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Organic Rankine Cycle Utilization for Green Hydrogen Production in Geothermal Power Plants: Review

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Keywords
Geothermal Energy; Organic Rankine Cycle; Green Hydrogen.

Abstract
The global shift toward renewable energy necessitates solutions for intermittency and energy storage. This review comprehensively examines the integration of Organic Rankine Cycle (ORC) technology in geothermal power plants for sustainable green hydrogen production. Geothermal energy provides a stable, base-load heat source, which ORC effectively converts into electricity to power water electrolysis—overcoming the variability of other renewables like solar and wind. The analysis highlights that the choice of organic working fluid (e.g., R245fa, R123, isobutane) is critical for system performance, hydrogen production rate, and economic feasibility. Furthermore, advanced ORC configurations (e.g., regenerative, dual-pressure) generally yield higher efficiency and power output, albeit with increased complexity and cost. The temperature and flow rate of the geothermal fluid are identified as paramount factors; higher temperatures typically increase hydrogen output and reduce costs, though an optimal balance must be found to avoid escalating operational expenses. A key strategy for improving economic performance is utilizing waste geothermal heat to preheat water for electrolysis, significantly reducing its electrical energy demand. Thermoeconomic assessments indicate that this integrated approach can be economically competitive, with reported hydrogen production costs ranging from approximately 1.1–4.2 USD/kg H_2 and attractive payback periods. In conclusion, coupling geothermal-powered ORC systems with electrolyzers represents a promising and synergistic pathway for producing green hydrogen, enhancing the viability of geothermal plants and contributing to the clean energy landscape.

Introduction

The global energy sector has undergone a significant transformation over the past decade, driven by the urgent need to combat global warming, mitigate the exhaustion of fossil fuels, and meet rising energy consumption demands (Zakaria et al., 2020; Notton et al., 2018). Renewable energy sources (REs) have emerged as pivotal alternatives, yet many such as solar and wind are inherently intermittent (Deb, 2022). This intermittency leads to fluctuations in energy production and efficiency, posing challenges to maintaining a stable balance between energy supply and demand (Zakaria et al., 2020; Notton et al., 2018). Despite the critical role of renewables in the energy transition, energy storage remains a persistent financial and logistical hurdle that must be addressed to ensure grid stability and reliability. A promising solution lies in converting excess intermittent energy into hydrogen---an efficient, storable energy carrier---rather than allowing it to go to waste (Acar & Dincer, 2020; Yue et al., 2021).

Hydrogen, as a versatile energy carrier, enables large-scale energy storage in integrated power systems and serves as a clean fuel for transportation (Acar & Dincer, 2020; Yue et al., 2021). Its adoption is considered a viable strategy to manage imbalances between energy demand and supply. Hydrogen can be deployed across a wide range of applications, offering high-quality energy services with high efficiency and a low carbon footprint (Uyar & Beşikci, 2017; Nakamura et al., 2015). Consequently, the integration of renewable and hydrogen-based energy systems is crucial to meeting global energy demand, enhancing energy security, and delivering environmental and economic benefits (Acar & Dincer, 2019; Mahmoud et al., 2021).

Hydrogen is also an important gas for fertilizer, oil refineries, steel and other infrastructure industries like cement and the annual production of molecular hydrogen is 9 billion kilograms and almost 48 % of it is produced through the steam methane reforming process which releases carbon dioxide as a by-product (Mahmoud et al., 2021; Mohammed-Ibrahim & Moussab, 2020). The green hydrogen production through electrolyzers is an energy-intensive process and has high production costs in comparison to hydrogen produced by fossil fuels (Hand, 2008). The co-generation of hydrogen in geothermal plants can be a promising way to bridge the output energy to clean fuel and the geothermal energy output diversification will maximize economic viability and utilization efficiency of thermal energy subsequently reducing the wastage of geothermal heat in geothermal power plants (IEA, 2019).

The cogeneration of hydrogen in a geothermal power plant also adds up to the revenue which subsequently decreases the plant operation cost and reduces the cost of production of hydrogen and geothermal energy. The preheating in hydrogen generation from geothermal plants also utilizes the waste thermal energy of the plant leading to the efficient use of thermal energy and higher efficiency of hydrogen generation (Mosca et al., 2020).

