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Feasibility Study of Geothermal Energy Development in Egypt: Power Generation and Direct Use in Gulf of Suez, Red Sea, and Western Desert

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ABSTRACT This feasibility study examines the potential for developing geothermal energy resources in Egypt, specifically targeting power generation and direct-use applications in the Gulf of Suez, Red Sea, and Western Desert regions. Egypt's geothermal resources are primarily low to medium enthalpy, with surface temperatures ranging from 35°C to 76°C. In the Gulf of Suez, geothermal gradients of 45°C/km and heat flow values of 120 mW/m² indicate the viability of small-scale binary cycle power plants. The Hammam Faraun geothermal spring, in particular, shows an estimated geothermal reserve capacity of 12.4 MWt, highlighting its potential for localized power generation. Quantitative analysis suggests that geothermal wells in the Western Desert and thermal springs near Helwan (35-45°C) can be effectively used for direct-use applications, such as district heating, greenhouse agriculture, and recreational facilities. Developing these resources could provide an estimated 20-30 MWt of energy in the short term through pilot projects and small-scale installations.If implemented, this project would contribute to Egypt's sustainability goals, particularly in achieving affordable and clean energy (SDG 7), climate action (SDG 13), and sustainable cities and communities (SDG 11). Utilizing geothermal energy would reduce greenhouse gas emissions, enhance energy diversity, and create opportunities for local economic growth, thus supporting Egypt's transition to a more sustainable and resilient energy system.

KEYWORDS Geothermal Energy, Binary Cycle Power Plant, Renewable Energy, Sustainability, Sustainable Development Goals (SDGs), Heat Flow, Energy Diversification, Climate Action.

I. INTRODUCTION

Egypt's energy sector is heavily reliant on fossil fuels, which constitute approximately 95% of its energy consumption, raising concerns about energy security and environmental sustainability [1]. To mitigate these issues, Egypt has significant potential to transition to renewable energy sources, particularly solar photovoltaic (PV) and wind energy, which could reduce greenhouse gas emissions and enhance energy security [2]. The International Renewable Energy Agency (IRENA) recommends that Egypt targets 53% of its electricity from renewable technologies by 2030, necessitating an additional investment of USD 16.4 billion beyond current plans [3]–[7]. Ongoing investments of USD 10.4 billion in renewable projects could bolster foreign reserves and lower energy costs, contributing to economic stability [8]. However, socio-economic barriers, including political instability and insufficient international climate funding, must be addressed to facilitate this transition [9]–[11].

The feasibility of harnessing geothermal energy in Egypt, particularly in the Gulf of Suez and Red Sea regions, is supported by extensive geological assessments and thermal modeling. Research indicates that the Central Eastern Desert and Red Sea exhibit significant geothermal potential, with temperature models revealing promising anomalies and high-density zones that suggest effective heat transfer mechanisms [12]. The hydrothermal potential in these areas could generate substantial electricity, potentially producing around 75 MW over a 25-year lifespan [13]–[16]. Moreover, the sustainable extraction of geothermal resources is viable due to natural replenishment processes, provided that extraction rates are managed appropriately [17]. Integrating advanced geothermal technologies and strategic policies could enhance energy security and contribute to Egypt's sustainability goals, addressing energy and freshwater demands amid growing population pressures [18]. Overall, these findings underscore the importance of geothermal energy in reducing CO2 emissions and supporting renewable energy initiatives in Egypt [19]–[23].Egypt's geothermal energy potential, particularly in the Gulf of Suez, Red Sea area, and Western Desert, is substantial due to favorable geological conditions and active tectonic processes. The Gulf of Suez and Red Sea regions exhibit high geothermal gradients, with values reaching up to 45 °C/km and heat flow measurements as high as 175 mW/m², indicating significant resources for power generation and direct-use applications [24]. The Red Sea's thinner oceanic crust enhances heat transfer, making it a prime area for exploration [25]. In the Western Desert, geothermal resources, although less explored, show promise near thermal springs, with temperatures ranging from 35-45 °C suitable for low-temperature applications [26]. Additionally, innovative approaches, such as the Earth-to-Air Heat Exchanger model, highlight the potential for geothermal energy in arid regions like Egypt's New Delta, emphasizing its viability for sustainable agricultural practices [27]. Targeted exploration and detailed assessments are essential to fully realize Egypt's geothermal potential [28].

