

Economic and Prospect Analysis of Geothermal Energy Production from Abandoned Petroleum Wells: A Brief Review

Md. Nasirul Islam^{1,*}, Mohammad Mujtaba Hasan¹, Rangan Mouni Mandal¹, Mahfuj Ahmed¹, Shehoba Yasmin¹, Shakil Ahmed Razo¹, A T M Masum²

¹Department of Petroleum and Mining Engineering, Military Institute of Science and Technology, Dhaka-1216, Bangladesh.

²Department of Civil Engineering, Military Institute of Science and Technology, Dhaka-1216, Bangladesh.

Abstract

Bangladesh is currently facing a critical energy crisis with natural gas supplies anticipated to run out within the next 10-15 years. As such the country becomes more reliant on foreign energy imports. Hence, there is an urgent need to explore and utilize its untapped energy resources. This paper evaluates the feasibility of extracting geothermal energy from the country's large sedimentary basins and abandoned petroleum wells. The findings of the study show that these wells have great geothermal potential, notably in the northwest region, where temperatures approach 100°C at depths of 3 to 4 kilometers. Moreover, the present work estimates that as little as 10% conversion of the abandoned wells could generate approximately 500 MW of electricity, enough to power more than 2 million households. Furthermore, techniques such as CO₂-ECBM could increase geothermal recovery by 30% while simultaneously aiding carbon capture and storage programs. Additionally, the use of geothermal energy benefits the environment by reducing greenhouse gas emissions by 90% compared to nonrenewable fossil fuels. Finally, this study argues that the economic feasibility of geothermal energy extraction in the country is promising, and advocates for state and federal investments in the geothermal energy sector.

Keywords: Geothermal Energy, Abandoned Well, Energy Crisis in Bangladesh, Geothermal Powerplant, Electricity Generation.



Copyright @ All authors

This work is licensed under a [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Bangladesh is a South Asian developing country and is now in a very bad condition of power crisis because the power demand in Bangladesh is increasing much faster than the production [1]. Natural gas remains the most popular source of energy, contributing to 8 percent of the installed electricity capacity from natural gas [1]. On the other hand, these reserves are declining and the prognosis of the further trend and stocks indicate that they will only be available for a couple of years from now [2]. Thus, if in the future there is a lack of energy, it will be appropriate to use other types of energy especially renewable energy to enhance energy development.

Geothermal energy can be an excellent solution for the current energy crisis in Bangladesh [3]. The nation falls within the Ganges–Brahmaputra Delta, which is characterized by extensive sedimentary basins and many abandoned wells [4]. The geological studies indicate that these wells in the northwest area have temperature regimes that are higher than 100°C at a depth of 3-4 kilometers, and as a result, they have a strong potential for the production of geothermal energy [5]. Even though some of these producing wells might not have a very high production rate, it is possible to convert them to geothermal usage in an effective manner. This would allow them to leverage their

full production capacity to create energy while simultaneously making the most of the resources.

Binary cycle plants and flash steam systems are two of the most prevalent operational techniques that have been employed in geothermal power generation [6]. Binary cycle power plants employ a second working fluid to create electricity from low-temperature geothermal and flash steam uses direct steam from thermal fluids [7]. Furthermore, the adoption of procedures that employ injection about annually has the capability of improving geothermal recovery and at the same time supporting carbon dioxide storage in the subsurface [8].

It may be concluded that the influence of geothermal energy on the environment is smaller as compared to oil, coal, and natural gases. The extraction procedure is related to this sort of land usage and produces resources, but overall, carbon blot is substantially diminished. Geothermal energy decreases the societal cost connected with the exploitation of traditional energy sources since it considerably reduces the production of gases and particles that are detrimental to the atmosphere, ergo speaks volumes about Bangladesh's ability to battle climate change. Some of the main variables for next-generation geothermal energy production in Bangladesh are; technology advancement, state policy assistance, and investment in infrastructure. Geothermal projects must have economic viability that is established by

the expenses of establishing the geothermal plant as well as the costs of producing the energy [9].

Therefore, with a correct strategic approach, geothermal energy has the potential to be one of the most important sources of energy in Bangladesh and will ensure an uninterrupted supply of energy once the right framework is established [10]. Last but not least, based on the data analysis it can be argued that geothermal power plants are highly viable in Bangladesh and the deployment of such infrastructure can revolutionise the energy industry in the nation [11].

Here in Figure 1, the geothermal powerplant process flow layout is visualized.