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Materials and Method

This review systematically examines the integration of Organic Rankine Cycle (ORC) technology with geothermal power plants for green hydrogen production. The literature was sourced from major academic databases including Web of Science, Scopus, ScienceDirect, and Google Scholar. The review encompasses studies published primarily between 2010 and 2024, focusing on peer-reviewed journal articles, conference proceedings, and technical reports that address thermodynamic analysis, thermoeconomic evaluation, and system optimization of geothermal-ORC-hydrogen production systems. Search terms included combinations of "organic Rankine cycle," "geothermal energy," "hydrogen production," "electrolysis," and "green hydrogen." Studies were selected based on their relevance to system integration, working fluid selection, efficiency analysis, and economic assessment.

Geothermal energy is a gift from nature to mankind. It is a huge natural energy contained in the earth. It has become one of the renewable energy sources that must be valued in the development of energy in the new century. It is also one of the most realistic and competitive resources in renewable energy (Wang & Gong, 2010). There are several types of geothermal power plants which include dry steam power plant, flash steam power plant and binary power plant (Assad et al., 2021; El Haj Assad et al., 2021) which is also known as Organic Rankine cycle. Organic Rankine cycles are simple and cost effective compared to typical Rankine cycles. As a sustainable energy source, geothermal energy may be employed in a variety of sectors for cooling, heating, desalination, and power generation (Khosravi et al., 2019). One of geothermal energy's key benefits over other energy sources is its weather independence; this trait makes it trustworthy for base load power generation (Khosravi et al., 2019). Refrigerants like butane and pentane which have a lower boiling point than water are used as working fluids in ORCs. They are heated with low temperature sources (such as geothermal energy) (Wang & Gong, 2010).

The first commercial ORC powered by geothermal and solar energy sources was operated between the 1970s and 1980s (Wang & Gong, 2010). Nowadays, many countries like United States, Indonesia, Philippines and Mexico have also installed ORC power plants. Compared to traditional electrical systems, ORCs are quieter, compact and have lower temperature applications and lower operational costs and require smaller expanders. A research concluded that the typical operational temperature for geothermal Organic Rankine cycles is in the range of 30 to 100 °C and the highest pressure should not exceed 20 bar (Saleh et al., 2007).

The slope of the saturation curve for organic working fluids can be positive (wet fluid), negative (dry fluid) or vertical (isentropic fluid) and only wet fluids need to be superheated (Hung et al., 1997). It was concluded that the most suitable fluids for recovering waste heat were the isentropic fluids (Hung et al., 1997). The most commonly used organic fluids are as follows (Mago et al., 2007):

Table 1. Organic fluids properties

Organic fluid	R-134a	Propane (R290)	R-123	R-245fa	R-125	Iso-pentane	Iso-butane	R-113	R-245ca
Molecular weight (g/mol)	102.03	44.10	152.93	134	120.02	72.17	58.122	187.38	134.05
Boiling point (ºC)	-26.1	-42	27.82	14.9	-48.089	20.2	-11.670	47.6	25.13
Critical temperature (ºC)	101	96.74	183.68	154	66.02	187.2	134.67	214.06	174.42
Critical Pressure (kPa)	4060	4250	3668	3651	3617.7	3370	3647	3392.2	3925
Heat of vaporization (kJ/kg)	217	428	170.6	196	164.1	342.5	365.2	144.32	-

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The effects of different working fluids on the rate and cost of hydrogen were analysed during the thermodynamic and exergo-economic evaluation. The thermodynamic and thermos-economic analyses showed that R245fa was the most efficient and cost-effective working fluid (Ghaebi et al., 2018). The R114 was considered to be the best choice economically because of the lowest hydrogen production cost (Gholamian et al., 2018). Isobutane was identified to be the best working fluid of an ORC, as it decreased the exergy destructions and increased the turbine work output (Bicer & Dincer, 2016). It was concluded that R123 with a hydrogen production rate of 11.42 g/s, and isopentane with a minimum cost per unit exergy of 36.9 USD/GJ were the best choices (Cao et al., 2020).

Results and Discussions

Integration of ORC for producing hydrogen

The integration of flash cycles powered by geothermal resources for producing hydrogen is designed to exploit steam from hot water reservoirs through flash separators (Ratlamwala & Dincer, 2012a, 2012b). In multiple flash power plants, several separators are used to make maximum use of the geothermal fluid energy. Geothermal power plants with more flash stages would be more efficient in producing hydrogen (Ratlamwala & Dincer, 2012a). Multi-objective optimization (MOO) of a modified double flash steam power cycle, fuelled by a high-temperature geothermal brine at 230◦ C, yielded an exergy efficiency of 12.63% with a total cost rate of 10.42 USD/h (Zuo et al., 2024). Integrating flash power plants with binary cycles has become one of the most common power cycles for electricity generation from high-temperature geothermal reservoirs since this combined configuration can yield more effectively than individual flash cycles (Zeyghami, 2015).