This paper provides Assessment of Power Generation and Direct-Use Applications in the Gulf of Suez, Red Sea, and Western Desert Regions

II. THEORETICAL BASIS

Egypt's geothermal resources present significant opportunities for sustainable energy utilization, particularly in arid regions like the New Delta, where innovative assessments have identified optimal conditions for geothermal applications, such as greenhouse heating and cooling through Earth-to-Air Heat Exchangers (EAHE) [29]. The effectiveness of these technologies hinges on the quality of geothermal resources, which can vary based on temperature and chemical characteristics, necessitating careful monitoring to mitigate potential environmental impacts [30]. Furthermore, the repurposing of abandoned oil and gas wells for geothermal energy generation offers a promising avenue for enhancing energy efficiency and reducing greenhouse gas emissions, aligning with global sustainability goals [31]. Overall, the integration of geothermal technologies in Egypt can yield substantial economic and environmental benefits across various sectors, provided that resource management is conducted responsibly [32]. The development of geothermal energy in Egypt presents substantial opportunities for economic growth and resource sustainability, particularly in regions like the New Delta, Hurghada-El Gouna, and Siwa Oasis. Studies indicate that the New Delta region has significant geothermal potential for greenhouse applications, with effective cooling and heating capacities demonstrated through innovative modeling techniques [33]. Additionally, the Siwa Oasis, characterized by thermal springs and favorable geothermal gradients, offers a viable solution for addressing fresh water shortages and enhancing agricultural productivity [34]. Furthermore, utilizing abandoned oil and gas wells for geothermal energy extraction can optimize resource use and reduce investment risks, with potential outputs reaching up to 44.6 MW in the Gulf of Suez [35]. Collectively, these findings underscore the necessity for regional support and technological advancements to harness geothermal energy effectively in Egypt. As shown in Fig. 1, in the mining and operation of a geothermal energy system, when the fluid flows through the surface pipe and underground borehole heat exchanger, there is a specific resistance in the surface pipe and underground borehole heat exchanger. The fluid resistance in the underground borehole heat exchanger will gradually accumulate with the increase of the length of the borehole heat exchanger. As a result, pumping power increases, resulting in energy loss and affecting the operation of the entire geothermal system.

III. CHALLENGES AND RECOMMENDATIONS

The development of geothermal projects in Egypt is hindered by a multifaceted array of challenges, including technical, financial, regulatory, and market barriers. Financial constraints are particularly significant, as the high risks associated with exploration deter private investment, necessitating government intervention through financial incentives and supportive legal frameworks [37]. Additionally, the lack of infrastructure in remote areas where geothermal resources are located exacerbates these challenges, highlighting the need for improved public services to support local communities. Furthermore, social acceptance remains a critical issue, with insufficient awareness and local political support impeding project progress [38]. To address these obstacles, it is essential for the Egyptian government and companies to implement comprehensive policies that include training programs to enhance local technical skills, thereby fostering a skilled workforce capable of supporting geothermal development [39]. The successful implementation of geothermal energy projects in Egypt hinges on establishing a robust regulatory framework and supportive policies that enhance financial and technical feasibility. Governments can facilitate this through various incentives such as feed-in tariffs, tax credits, and risk insurance, which have proven effective in other countries [40]–[42], [42]. Additionally, fostering local capabilities and promoting international cooperation can significantly bolster project viability, as evidenced by the socioeconomic benefits observed in geothermal sectors globally, including job creation and local development opportunities [43]. Furthermore, specific studies highlight Egypt's geothermal potential, particularly in arid regions like the New Delta, where innovative assessment methods have identified optimal conditions for geothermal applications [44]. By integrating these strategies, Egypt can position geothermal energy as a vital component of its sustainable energy mix, aligning with broader environmental and economic goals.

Future research is crucial for advancing the geothermal

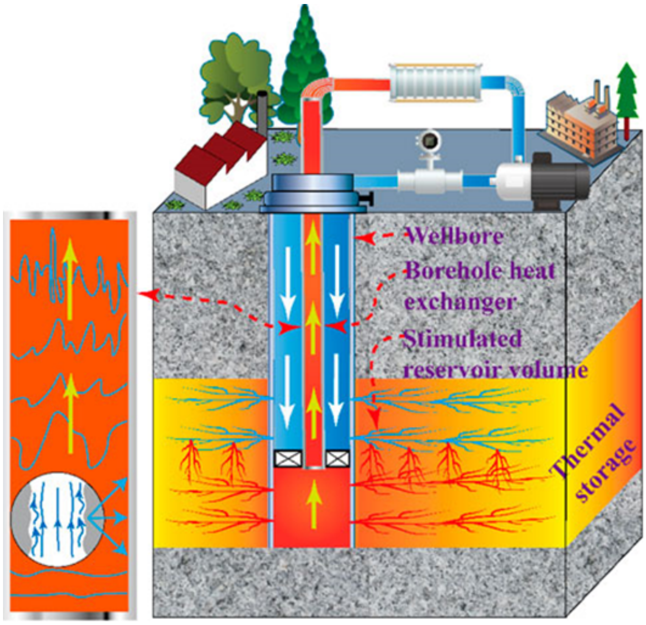

FIGURE 1. Schematic diagram of geothermal system operation [36]

