in the field of hydrogen and the available primary energy resources in Egypt, five HPT pathways were chosen in this study as follows: steam Methane reforming (SMR), biomass gasification (BG), PV-Electrolysis (PVE), wind-Electrolysis (WE), Grid-Electrolysis (GE).

The present study aims to advance an MCDM-based model, which incorporates uncertainties to evaluate the sustainability of HPTs, a case study of Egypt. The proposed model utilizes the FAHP methodology to establish a sustainability criteria hierarchy, thereby assigning weights to each criterion. Furthermore, the FAHP method will be employed to rank the different HPT alternatives, thus enabling the identification of the most sustainable options. The general aim of this study could be summarized as follows:

I. Illustrate and analysis of the crucial components of the energy sector in Egypt, with a specific focus on country energy sources, including renewable energy. The primary objective is to assess the potential for hydrogen production.
II. Define the best available HPTs that can be developed commercially in Egypt.
III. Define the main criteria and sub-criteria for the evaluation of HPT concerning sustainability, then construct the hierarchy structure of the evaluation process.
IV. Utilize the FAHP method as one of MCDM's approaches to prioritizing HPT to help Egyptian decision-makers develop a country hydrogen economy strategy, which could effectively contribute to Egypt's sustainable development strategy

Methods

In this study, we propose the implementation of FAHP model to evaluate different HPT in Egypt. The FAHP model is a multi-criteria decision-making method that uses a hierarchical structure to evaluate the relative importance of different criteria and sub-criteria in the decision-making process to prioritize or select best option among other alternatives. The proposed FAHP model will evaluate five hydrogen production technologies. The evaluation will consider several sustainability criteria main and sub criteria. The purpose of the model is to provide valuable insights into the feasibility and sustainability of HPT in Egypt. The findings will inform policymakers and industry stakeholders in their decision-making process to develop a sustainable and efficient hydrogen economy strategy. Furthermore, by identifying sustainable hydrogen production options, contribute to the global efforts to transition to a low-carbon economy.

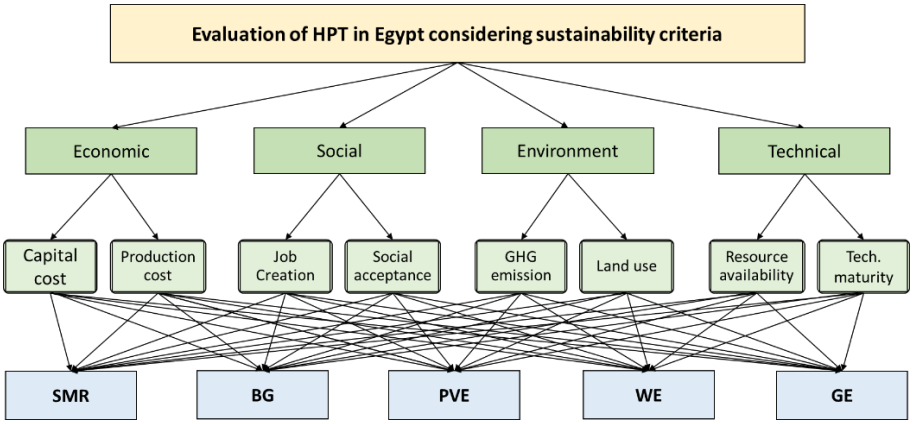

Figure 1 Hierarchical Structure Construction of the FAHP model

Results

The first step in the proposed framework is to identify the applicable criteria for evaluating EE projects; we obtained those criteria from a comprehensive literature review. Then we applied the FAHP method to the calculation of criteria weights based on selected decision-making opinion as follows; capital cost (0.459), production cost (0.148), job creation (0.064), social acceptance (0.016), GHG emission (0.075), land use (0.087), resource availability (0.038), technology maturity (0.114). The second step is the prioritization of a list of proposed hydrgogen production technoliges as figure shows the PVE ranked first (0.40) followed by GE (0.20), WE (0.18), SMR (0.12), and BG (0.9).

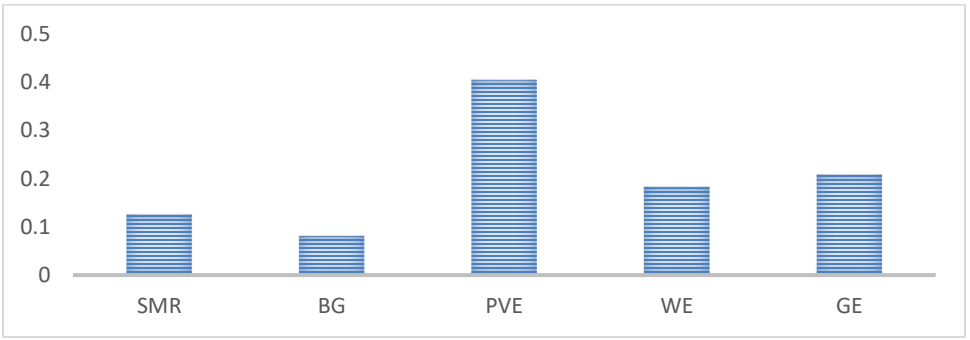

Figure 2 final rank of hydrogen production technologes in Egypt

Conclusions

The results indicate that hydrogen production via photovoltaic electrolysis (PVE) ranks the highest among the five selected technologies. This is because does not use fossil fuels, has low CO2 emissions, and abundant resources availability; capital cost and production cos are both perceived important by experts. Fo. Hence, referring to the proposed assessment model, PVE is the most appropriate hydrogen production technology in Egypt. The main benefits of hydrogen production by solar power are very low CO2 emission and resources availability. The strengths of this technology are job creation and social acceptance. The weakness of using PVE technology is higher land use

References

Edwards, P. P., Kuznetsov, V. L., David, W. I. F., & Brandon, N. P. (2008). Hydrogen and fuel cells: Towards a sustainable energy future. *Energy Policy*, *36*(12), 4356–4362. https://doi.org/https://doi.org/10.1016/j.enpol.2008.09.036

Falcone, P. M., Hiete, M., & Sapio, A. (2021). Hydrogen economy and sustainable development goals: Review and policy insights. *Current Opinion in Green and Sustainable Chemistry*, *31*, 100506. https://doi.org/https://doi.org/10.1016/j.cogsc.2021.100506

Griffiths, S., Sovacool, B. K., Kim, J., Bazilian, M., & Uratani, J. M. (2021). Industrial decarbonization via hydrogen: A critical and systematic review of developments, socio-technical systems and policy options. *Energy Research & Social Science*, *80*, 102208. https://doi.org/https://doi.org/10.1016/j.erss.2021.102208

IRENA. (2018). *Renewable Energy Outlook: Egypt*. https://www.irena.org/publications/2018/Oct/Renewable-Energy-Outlook-Egypt