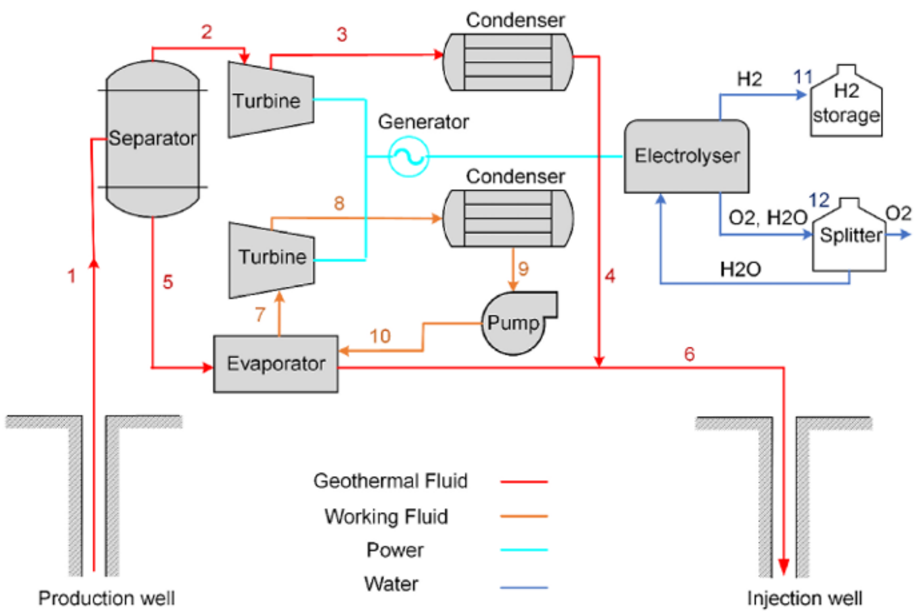

Fig 1. Hydrogen production using power generated from the flash-binary cycle [25]

The performance and the outputs of a combined flash-binary cycle integrated with Alkaline electrolysis were analysed from a thermodynamic and economic perspective (Yilmaz et al., 2019; Yilmaz, 2017). These works reported the system's exergy, energy efficiency, and hydrogen production rate as 38.37%, 8.489%, and 187.2 kg/h. The cost of hydrogen and the simple payback period were found to be 1.088 USD/kg H_2 and 4.074 years, respectively. Kanoglu and Yilmaz (2016) thermodynamically analysed a model of hydrogen production based on a combined flash-binary cycle driven by the geothermal source. In the system presented by Kanoglu and Yilmaz (2013), applying a geothermal fluid at a temperature of 230ºC and a rate of 230 kg/s through Alkaline electrolysis produced 405 kg/h H_2. The economical and thermodynamical assessment of a water electrolysis process driven by a combined flash-binary cycle resulted in a 4.16 USD/kg H_2 unit exegetic cost of hydrogen, 12.1%, and 57.4% energy and exergy efficiency. Some studies investigated the possibility of geothermal energy for both producing and liquifying hydrogen at the same site to improve the flexibility and productivity of geothermal reservoirs, particularly for those located in remote areas. In other studies, conducted by Yilmaz and co-workers (Yilmaz, 2020; Koyuncu et al., 2020), the life cycle cost assessment of a combined geothermal power-based hydrogen production and liquefaction system was investigated. The system provided a capacity of 7856 kW and a liquid hydrogen rate of 180 kg/h. The unit costs of the hydrogen and system payback period were calculated as 2.154 USD/kg H_2 and 6.17 years.

Table 2. Summary of hydrogen production via electrolysis using power generated from the flash-binary cycle

Reference	Geo condition	Power cycle	Electrolyser	Products power /H_2	Findings
Kanoglu and Yilmaz 2016 [27]	200 ºC Temp 100 kg/s flow	Flash-binary	Alkaline	7572 kWe 173.5 kg/h H_2	Thermodynamic model 7.76% en
Yilmaz 2017 [26]	200 ºC temp 100 kg/sflow	Flash-ORC	Alkaline	7993 kWe 187.2 kg/h H_2	Thermo-economic And optimization 8.489% en, 38.44% ex, and 1.08 USD/kg H_2
Kanoglu and Yilmaz 2013 [28]	230 ºC Temp 230 kg/sflow	Flash-binary	Alkaline	21545 kWe 405 kg/h H_2	Thermo-economic 12.1% en, 57.4% ex, and 4.16 USD/kg H_2
Yilmaz 2020 [29]	200 T ºC emp 100 kg/sflow	Flash-binary	Alkaline	7856 kWe 180 kg/h H_2	Life cycle cost assessment 6.5% en, 32.4% ex, and 2.154 USD/kg H_2
Yilmaz et al., 2019 [25]	200 ºC Temp 100 kg/sflow	Flash-binary	Alkaline	7978 kWe 190.44 kg/h H_2	ANN optimization
Zuo et al., 2024 [23]	230ºC Temp 1kg/s flow	Double-Flash	Alkaline		Thermodynamic, 341nvesti-economic, and optimization 12.63% ex and 10.42 $/h