energy sector in Egypt, particularly in enhancing technical efficiency, resource identification, and assessing economic and environmental feasibility. The integration of various geothermal exploitation techniques, such as binary cycle and flash geothermal systems, can optimize energy production from Egypt's geothermal resources, which remain largely untapped [45]. Addressing geological and geophysical challenges, alongside technological hurdles, is essential for maximizing resource utilization [46]. Furthermore, Egypt's commitment to renewable energy is vital for meeting its growing energy demands sustainably, especially as fossil fuel reserves dwindle. Evaluating the environmental, economic, and social impacts of geothermal projects will help mitigate opposition and enhance community acceptance [47]. A multidisciplinary approach to research, focusing on Enhanced Geothermal Systems (EGS), is necessary to ensure the safety and profitability of geothermal facilities, thereby supporting Egypt's transition to a sustainable energy future [48]–[50].

Similarly, another map is created and shown in Fig. 2 to show the possible places for renewable energy sources in Egypt. The aforementioned sites on the map have the highest solar irradiance compared to other parts of Egypt, making them the ideal places to install future solar plants (CSP & PV), even though solar energy has the potential to be high in many places in Egypt. Hydropower and bioenergy have enormous potential in Northern Egypt's Delta region, while wind energy can be generated along the Mediterranean coast in places like Sallum, Matruh, and Port Saied. Due to the great potential of solar energy, the Gulf of Suez is regarded as the greatest place in Egypt to get all of its energy from renewable sources. Geothermal and wind sources. Although it is not as concentrated as the Gulf of Suez region, southern Egypt likewise has a lot of potential for solar, wind, and bioenergy. Because Egypt has a wide variety of renewable energy sources, energy system analysis tools like Energy PLAN, which enable thorough socioeconomic feasibility assessments, can be used to compare possible energy systems A similar analysis was conducted in Iran, which enabled the development of five distinct energy systems that focused on the underlying RE generation and efficiency improvements. This should enable Egypt to implement an energy transition from conventional to RE resources.

IV. ECONOMIC AND ENVIRONMENTAL ANALYSIS

A preliminary cost-benefit analysis of geothermal development reveals significant regional variations influenced by geological conditions, technological capabilities, and economic frameworks. In sedimentary basins, geothermal systems demonstrate lower upfront investment costs and leverage existing oil and gas infrastructure, which can reduce drilling and completion expenses, thus enhancing economic viability [51]. Conversely, direct-use hydrothermal reservoirs face marginal economic outputs often reliant on subsidies, necessitating a balance between fault stability and net present value (NPV) to ensure sustainable development [52]. In East Africa, abundant geothermal resources present a unique opportunity to mitigate energy poverty while supporting the energy-water-food nexus, with models indicating substantial socioeconomic benefits from geothermal projects [53]. Overall, while geothermal energy offers promising returns, its economic feasibility is contingent upon regional characteristics and supportive policy frameworks [54]–[56].

Environmental Impact Assessments (EIAs) play a crucial role in identifying potential environmental benefits and risks associated with development projects. They facilitate the reduction of greenhouse gas emissions by evaluating alter-

