TOWARDS DEVELOPING A GREEN HYDROGEN POTENTIAL MAP FOR THE KINGDOM OF SAUDI ARABIA

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Overview

The objective of this paper is to develop a green hydrogen potential map for the Kingdom of Saudi Arabia. Recognizing the importance of resource assessment maps for encouraging investment at lower risk, similar maps exist for assessing the wind and solar photovoltaic potential in the Kingdom. However, a hydrogen potential map is yet to be developed. the hydrogen potential map will help the government of Saudi Arabia to develop and implement an effective policy for the utilization of renewable resources. Also, this will help them to explore the use of these renewables as a key enabler in the development of sustainable electrical energy, market opportunities, and continuous economic growth. This green hydrogen can be an alternative source to conventional sources because it is clean and environment friendly, thus may help mitigate GHG emissions

Methods

This paper is based on a case study to produce hydrogen by the means of water electrolysis powered by 4 gigawatts of renewable resources, which are solar PV and wind energy. The results are based on comprehensive data collection along with real cost information. The study was conducted using a standard discounted cash flow rate of return methodology on different scenarios to obtain an optimum solution for the Levelized Cost of Hydrogen (LCOH) for different regions in the Kingdom. The cost calculation is based on a wide variety of inputs that characterize financial assumptions as well as capital, operating, maintenance, and replacement costs. The study also includes the cost of desalinated water used in the electrolysis process. Moreover, A sensitivity analysis has been conducted to investigate how the PV capital cost forecast for the year 2025 will affect the choice of an energy source. The equeation used to calculate the Levelized Cost of Hydrogen (LCOH) in ($/kg), is the total lifetime cost of the project divided by the total lifetime of hydrogen produced, and it is calculated as follows :

$$LCOH = \frac{CAPEX + \sum_{t=1}^{N} \frac{OPEX_t + REP_t}{(1+d)^t}}{\sum_{t=1}^{N} M_{H2} \times \frac{(1 - SRD)^t}{(1+d)^t}}$$

Results

NEOM was chosen as a case study to be the location for the economic analysis of a system, which includes 4 GW of renewable resources, PV, and Wind. These resources are supplying a 4 GW electrolyzer plant. The economic analysis was performed from the investor's and entrepreneur's perspective to see whether it is profitable to invest in a new project that uses renewable sources to sell hydrogen as a feedstock. Desalinated water is an important part of producing hydrogen; thus, the model takes into account the levelized cost of water (LCOW) to calculate the LCOH. After trying multiple scenarios using the metrological data of solar and wind obtained from the European Commission data. it was found that the LCOH of 2.70 $/kg. In addition, 4 GW size is considered to be an optimal size, since how matter the size is increased, the LCOH is only limited to a decrease of 2.3%. The Hydrogen Model was expanded to include a financial analysis of different regions in the Kingdom. In order to calculate the LCOH for the other regions, different values of levelized cost of water were taking into consideration from Saudi Water Partnership Company for the selected regions. Furthermore, to make the analysis more realistic, the cost of pumping desalinated water to the non-coastal region was also considered. then the LCOH was calculated for all the regions and a graphical representation of LCOH was produced as seen in below figure. We can see that NEOM has the lowest LCOH of 2.70 $/kg while Arar has the highest of 5.85 $/kg.

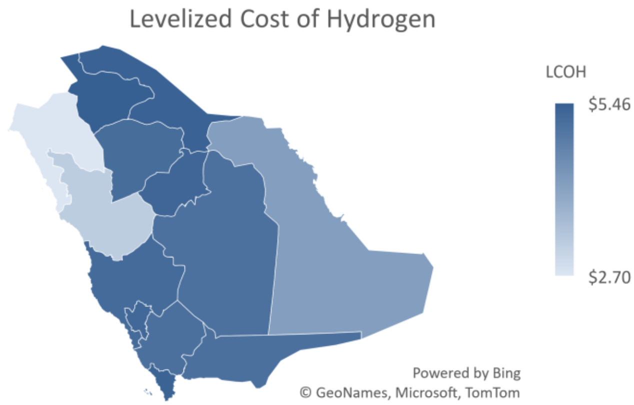

Figure 1. LCOH Potential Map

Conclusions

In this study, an economic analysis has been performed based on LCOH to evaluate the potential of renewable-powered hydrogen production in the Kingdom. The study is to produce hydrogen by the means of water electrolysis powered by 4 gigawatts of renewable resources, which are solar PV and wind energy. NEOM was considered as a case study to build the Hydrogen Model, and later this model was applied to the Kingdom's regions. The desalinated water cost and pumping cost have been also taken into consideration in the calculation of LCOH. The LCOH results of the thirteen regions show that NEOM is the most optimal choice with an LCOH of 2.70 $/kg. A consideration that could be drawn from this study is that 4 GW is an optimal size to supply the electrolyzer with energy since a lower size will increase the LCOH.