Development in ORC efficiency

The efficiency of the geothermal-based ORC power plant systems can be improved by modifying the performance of the state-of-the-art technologies as well as decreasing energy losses. Considering the importance of the configuration of geothermal-based ORC on the performance and consequent output of the power generation system, some researchers have studied various configurations of the ORC cycle from thermodynamic and economic points of view (Braimakis & Karellas, 2018; Bina et al., 2017). The effect of adding an internal heat exchange (IHE) on ORC performance was 341nvestingated from the thermodynamic and economic perspective. The results demonstrated that ORC systems with an internal heat exchanger have higher thermodynamic performance (Algieri & Šebo, 2017), while a simple ORC is preferred in terms of the considered economic criteria (Zare, 2015). Some published research found that two-stage ORC cycles, in which the working fluid undergoes two heating processes and runs two turbines for power generation, can be more efficient and produce higher power than the basic ORC, although higher initial costs appeared to be inevitable (Li et al., 2018; Surendran & Seshadri, 2020). A dual-pressure had a better performance in terms of exergy efficiency and net power compared with the simple ORC (Guzović et al., 2014). By contrast, a simple ORC had the lowest cost of power production due to fewer required components than dual fluid and dual-pressure (Shokati et al., 2015).

The result of an optimization study showed that the regenerative ORC with R123 had better thermal efficiency, while the superheated cycle with R123 had a lower capital cost (Liu et al., 2017). These advanced configurations of ORC have been adopted by some scholars and integrated with hydrogen production systems including integration of a dual-fluid ORC (Kianfard et al., 2018), regenerative ORC (Ghaebi et al., 2018), and two-stage ORC with dual fluid (Cao et al., 2020) with PEM electrolyser. Hassani et al. (2023) utilized Gray Wolf

Optimizer (GWO) and showed that the geothermal-based ORC incorporating IHX-PEM outperformed other hybrid ORC-PEM configurations, such as open regenerative (ORG)-PEM, close regenerative (CRG)-PEM, and IHX-CRG-PEM schematically shows these advanced ORC power plants coupled with electrolysis.

Performance analysis of H_2 production system

As geothermal heat energy is the input of the hydrogen production system, the geothermal source temperature plays a crucial role in improving power, hydrogen production rates, and cost (Emadi & Mahmoudimehr, 2019). Geothermal sources with higher temperatures display higher enthalpy and the rise in geothermal fluid temperature has a positive effect on the system output rates (Akrami et al., 2017; AlZaharani et al., 2013). In addition, the rise in geothermal temperature leads to an increase in the steam temperature entering the turbine and produces more power (Yuksel et al., 2018).

Economic assessments indicated that the cost of hydrogen production highly depends on the geothermal water temperature. As the temperature of the geothermal resource increases, the cost of hydrogen decreases (Yilmaz et al., 2012). The total unit cost reduced from 23.18 to 22.73 USD/GJ when the geothermal temperature increased from 185 to 215 ºC (Akrami et al., 2017). Yuksel et al. (2017) revealed that for water temperatures of 130—200 ºC, the cost of hydrogen production reduced from 4.8 USD/kg H_2 to 1.1 USD/kg H_2. The life cycle cost—f a system including both hydrogen production and liquefaction process using geothermal energy showed the positive effect of the geothermal temperature on the unit cost of hydrogen production and other economic indicators such as the levelized annual cost and payback (Yilmaz, 2020; Koyuncu et al., 2020). However, the higher geothermal temperature did not always lead to better economic performance. The findings indicated that higher geothermal fluid temperatures increased hydrogen production but also increased the operating costs of electrolysis, heat exchangers and turbines, and finally, hydrogen production costs, as shown in Fig. 2 (Yilmaz, 2017). Fig. 2 compares hydrogen production costs for different geothermal conditions and hydrogen production rates (Hamlehdar et al., 2024). Accordingly, increasing the geothermal flow rates and temperatures to an average of 165 kg/s and 215 cost of 3.65 USD/kg H2,while lower flow rates and temperatures, averaging 100 kg/s and 197 ºC, achieve a lower cost of 1.5 USD/kg H2. Despite the potential of mentioned higher flow rates and temperatures to increase hydrogen production, reaching an average of 300 kg/h, this does not necessarily translate to improved economic performance. As illustrated in Fig. 2 (b), while the mentioned higher flow rates and temperatures can Increase hydrogen production to an average of 300 kg/h, this does not always translate to improved economic performance.