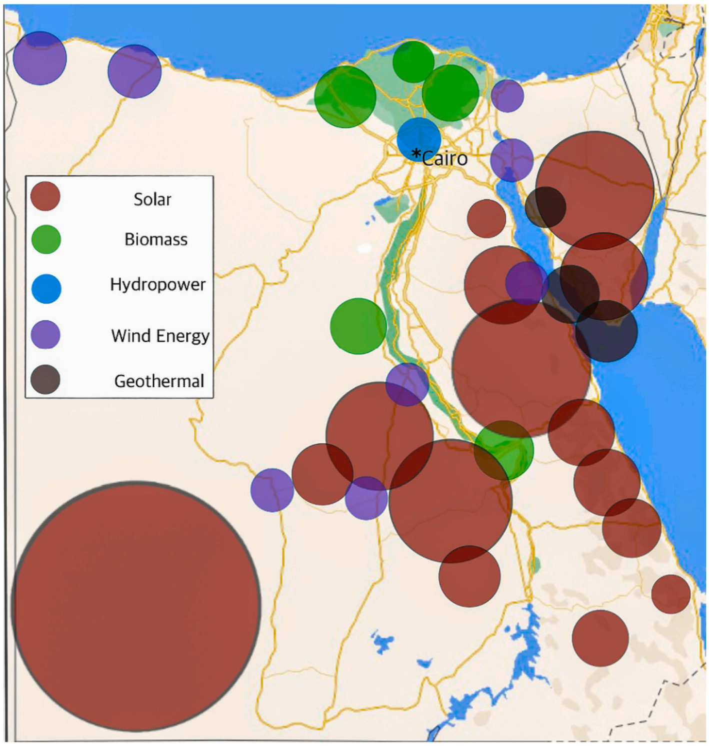

FIGURE 2. Egypt's map of the potential renewable energy locations [3]

native project designs and promoting sustainable practices, thereby aligning with international environmental agreements [57]. EIAs assess both positive and negative impacts, considering ecological, social, and economic factors, which helps in mitigating risks associated with human activities that may harm the environment [58]. In the United States, EIAs are mandated under the National Environmental Policy Act (NEPA), ensuring that environmental considerations are integrated into project planning [59]. However, challenges persist, such as the need for comprehensive data analysis and the potential for industrial activities to contribute to pollution if not managed effectively [60]. Thus, while EIAs can significantly enhance environmental protection, their effectiveness depends on rigorous implementation and continuous monitoring.

The geothermal project in Egypt significantly contributes to the country's sustainability goals, particularly in achieving SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 11 (Sustainable Cities and Communities). By harnessing geothermal energy from regions like the Gulf of Suez and the Red Sea, the project reduces reliance on fossil fuels and lowers greenhouse gas emissions, thus promoting cleaner energy access in underserved areas [61]. The geothermal potential in these regions is substantial, with studies indicating significant geothermal gradients and heat flow, which can support both electricity generation and direct-use applications for agriculture and residential heating [62]. Furthermore, the project fosters local economic development through job creation and enhances resilience in urban and rural communities by diversifying the energy mix and minimizing environmental impacts [63]. Overall, this initiative aligns with Egypt's climate strategies, making its energy system more sustainable and self-sufficient. Future research and development should focus on several key areas to validate and expand upon existing findings across various fields. In the realm of public sector auditing, studies should explore the integration of artificial intelligence within continuous auditing frameworks, emphasizing strategic policy recommendations and methodologies for implementation. For unmanned aerial vehicles (UAVs), research should investigate advanced applications such as urban air mobility, ensuring that guidance, navigation, and control systems evolve to meet future demands. Additionally, identity theory warrants further exploration, particularly regarding the interplay of social identities and their implications across different societal levels. In urban finance, aligning fiscal and urban planning systems is crucial, necessitating the development of transparent financing tools to support sustainable urban development as outlined in the New Urban Agenda. Lastly, the aviation sector must prioritize sustainable business models and digital innovations to address environmental impacts, advocating for collaborative efforts among government, industry, and research organizations.

V. CONCLUSION

The studies collectively highlight Egypt's significant geothermal potential across various regions, emphasizing the Central Eastern Desert, New Delta, Siwa Oasis, and Abu Gharadig

Basin. In the Central Eastern Desert and Red Sea, gravity and magnetic inversion modeling revealed high-density zones and elevated temperatures, indicating promising geothermal resources, particularly influenced by the Red Sea's geological characteristics. The New Delta region demonstrated optimal conditions for geothermal energy utilization in greenhouse farming, with minimal temperature variation at depths suitable for Earth-to-Air Heat Exchanger systems. The Siwa Oasis, characterized by thermal springs and a geothermal gradient of 18 to 42 °C/km, presents substantial geothermal energy potential for sustainable agriculture and water desalination. Additionally, the Abu Gharadig Basin's analysis indicated significant geothermal gradients and heat flow, correlating basement rock characteristics with geothermal potential. Overall, these findings underscore Egypt's capacity to harness geothermal energy for sustainable development. The findings from the reviewed papers highlight several implications for energy policy, local economic development, and investment in renewable energy. Renewable energy adoption, particularly in rural areas, has demonstrated significant benefits, including job creation and increased local tax revenues, which can inform policies aimed at fostering economic diversification. Additionally, community renewable energy (CRE) projects emphasize the importance of tailoring policies to address the unique motivations and needs of different demographic groups, thereby enhancing community engagement and investment in renewable initiatives. The UK field trial illustrates the effectiveness of community-oriented approaches that align local energy supply and demand, suggesting that such models can improve financial returns and sustainability in energy transitions. Furthermore, local governments play a crucial role in implementing sustainable energy solutions, necessitating investments in infrastructure and planning tools to overcome existing barriers to energy access. Collectively, these insights advocate for comprehensive, localized policy frameworks that support renewable energy adoption and economic resilience.