References

[1] H. Alatawi and A. Darandary, "The Saudi Move into Hydrogen: A Paradigm Shift," KAPSARC, Dec. 2020.
[2] S. Touili, A. Alami Merrouni, Y. El Hassouani, A.-illah Amrani, and S. Rachidi, "Analysis of the yield and production cost of large-scale electrolytic hydrogen from different solar technologies and under several Moroccan climate zones," International Journal of Hydrogen Energy, vol. 45, no. 51, pp. 26785–26799, 2020.
[3] M. Mohsin, A. K. Rasheed, and R. Saidur, "Economic viability and production capacity of wind generated renewable hydrogen," International Journal of Hydrogen Energy, vol. 43, no. 5, pp. 2621–2630, 2018.
[4] S. Rahmouni, N. Settou, B. Negrou, and A. Gouareh, "GIS-based method for future prospect of hydrogen demand in the Algerian road transport sector," International Journal of Hydrogen Energy, vol. 41, no. 4, pp. 2128–2143, 2016.
[5] A. Nicita, G. Maggio, A. P. F. Andaloro, and G. Squadrito, "Green hydrogen as feedstock: Financial analysis of a photovoltaic-powered electrolysis plant," International Journal of Hydrogen Energy, vol. 45, no. 20, pp. 11395–11408, 2020.
[6] L. Idoko, O. Anaya-Lara, and A. McDonald, "Enhancing pv modules efficiency and power output using multi-concept cooling technique," Energy Reports, vol. 4, pp. 357–369, Nov. 2018.
[7] Y. Zhang, Q. S. Hua, L. Sun, and Q. Liu, "Life cycle optimization of renewable energy systems configuration with hybrid battery/hydrogen storage: A comparative study," Journal of Energy Storage, vol. 30, p. 101470, Aug. 2020.
[8] National Academies Press, "The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs," National Academies Press: OpenBook, 2004. [Online]. Available: https://www.nap.edu/read/10922/chapter/21.
[9] thyssenkrupp, "Hydrogen from large-scale electrolysis," thyssenkrupp, Mar-2019. [Online]. Available: https://ucpcdn.thyssenkrupp.com/_legacy/UCPthyssenkruppBAISUhdeChlorineEngineers/assets.files/products/water_electrolysis/tk_19_0820_hydrogen_broschuere_2019_03.pdf.
[10] S. G. Simoes, J. Catarino, A. Picado, T. F. Lopes, S. di Berardino, F. Amorim, F. Gírio, C. M. Rangel, and T. Ponce de Leão, "Water availability and water usage solutions for electrolysis in hydrogen production," Journal of Cleaner Production, vol. 315, p. 128124, Jun. 2021.
[11] Saudi Electricity Company, "Tariffs and Connection Fees," Saudi Electricity Company, 12-Dec-2017. [Online]. Available: https://www.se.com.sa/en-us/customers/Pages/TariffRates.aspx.
[12] D. Feldman, V. Ramasamy, R. Fu, A. Ramdas, J. Desai, and R. Margolis, "U.S. solar photovoltaic system and energy storage Cost Benchmark: Q1 2020," National Renewable Energy Laboratory, Jan. 2021.
[13] G. Li and J. Zhi, "Analysis of wind power characteristics," Large-Scale Wind Power Grid Integration, pp. 19–51, 2016.
[14] T. Stehly and P. Beiter, "2018 cost of wind Energy Review," National Renewable Energy Laboratory, Dec. 2019.
[15] H. Rezk, N. Kanagaraj, and M. Al-Dhaifallah, "Design and Sensitivity Analysis of Hybrid Photovoltaic-Fuel-Cell-Battery System to Supply a Small Community at Saudi NEOM City," Sustainability, vol. 12, no. 8, p. 3341, 2020.
[16] Iea, "Global average levelised cost of hydrogen production by energy source and technology, 2019 and 2050 – Charts – Data & Statistics," IEA, 23-Sep-2020. [Online]. Available: https://www.iea.org/data-and-statistics/charts/global-average-levelised-cost-of-hydrogen-production-by-energy-source-and-technology-2019-and-2050.
[17] Saudi Press Agency, "NEOM announces construction of first desalination plant with solar dome technology the OFFICIAL Saudi press agency," Saudi Press Agency. [Online]. Available: https://www.spa.gov.sa/viewfullstory.php?lang=en&newsid=2028374. [Accessed: 26-Jul-2021].
[18] European Commission, "JRC photovoltaic geographical information System (PVGIS) ," European Commission, 11-Jan-2016. [Online]. Available: https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html.
[19] M. Taylor, P. Ralon, and A. Ilas, "The Power to Change: Solar and Wind Cost Reduction Potential to 2025," International Renewable Energy Agency, Jun-2016. [Online]. Available: https://www.irena.org/publications/2016/Jun/The-Power-to-Change-Solar-and-Wind-Cost-Reduction-Potential-to-2025.