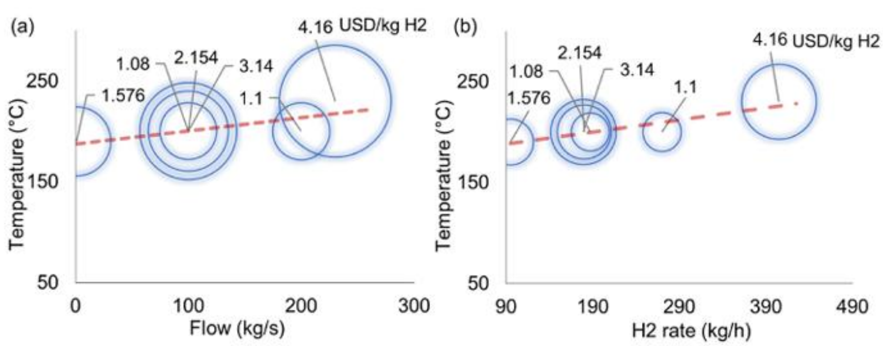

Fig 2. Hydrogen production cost (USD/kg): a) considering the geothermal conditions of geothermal reservoir temperature and flow rate, and b) hydrogen production rates (Hamlehdar et al., 2024).

A key determinant of the hydrogen production rate, power requirement, and operating cost is the temperature of the water entering the electrolyzer. Investigations documented in the literature reveal that elevating this inlet temperature reduces the power consumed during electrolysis. The predominant technique for achieving this temperature increase is to preheat the water with geothermal fluid, which typically retains a substantial amount of usable heat even after exiting the power generation cycle.

Boyaghchi and Nazer (2017) considered the PEM electrolyser current density and temperature effect on the annual efficiency and product cost of the system. The results indicated that increasing the temperature of the electrolyser boosted the annual exergy of the system by 49.6%. Yilmaz et al. (2019) studied the impact of the inlet water on electrolysis in geothermal-assisted hydrogen production using a neural network. Their results showed that geothermal power consumption was reduced by almost 3% when the inlet water temperature increased from 25º to 70 ºC. Some multigenerational systems recovered the geothermal heat after power generation for preheating water entering the electrolyser (Abdolalipouradl et al., 2020; Cao et al., 2021). Yilmaz (2017) utilized the waste heat of a combined binary-flash cycle with a geothermal temperature source of 76º to preheat water from 25º to 73 ºC for the electrolysis process in an Alkaline electrolyser. By preheating water from 25º to 85 ºC, it was possible to produce hydrogen at the cost of 1.961—1.857 USD/kg H_2, demonstrating that using recoverable geothermal heat to preheat water during the electrolysis process can lower the cost of hydrogen production (Yilmaz et al., 2012). Kanoglu and Yilmaz (2010) demonstrated that using the excess heat found in the geothermal fluid to preheat the water in the electrolyser could produce up to 1.42×10^3 kg H_2/kg water, while the corresponding value for the case of without recovering geothermal heat for preheating water for the same geothermal reservoir of 200°C was 1.34×10^3 kg H_2/kg water. An increase in hydrogen production resulted from increasing the electrolyser temperature, while hydrogen production cost decreased because of increasing electrolyser temperatures (Ghaebi et al., 2018).

Conclusion

This review underscores the promising integration of Organic Rankine Cycle (ORC) technology in geothermal power plants for green hydrogen production, leveraging stable, weather-independent geothermal energy to power water electrolysis and mitigate intermittency issues in other renewables. Key findings highlight the critical role of organic working fluids like R245fa, R123, and isobutane for optimal thermodynamic performance and cost reduction, alongside advanced configurations (e.g., regenerative, dual-pressure) that boost efficiency despite added complexity and capital costs. System performance hinges on geothermal fluid temperature and flow rate—higher values enhance hydrogen output but require balancing against operational expenses—while utilizing waste heat for electrolysis preheating significantly improves economic viability, with thermoeconomic analyses reporting competitive production costs and payback periods. Overall, this approach offers a cost-effective renewable pathway, and future research should prioritize large-scale pilot demonstrations, hybrid integrations with solar or wind resources, and advanced optimization techniques (e.g., AI-driven fluid selection and cycle design) to further elevate efficiency, scalability, and commercialization potential.