REFERENCES

[1] A. Gibson, Z. Makuch, R. Yeganyan, N. Tan, C. Cannone, and M. Howells, "Long-term energy system modelling for a clean energy transition in egypt's energy sector," Energies, vol. 17, no. 10, p. 2397, 2024.

[2] O. Analytica, "Egypt will prioritise its renewable energy sector," Emerald Expert Briefings, no. oxan-db, 2024.

[3] S. I. Salah, M. Eltaweel, and C. Abeykoon, "Towards a sustainable energy future for egypt: A systematic review of renewable energy sources, technologies, challenges, and recommendations," Cleaner Engineering and Technology, vol. 8, p. 100497, 2022.

[4] J. G. Vaghasia, J. K. Ratnadhariya, H. Panchal, K. K. Sadasivuni, D. Ponnamma, M. Elkelawy, and H. A.-E. Bastawissi, "Experimental performance investigations on various orientations of evacuated double absorber tube for solar parabolic trough concentrator," International Journal of Ambient Energy, vol. 43, no. 1, pp. 492–499, 2022.

[5] A. M. Elbanna, X. Cheng, C. Yang, M. Elkelawy, and H. A.-E. Bastawissi, "Investigative research of diesel/ethanol advanced combustion strategies: A comparison of premixed charge compression ignition (pcci) and direct dual fuel stratification (ddfs)," Fuel, vol. 345, p. 128143, 2023.

[6] M. M. El-Sheekh, A. A. El-Nagar, M. ElKelawy, and H. A.-E. Bastawissi, "Bioethanol from wheat straw hydrolysate solubility and stability in waste cooking oil biodiesel/diesel and gasoline fuel at different blends ratio," Biotechnology for Biofuels and Bioproducts, vol. 16, no. 1, p. 15, 2023.

[7] M. M. El-Sheekh, A. A. El-Nagar, M. ElKelawy, and H. A.-E. Bastawissi, "Maximization of bioethanol productivity from wheat straw, performance and emission analysis of diesel engine running with a triple fuel blend through response surface methodology," Renewable energy, vol. 211, pp. 706–722, 2023.

[8] G. G. Ubay and H. Karakuş, "The role of technology-based renewable energy investments on macroeconomic stability," Strategic Outlook for Innovative Work Behaviours: Interdisciplinary and Multidimensional Perspectives, pp. 119–130, 2020.

[9] M. A. Abdelhady, D. M. I. Badran, and I. M. S. Alotaibi, "Renewable energy as a constitutional commitment: An analytical study considering. the egyptian constitution and international agreements," Journal of Law and Sustainable Development, vol. 11, no. 4, pp. e944–e944, 2023.

[10] A. Kabeel, M. Elkelawy, H. A.-E. Mohamad, A. M. Elbanna, H. Panchal, M. Suresh, and M. Israr, "The influences of loading ratios and conveying velocity on gas-solid two phase flow characteristics: a comprehensive experimental cfd-dem study," International Journal of Ambient Energy, vol. 43, no. 1, pp. 2714–2726, 2022.

[11] A. M. Elbanna, C. Xiaobei, Y. Can, M. Elkelawy, H. A.-E. Bastawissi, and H. Panchal, "Fuel reactivity controlled compression ignition engine and potential strategies to extend the engine operating range: A comprehensive review," Energy Conversion and Management: X, vol. 13, p. 100133, 2022.

[12] G. M. Gaber, S. Saleh, and A. Kotb, "3d gravity and magnetic inversion modelling for geothermal assessment and temperature modelling in the central eastern desert and red sea, egypt," Scientific Reports, vol. 14, no. 1, p. 15266, 2024.

[13] M. A. Zaher, S. Elbarbary, A. T. Mohammad, H. Saibi, M. Matsumoto, J. Nishijima, and Y. Fujimitsu, "Numerical simulation of heat and mass transfer in the hurghada–el gouna geothermal field in egypt," Geothermics, vol. 115, p. 102820, 2023.