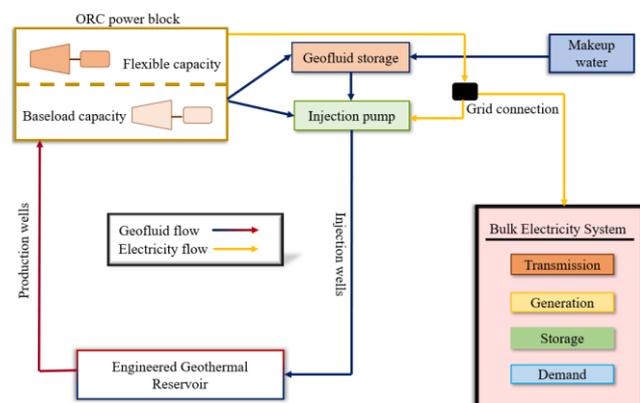


Figure 1: Geothermal Powerplant Process Flow Layout

2. Geothermal Prospects of Bangladesh

Up till today, this nation has produced no noteworthy geothermal energy research. Under support from KTH Figure 2, The geothermal gradient of Bangladesh at 3 km depth, shows the results of a study on the likelihood of geothermal energy undertaken by Herbert Henkel (Sweden), Prof. D.K. Guha (Bangladesh), and (The Royal Institute of Technology Stockholm, Sweden) (modified from Guha, 2010). Deep wells were abandoned by Bangladesh, which was primarily concerned with the gas resources. After looking at fifty more wells that had been abandoned in Bangladesh, they made some recommendations for how to use these wells to produce geothermal energy. Professor Dr. Badrul Imam of Dhaka University oversaw the team's project proposal, which was based on the research and conclusions of Herbert Henkel and Guha [12].

Figure 2 depicts Bangladesh's geothermal gradient at a depth of 3 km. It is seen that the northwestern part of Bangladesh has a high geothermal gradient and thus has a higher potential to produce geothermal energy. On the other hand, the southeastern part of Bangladesh has a low geothermal gradient. The temperature profile is decreasing from north to south and west to east. So surely this part of Bangladesh will face problems in producing geothermal energy in comparison to the other parts of the country.

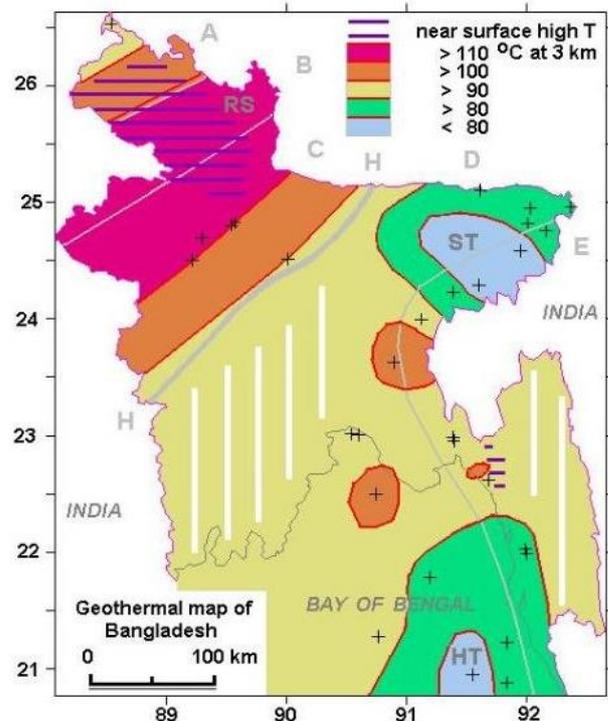


Figure 2: Bangladesh's Geothermal Gradient at a Depth of 3 km (adapted from Guha, 2010).

Geothermal energy could be produced from abandoned wells, which would lower well drilling costs and increase the amount of renewable energy available. Since the fluid circulation system is closed and the working fluid does not come into direct contact with rocks because only one well is utilized for geothermal production, the issues of re-injection, corrosion, and scaling can be resolved simultaneously. The use of abandoned wells has received a lot of attention lately from several scholars. Kujawa and associates [13] looked at the use of already-existing deep geological wells for geothermal energy acquisition and found that insulation and flow rates had a significant impact on heat exchange. Michaelides and Davis [14] investigated the production of geothermal energy from decommissioned oil wells, analyzing the data while accounting for well depths and regional geothermal gradients. The power generation estimated in this article was larger than the actual value, though, because the temperature of the rocks was taken to be constant over time in this work. Geothermal water extraction from oil wells was tested to produce electricity in China's Huabei oil sector. [15]. The findings of the experiment revealed that the mass flow rate of hot water extracted was 1932 t/d at a temperature of 116 °C. Nevertheless, only a small number of studies took a thorough look at the heat exchange between rocks and fluid. Thus, determining an accurate method for calculating the heat exchange between rocks and fluid as well as the production of geothermal energy from abandoned wells is crucial.