References

Abdolalipouradl, M., Mohammadkhani, F., Khalilarya, S., & Yari, M. (2020). Thermodynamic and exergoeconomic analysis of two novel tri-generation cycles for power, hydrogen and freshwater production from geothermal energy. *Energy Conversion and Management*, *226*, 113544.

Acar, C., & Dincer, I. (2019). Review and evaluation of hydrogen production options for better environment. *Journal of Clean Production*, *218*, 835–849.

Acar, C., & Dincer, I. (2020). The potential role of hydrogen as a sustainable transportation fuel to combat global warming. *International Journal of Hydrogen Energy*, *45*(5), 3396–3406.

Akrami, E., Chitsaz, A., Nami, H., & Mahmoudi, S. (2017). Energetic and exergoeconomic assessment of a multi-generation energy system based on indirect use of geothermal energy. *Energy*, *124*, 625–639.

Algieri, A., & Šebo, J. (2017). Energetic investigation of organic Rankine cycles (ORCs) for the exploitation of low-temperature geothermal sources—A possible application in Slovakia. *Procedia Computer Science*, *109*, 833–840.

AlZaharani, A. A., Dincer, I., & Naterer, G. (2013). Performance evaluation of a geothermal based integrated system for power, hydrogen and heat generation. *International Journal of Hydrogen Energy*, *38*(34), 14505–14511.

Assad, M. E. H., Aryanfar, Y., Radman, S., Yousef, B., & Pakatchian, M. (2021). Energy and exergy analyses of single flash geothermal power plant at optimum separator temperature. *International Journal of Low-Carbon Technologies*, *16*(3), 873–881.

Bicer, Y., & Dincer, I. (2016). Development of a new solar and geothermal based combined system for hydrogen production. *Solar Energy*, *127*, 269–284.

Bina, S. M., Jalilinasrabady, S., & Fujii, H. (2017). Thermo-economic evaluation of various bottoming ORCs for geothermal power plant, determination of optimum cycle for Sabalan power plant exhaust. *Geothermics*, *70*, 181–191.

Boyaghchi, F. A., & Nazer, S. (2017). Assessment and optimization of a new sextuple energy system incorporated with concentrated photovoltaic thermal-geothermal using exergy, economic and environmental concepts. *Journal of Clean Production*, *164*, 70–84.

Braimakis, K., & Karellas, S. (2018). Energetic optimization of regenerative organic Rankine cycle (ORC) configurations. *Energy Conversion and Management*, *159*, 353–370.

Cao, Y., Haghghi, M. A., Shamsaiee, M., Athari, H., Ghaemi, M., & Rosen, M. A. (2020). Evaluation and optimization of a novel geothermal-driven hydrogen production system using an electrolyser fed by a two-stage organic Rankine cycle with different working fluids. *Journal of Energy Storage*, *32*, 101766.

Cao, Y., Xu, D., Togun, H., Dhahad, H. A., Azariyan, H., & Farouk, N. (2021). Feasibility analysis and capability characterization of a novel hybrid flash-binary geothermal power plant and trigeneration system through a case study. *International Journal of Hydrogen Energy*, *46*(79), 39209–39226.

Deb, N. (2022). *Implementation of SiC Power Electronics for Green Energy Based Electrification of Transportation*.

El Haj Assad, M., Ahmadi, M. H., Sadeghzadeh, M., Yassin, A., & Issakhov, A. (2021). Renewable hybrid energy systems using geothermal energy: Hybrid solar thermal–geothermal power plant. *International Journal of Low-Carbon Technologies*, *16*(2), 518–530.

Emadi, M. A., & Mahmoudimehr, J. (2019). Modeling and thermo-economic optimization of a new multi-generation system with geothermal heat source and LNG heat sink. *Energy Conversion and Management*, *189*, 153–166.

Ghaebi, H., Farhang, B., Parikhani, T., & Rostamzadeh, H. (2018). Energy, exergy and exergoeconomic analysis of a cogeneration system for power and hydrogen production purpose based on TRR method and using low grade geothermal source. *Geothermics*, *71*, 132–145.

Gholamian, E., Habibollahzade, A., & Zare, V. (2018). Development and multi-objective optimization of geothermal-based organic Rankine cycle integrated with thermoelectric generator and proton exchange membrane electrolyzer for power and hydrogen production. *Energy Conversion and Management*, *174*, 112–125.