[14] M. Elkelawy, H. A.-E. Bastawissi, A. M. Radwan, M. T. Ismail, and M. El-Sheekh, "Biojet fuels production from algae: conversion technologies, characteristics, performance, and process simulation," in Handbook of algal biofuels, pp. 331–361. Elsevier, 2022.

[15] M. Elkelawy, E. El Shenawy, H. Bastawissi, and I. El Shennawy, "The effect of using the wco biodiesel as an alternative fuel in compression ignition diesel engine on performance and emissions characteristics," in Journal of Physics: Conference Series, vol. 2299, no. 1, p. 012023. IOP Publishing, 2022.

[16] M. Elkelawy, A. Kamel, A. Abou-Elyazied, and S. M. El-malla, "Experimental investigation of the effects of using biofuel blends with conventional diesel on the performance, combustion, and emission characteristics of an industrial burner," Egyptian Sugar Journal, vol. 19, pp. 44–59, 2022.

[17] A. K. Ogundana and S. A. Afolalu, "Geothermal energy potentials for electricity generation: An overview," in 2024 International Conference on Science, Engineering and Business for Driving Sustainable Development Goals (SEB4SDG), pp. 1–6. IEEE, 2024.

[18] R. E. Okoroafor, "Technology focus: Geothermal energy (march 2024)," Journal of Petroleum Technology, vol. 76, no. 03, pp. 86–87, 2024.

[19] B. Yalcin, J. Ezekiel, and P. M. Mai, "Potential for co2 plume geothermal and co2 storage in an onshore red sea rift basin, al-wajj, saudi arabia: 3d reservoir modeling and simulations," Geothermics, vol. 119, p. 102966, 2024.

[20] S. E.-d. H. Etaiw, M. Elkelawy, I. Elziny, M. Taha, I. Veza, and H. A.-E. Bastawissi, "Effect of nanocomposite scp1 additive to waste cooking oil biodiesel as fuel enhancer on diesel engine performance and emission characteristics," Sustainable Energy Technologies and Assessments, vol. 52, p. 102291, 2022.

[21] M. Elkelawy, H. Alm ElDin Mohamad, E. Abd Elhamid, and M. A. El-Gamal, "A critical review of the performance, combustion, and emissions characteristics of pcci engine controlled by injection strategy and fuel properties," Journal of Engineering Research, vol. 6, no. 5, pp. 96–110, 2022.

[22] M. Elkelawy, H. Alm ElDin Mohamad, A. K. Abdel-Rahman, A. Abou Elyazied, and S. Mostafa El Malla, "Biodiesel as an alternative fuel in terms of production, emission, combustion characteristics for industrial burners: a review," Journal of Engineering Research, vol. 6, no. 1, pp. 45–52, 2022.

[23] M. Elkelawy, H. Alm ElDin Mohamad, M. Samadony, A. M. Elbanna, and A. M. Safwat, "A comparative study on developing the hybrid-electric vehicle systems and its future expectation over the conventional engines cars," Journal of Engineering Research, vol. 6, no. 5, pp. 21–34, 2022.