Bangladesh, which was mostly focused on the gas fields abandoned deep wells. They examined fifty more wells that had been abandoned in Bangladesh and made some recommendations for how to get geothermal energy from them. Prof. Dr. Badrul Imam of Dhaka University oversaw the team's project proposal, which was based on the research and conclusions of Herbert Henkel and Guha. Finally, it was proposed that at least one of the three wells

(the Sitakund, Shalbanhat, and Singra wells) be used for a pilot study (reopening of the closed wells), but this idea was never implemented. The Geological Survey of Bangladesh carried out a drilling operation in the Thakurgaon district (GDH-65/11). The drilling was completed at a depth of 586 meters, with a temperature recorded at 47°C, which is about Bangladesh's typical gradient.

3. Repurposing Hydrocarbon Wells

The utilization of abandoned gas wells as geothermal resources for energy generation presents a viable method for harnessing geothermal energy from geological formations. Enhanced geothermal systems involving repurposing of existing abandoned oil and gas wells could be an effective way of reducing development costs compared to drilling new wells. The process of repurposing should take into account local energy requirements, prospective markets, current infrastructure, and technical obstacles. Research has concentrated on repurposing hydrocarbon wells for the generation of geothermal energy and heat storage applications.

In Figure 3, an open-loop and a close-loop geothermal heat recovery system is shown from the perspective of repurposing hydrocarbon wells in Bangladesh.

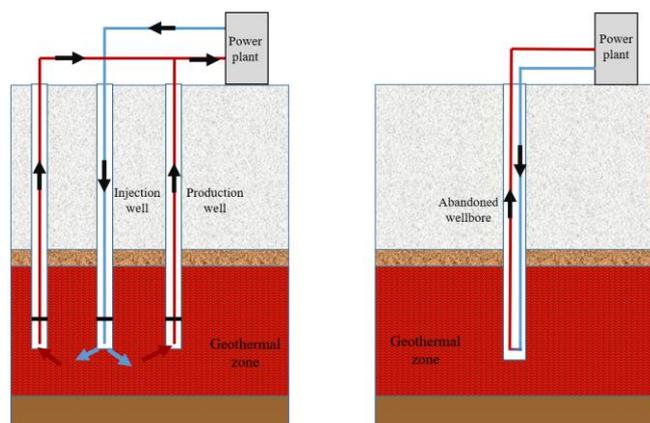


Figure 3: (a)Open loop (b)Close loop Geothermal Heat Recovery System [16]

Research conducted in the UK examined the potential candidate locations and evaluated the feasibility of repurposing the hydrocarbon wells for geothermal purposes. As part of the study, the thermal energy and onshore field/volumes that hold promising geothermal resources were evaluated. The paper's findings suggest that the concept of using these wells as a renewable energy source might significantly impact the UK's energy grid, particularly in the areas of existing hydrocarbon exploration [17]. The success of these efforts relies on careful site selection, which must take into account well depth, location, surrounding geological characteristics, and the existing infrastructure. There are five primary challenges associated with well selection, data accessibility, underground infrastructure, well integrity, and regulatory considerations [18]. Considering all these factors, Bangladesh can utilize similar efforts as its prospect for geothermal energy production.

4. Conversion of Hydrocarbon Wells

Well Conversion therefore means the transformation of an existing hydrocarbon well into a geothermal well. This entails retrofitting the well's structures and traits to facilitate a shift of resource extraction from hydrocarbons to geothermal energy. The conversion process is therefore important for using existing wells, especially the inactive, abandoned oil and gas wells to exploit renewable energy sources. A method was introduced for extracting geothermal energy from abandoned hydrocarbon wells by utilizing an injection-production well pair, while also considering the associated economic and environmental implications. Bangladesh may succeed by following these reliable operational examples. Their study employed a numerical modeling technique that integrated both thermal and hydraulic processes [19]. They explored the conversion of abandoned hydrocarbon reservoirs into geothermal reservoirs through a three-dimensional numerical model [20]. A sensitivity analysis was conducted to assess the influence of key parameters, including inlet temperature, inlet pressure, and well distance, on the outlet temperature. The findings indicated that the inlet temperature must be carefully regulated to prevent damage to the well assembly and downhole equipment, while also ensuring adequate heat flow. Furthermore, the injection pressure should remain below 35 MPa to prevent premature thermal break between the injection and production wells. It was also noted that maintaining a reasonably well distance is crucial to avoid early thermal breakthroughs and to ensure the sustainability of the system [19]. In Hungary, an old abandoned oil well was transformed into a closed-loop geothermal system with 0.5 MW of thermal energy. The project developed by MS Energy Solutions effectively reflected the real-life utilization of repurposing hydrocarbon wells and the possibility of using current structures to create green energy [20]. The assessment of 349 abandoned onshore wells for potential repurposing into geothermal energy sources in New Zealand was aimed at utilizing the heat for direct applications, power generation, and the development of tourist attractions through the creation of pseudo hot springs. The depths of these wells vary from 17 to 5000 meters, with bottom hole temperatures ranging from 16°C to 172°C. Comparing all these with the sedimentary geological settings in Bangladesh, we can show better results in the field of geothermal energy production. Therefore, the major targets for geothermal powerplant construction regions would consist of abandoned petroleum wells and currently producing wells that will eventually decline its production over time.