Guzović, Z., Rašković, P., & Blatarić, Z. (2014). The comparision of a basic and a dual-pressure ORC (organic Rankine cycle): Geothermal power plant Velika Ciglena case study. *Energy*, *76*, 175–186.

Hamlehdar, M., Beardsmore, G., & Narsilio, G. A. (2024). Hydrogen production from low-temperature geothermal energy—A review of opportunities, challenges, and mitigating solutions. *International Journal of Hydrogen Energy*, *77*, 742–768. https://doi.org/10.1016/j.ijhydene.2024.06.104

Hand, T. W. (2008). *Hydrogen production using geothermal energy* [Master's thesis, Utah State University]. https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1038&context=etd

Hasani, M. R., Nedaei, N., Assareh, E., & Alirahmi, S. M. (2023). Thermo-economic appraisal and operating fluid selection of geothermal-driven ORC configurations integrated with PEM electrolyzer. *Energy*, *262*, 125550.

Hung, T., Shai, T., & Wang, S. (1997). A review of Organic Rankine Cycles (ORCs) for the recovery of low-grade waste heat. *Energy*, *22*(7), 661–667.

IEA. (2019). *The future of hydrogen: Seizing today's opportunities*. https://www.hydrogenexpo.com/media/9370/the_future_of_hydrogen_iea.pdf

Kanoglu, M., & Yilmaz, C. (2013). Thermal design of alkaline water electrolysis assisted by combined flash binary geothermal power plant. In *ASME International Mechanical Engineering Congress and Exposition*. American Society of Mechanical Engineers.

Kanoglu, M., & Yilmaz, C. (2016). Geothermal energy use in hydrogen production. *Journal of Thermal Engineering*, *2*(2), 699–708.

Kanoglu, M., Bolatturk, A., & Yilmaz, C. (2010). Thermodynamic analysis of models used in hydrogen production by geothermal energy. *International Journal of Hydrogen Energy*, *35*(16), 8783–8791.

Khosravi, A., Syri, S., Zhao, X., & Assad, M. E. H. (2019). An artificial intelligence approach for thermodynamic modeling of geothermal based-organic Rankine cycle equipped with solar system. *Geothermics*, *80*, 138–154.

Kianfard, H., Khalilarya, S., & Jafarmadar, S. (2018). Exergy and exergoeconomic evaluation of hydrogen and distilled water production via combination of PEM electrolyzer, RO desalination unit and geothermal driven dual fluid ORC. *Energy Conversion and Management*, *177*, 339–349.

Koyuncu, I., Yilmaz, C., Alcin, M., & Tuna, M. (2020). Design and implementation of hydrogen economy using artificial neural network on field programmable gate array. *International Journal of Hydrogen Energy*, *45*(41), 20709–20720.

Li, J., Ge, Z., Duan, Y., Yang, Z., & Liu, Q. (2018). Parametric optimization and thermodynamic performance comparison of single-pressure and dual-pressure evaporation organic Rankine cycles. *Applied Energy*, *217*, 409–421.

Liu, X., Wei, M., Yang, L., & Wang, X. (2017). Thermo-economic analysis and optimization selection of ORC system configurations for low temperature binary-cycle geothermal plant. *Applied Thermal Engineering*, *125*, 153–164.

Mago, P. J., Chamra, L. M., & Somayaji, C. (2007). Performance analysis of different working fluids for use in organic Rankine cycles. *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*, *221*(3), 255–263.

Mahmoud, M., Ramadan, M., Naher, S., Pullen, K., Abdelkareem, M. A., & Olabi, A.-G. (2021). A review of geothermal energy-driven hydrogen production systems. *Thermal Science and Engineering Progress*, *22*, 100854. https://doi.org/10.1016/J.TSEP.2021.100854

Mohammed-Ibrahim, J., & Moussab, H. (2020). Recent advances on hydrogen production through seawater electrolysis. *Materials Science for Energy Technologies*, *3*, 780–807. https://doi.org/10.1016/j.mset.2020.09.005

Mosca, L., Medrano Jimenez, J. A., Wassie, S. A., Gallucci, F., Palo, E., Colozzi, M., Taraschi, S., & Galdieri, G. (2020). Process design for green hydrogen production. *International Journal of Hydrogen Energy*, *45*(11), 7266–7277. https://doi.org/10.1016/J.IJHYDENE.2019.08.206

Nakamura, A., Ota, Y., Koike, K., Hidaka, Y., Nishioka, K., Sugiyama, M., & Fujii, K. (2015). A 24.4% solar to hydrogen energy conversion efficiency by combining concentrator photovoltaic modules and electrochemical cells. *Applied Physics Express*, *8*(10), 107101.