[24] H. Saibi, S. Elbarbary, and M. A. Zaher, "Geothermal signatures in north

africa: Examples from egypt and algeria," in The Geology of North Africa, pp. 501–515. Springer, 2024.
[25] A. H. RADWAN, E. A. ISSAWY, J. DÉREROVÁ, M. BIELIK, and I. KOHÚT, "Integrated lithospheric modelling in the red sea area," Contributions to Geophysics and Geodesy, vol. 36, no. 4, pp. 373–384, 2006.
[26] E. Ghoneim, C. Healey, M. Hemida, A. Shebl, and A. Fahil, "Integration of geophysical and geospatial techniques to evaluate geothermal energy at siwa oasis, western desert, egypt," Remote Sensing, vol. 15, no. 21, p. 5094, 2023.
[27] A. Hegazy and S. Z. Mohamed, "Unlocking geothermal energy for sustainable greenhouse farming in arid regions: a remote-sensed assessment in egypt's new delta," Scientific Reports, vol. 13, no. 1, p. 22043, 2023.
[28] A. Elmasry, M. Abdel Zaher, A. Madani, and T. Nassar, "Exploration of geothermal resources utilizing geophysical and borehole data in the abu gharadig basin of egypt's northern western desert," Pure and Applied Geophysics, vol. 179, no. 12, pp. 4503–4520, 2022.
[29] O. Abedrabboh, M. Koç, and Y. Biçer, "Computational modeling and assessment of novel irradiation-controlled geothermally cooled greenhouse in hot arid climates," Solar Energy, vol. 277, p. 112735, 2024.
[30] M. Alacalı, "Environmental effects of geothermal energy utilizations: A case study of the seferihisar geothermal system, izmir, türkiye," Gümüşhane Üniversitesi Fen Bilimleri Dergisi, vol. 14, no. 2, pp. 592–607, 2024.
[31] A. Latrach, A. Dehdouh, C. Abdelhamid, I. Mellal, and M. Rabiei, "Feasibility of repurposing oil and gas wells for geothermal energy production in wyoming, usa," in ARMA US Rock Mechanics/Geomechanics Symposium, p. D022S021R004. ARMA, 2024.
[32] B. Ajeeb, A. Figueiredo, K. Aljundi, A. Vieira, C. Cardoso, and R. Gholami, "Assessing the potential of using geothermal energy in buildings: Parametric analysis," in E3S Web of Conferences, vol. 544, p. 18002. EDP Sciences, 2024.
[33] I. Al-Helal, A. Alsadon, S. Marey, A. Ibrahim, M. Shady, and A. Abdel-Ghany, "Geothermal energy potential for cooling/heating greenhouses in hot arid regions," Atmosphere, vol. 13, no. 1, p. 105, 2022.
[34] N. H. Moghazy and J. J. Kaluarachchi, "Sustainable agriculture development in the western desert of egypt: A case study on crop production, profit, and uncertainty in the siwa region," Sustainability, vol. 12, no. 16, p. 6568, 2020.
[35] A. M. Moustafa, A. S. Shehata, A. I. Shehata, and A. A. Hanafy, "Reuse of abandoned oil and gas wells for power generation in western dessert and gulf of suez fields of egypt," Energy Reports, vol. 8, pp. 1349–1360, 2022.
[36] J. Zhang, Y. Liu, X. Qin, Z. Dou, Q. Meng, X. Xu, and J. Lv, "Optimization design and drag reduction characteristics of bionic borehole heat exchanger," Frontiers in Energy Research, vol. 10, p. 1024623, 2022.
[37] A. M. Abdi, "A csr framework proposal for the development of geothermal resources in djibouti."
[38] A. M. Abdi, T. Murayama, S. Nishikizawa, and K. Suwanteep, "Social acceptance and associated risks of geothermal energy development in east-africa: Perspectives from geothermal energy developers," Clean Energy, p. zkae051, 2024.
[39] R. Meirbekova, D. Bonciani, D. I. Olafsson, A. Korucan, P. Derin-Güre, V. Harcouët-Menou, and W. Bero, "Opportunities and challenges of geothermal energy: A comparative analysis of three european cases—belgium, iceland, and italy," Energies, vol. 17, no. 16, p. 4134, 2024.
[40] I. G. Haraldsson, "Government incentives and international support for geothermal project development," Short Course VI on Utilization of Low- and Medium-Enthalpy Geothermal Resources and Financial Aspects of Utilization", organized by UNU-GTP and LaGeo, in Santa Tecla, El Salvador, 2014.
[41] M. Elkelawy et al., "Experimental investigation of intake diesel aerosol fuel homogeneous charge compression ignition (hcci) engine combustion and emissions," Energy and Power Engineering, vol. 6, no. 14, p. 513, 2014.
[42] M. ElKelawy, H. A.-E. Bastawissi, E.-S. A. El-Shenawy, H. Panchal, K. Sadashivuni, D. Ponnamma, M. Al-Hofy, N. Thakar, and R. Walvekar, "Experimental investigations on spray flames and emissions analysis of diesel and diesel/biodiesel blends for combustion in oxy-fuel burner," Asia-Pacific Journal of Chemical Engineering, vol. 14, no. 6, p. e2375, 2019.
[43] S. Mosallanezhad and M. R. Rahimpour, "Social benefits and challenges of geothermal energy," 2024.
[44] A. M. Abdulaziz and A. M. Faid, "Evaluation of the groundwater resources potential of siwa oasis using three-dimensional multilayer groundwater flow model, mersa matruh governorate, egypt," Arabian Journal of Geosciences, vol. 8, pp. 659–675, 2015.
[45] J. Yu, "Analysis and research on the development of geothermal energy and future development trend," Highlights in Science, Engineering and Technology, vol. 69, pp. 89–96, 2023.
[46] L. Liu, L. Yang, L. Shen, and H. Xiao, "Research progress and prospect of geothermal resources," in E3S Web of Conferences, vol. 393, p. 01001. EDP Sciences, 2023.
[47] A. M. Abdi, T. Murayama, S. Nishikizawa, K. Suwanteep, and N. O. Mariita, "Determinants of community acceptance of geothermal energy projects: A case study on a geothermal energy project in kenya," Renewable Energy Focus, vol. 50, p. 100594, 2024.
[48] C. Meller, J. Bremer, S. Baur, T. Bergfeldt, P. Blum, T. Canic, E. Eiche, E. Gaucher, V. Hagenmeyer, F. Heberling et al., "Integrated research as key to the development of a sustainable geothermal energy technology," Energy Technology, vol. 5, no. 7, pp. 965–1006, 2017.
[49] J.-z. Yu, Z. Yu-Sheng, M. Elkelawy, and Q. Kui, "Spray and combustion characteristics of hcci engine using dme/diesel blended fuel by port-injection," SAE Technical Paper, Tech. Rep., 2010.
[50] H. A.-E. Bastawissi, M. Elkelawy et al., "Investigation of the flow pattern inside a diesel engine injection nozzle to determine the relationship between various flow parameters and the occurrence of cavitation," Engineering, vol. 6, no. 13, p. 923, 2014.
[51] O. Khankishiyev, S. Salehi, C. Vivas, R. Nygaard, and D. Rehg, "Techno-economic investigation of geothermal development in sedimentary basins," ASME Open Journal of Engineering, vol. 2, 2023.
[52] C. Zaal, A. Daniilidis, and F. C. Vossepoel, "Economic and fault stability analysis of geothermal field development in direct-use hydrothermal reservoirs," Geothermal Energy, vol. 9, no. 1, p. 12, 2021.
[53] O. Bamisile, D. Cai, H. Adun, M. Taiwo, J. Li, Y. Hu, and Q. Huang, "Geothermal energy prospect for decarbonization, ewf nexus and energy poverty mitigation in east africa; the role of hydrogen production," Energy Strategy Reviews, vol. 49, p. 101157, 2023.
[54] N. Bist, A. Sircar, and K. Yadav, "Geothermal energy from abandoned oil and gas wells in india," in Utilization of Thermal Potential of Abandoned Wells, pp. 373–386. Elsevier, 2022.
[55] M. Elkelawy, Z. Yu-Sheng, A. E.-D. Hagar, and J.-Z. Yu, "Challenging and future of homogeneous charge compression ignition engines; an advanced and novel concepts review," Journal of power and energy systems, vol. 2, no. 4, pp. 1108–1119, 2008.
[56] H. A. El-Din, M. Elkelawy, and Z. Yu-Sheng, "Hcci engines combustion of cng fuel with dme and h 2 additives," SAE Technical Paper, Tech. Rep., 2010.
[57] A. Morrison-Saunders, A. Bond, J. Pope, and F. Retief, "Sustainability assessment principles and practices," in Routledge handbook of environmental impact assessment, pp. 98–113. Routledge, 2022.
[58] J. Sudhakar, S. Sharmila, G. G. Samuel et al., "An overview of environment impact assessment studies in indian industries," International Journal of Science and Research Archive, vol. 8, no. 1, pp. 490–498, 2023.
[59] R. M. Sanford and D. G. Holtgrieve, Environmental Impact Assessment in the United States. Routledge, 2022.
[60] P. H. Z. Viduedo, V. C. U. Candeia, V. B. L. Martins, A. C. Destefani, and V. C. Destefani, "Harnessing the power of ai and machine learning for next-generation sequencing data analysis: A comprehensive review of applications, challenges, and future directions in precision oncology," Revista Ibero-Americana de Humanidades, Ciências e Educação, vol. 10, no. 8, pp. 2898–2904, 2024.
[61] S. Goff, "Effective use of environmental impact assessments (eias) for geothermal development projects," Los Alamos National Lab.(LANL), Los Alamos, NM (United States), Tech. Rep., 2000.
[62] B. Hoxha, J. Soto, Z. Bega, and A. Zuna, "New geothermal gradient data allows for evaluating applications in albania and kosova," in SPE Energy Transition Symposium, p. D011S004R006. SPE, 2024.
[63] L. Janota, K. Vávrová, and R. Bízková, "Methodology for strengthening energy resilience with smart solution approach of rural areas: Local production of alternative biomass fuel within renewable energy community," Energy Reports, vol. 10, pp. 1211–1227, 2023.