Notton, G., Nivet, M.-L., Voyant, C., Paoli, C., Darras, C., Motte, F., & Fouilloy, A. (2018). Intermittent and stochastic character of renewable energy sources: Consequences, cost of intermittence and benefit of forecasting. *Renewable and Sustainable Energy Reviews*, *87*, 96–105.

Ratlamwala, T., & Dincer, I. (2012a). Comparative efficiency assessment of novel multi-flash integrated geothermal systems for power and hydrogen production. *Applied Thermal Engineering*, *48*, 359–366.

Ratlamwala, T., & Dincer, I. (2012b). Performance analysis of a novel integrated geothermal-based system for multi-generation applications. *Applied Thermal Engineering*, *40*, 71–79.

Saleh, B., Koglbauer, G., Wendland, M., & Fischer, J. (2007). Working fluids for low-temperature Organic Rankine Cycles. *Energy*, *32*(7), 1210–1221. https://doi.org/10.1016/j.energy.2006.07.001

Shokati, N., Ranjbar, F., & Yari, M. (2015). Exergoeconomic analysis and optimization of basic, dual-pressure and dual-fluid ORCs and Kalina geothermal power plants: A comparative study. *Renewable Energy*, *83*, 527–542.

Surendran, A., & Seshadri, S. (2020). Performance investigation of two stage Organic Rankine Cycle (ORC) architectures using induction turbine layouts in dual source waste heat recovery. *Energy Conversion and Management: X*, *6*, 100029.

Uyar, T. S., & Beşikci, D. (2017). Integration of hydrogen energy systems into renewable energy systems for better design of 100% renewable energy communities. *International Journal of Hydrogen Energy*, *42*(4), 2453–2456.

Wang, J., Gong, Y., et al. (2010). Analysis and suggestions on the problems faced by the development of geothermal energy in China. In X. Du (Ed.), *Scientific and technological innovation promotes the sustainable development of China's energy: Proceedings of the first energy forum of Chinese Academy of Engineering/National Energy Administration* (pp. 1–10). Chemical Industry Press.

Yilmaz, C. (2017). Thermoeconomic modeling and optimization of a hydrogen production system using geothermal energy. *Geothermics*, *65*, 32–43.

Yilmaz, C. (2020). Life cycle cost assessment of a geothermal power assisted hydrogen energy system. *Geothermics*, *83*, 101737.

Yilmaz, C., Kanoglu, M., Bolatturk, A., & Gadalla, M. (2012). Economics of hydrogen production and liquefaction by geothermal energy. *International Journal of Hydrogen Energy*, *37*(2), 2058–2069.

Yilmaz, C., Koyuncu, I., Alcin, M., & Tuna, M. (2019). Artificial neural networks based thermodynamic and economic analysis of a hydrogen production system assisted by geothermal energy on field programmable gate array. *International Journal of Hydrogen Energy*, *44*(33), 17443–17459.

Yue, M., Lambert, H., Pahon, E., Roche, R., Jemei, S., & Hissel, D. (2021). Hydrogen energy systems: A critical review of technologies, applications, trends and challenges. *Renewable and Sustainable Energy Reviews*, *146*, 111180.

Yuksel, Y. E., & Ozturk, M. (2017). Thermodynamic and thermoeconomic analyses of a geothermal energy based integrated system for hydrogen production. *International Journal of Hydrogen Energy*, *42*(4), 2530–2546.

Yuksel, Y. E., Ozturk, M., & Dincer, I. (2018). Energetic and exergetic performance evaluations of a geothermal power plant based integrated system for hydrogen production. *International Journal of Hydrogen Energy*, *43*(1), 78–90.

Zakaria, A., Ismail, F. B., Lipu, M. H., & Hannan, M. A. (2020). Uncertainty models for stochastic optimization in renewable energy applications. *Renewable Energy*, *145*, 1543–1571.

Zare, V. (2015). A comparative exergoeconomic analysis of different ORC configurations for binary geothermal power plants. *Energy Conversion and Management*, *105*, 127–138.

Zeyghami, M. (2015). Performance analysis and binary working fluid selection of combined flash-binary geothermal cycle. *Energy*, *88*, 765–774.

Zuo, Z., Saraswat, M., Mahariq, I., Nutakki, T. U. K., Albani, A., & Seikh, A. H. (2024). Multi-criteria thermoeconomic optimization of a geothermal energy-driven green hydrogen production plant coupled to an alkaline electrolyzer. *Process Safety and Environmental Protection*, *182*, 154–165.