In Figure 4, a schematic of a double pipe and a u-tube heat exchanger in closed-loop heat exchanger is designed with the perspective of converting hydrocarbon wells in Bangladesh.

5. Power Generation

The amount of electricity generated in a geothermal power plant employing steam turbines depends on several parameters governed by the laws of thermodynamics governing such systems. The calculations will be divided into sections for the generation of electricity using steam obtained from water and the second one for the steam obtained from gas that is hydrocarbons. The predicted

power generation from closely settled multiple wells is shown in Table 1.

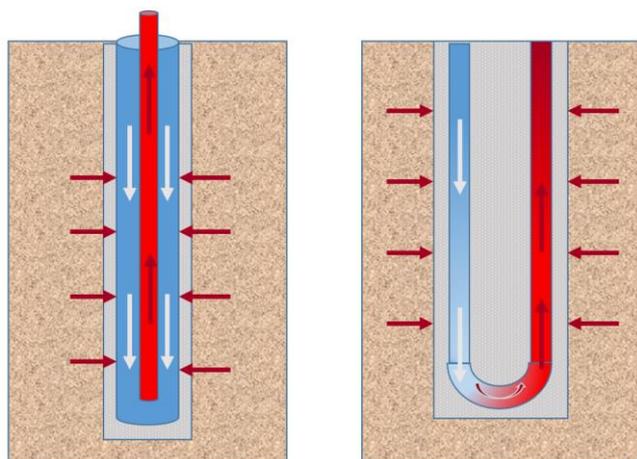


Figure 4: Schematic of (a) Double Pipe (b) U-Tube Heat Exchanger in Closed-loop Heat Exchanger[16]

Table 1: Calculation for Electricity Generation

Properties	Water steam	Gas
\dot{m} (kg/s)	10	10
h_{in} (kJ/kg)	2800	2500
h_{out} (kJ/kg)	2000	1800
$h_{resource}$ (kJ/kg)	3000	2700
η (%)	15	18
Parameters	Water steam	Gas
W (kJ)	8000	7000
Q_{in} (kJ)	10000	9000
E (kW)	1500	1620
Energy from 1 well	3120 KW	
Energy from 10 wells	31.2 MW	

As we understand from the temperature gradient profile, The generated power can highly benefit the northern and western part of Bangladesh.

6. Economic Viability

Reusing idle petroleum wells in geothermal energy production has added the advantage of minimizing the initial drilling costs. The current costs of drilling new geothermal wells can be estimated between \$5 million and \$10 million per well, but if existing wells are to be redeployed, these costs may be reduced by 60%. The total capital cost for the establishment of geothermal power plants in Bangladesh has been assessed to be ranging between \$2500 and \$5000 per kW of installed capacity. At a plant of 100MW, this can mean an investment between \$250 million to \$ 500 million. After being developed, geothermal plants have proven to have negligible operating and maintenance costs as compared to fossil fuel plants. The cost for power generation from geothermal components is expected to range between \$0.05 and \$0.10 per kilowatt hour for LCOE which is on the same level as other

renewable energy sources. The temperature in the northwest region is considered to be above 100°C at a depth of 3-4 kilometers now it is optimistic that Bangladesh can produce about 500MW of electricity from the repurposed well and provide electricity for about 2,00,000 households.

7. Eligibility of Geothermal Well

To produce energy from geothermal wells we need a temperature above 100°C. Because water becomes steam over this temperature. Usually in summer, the temperature of Bangladesh stays over 30°C and in winter it stays around 20°C. Climate forecasting studies show that Bangladesh will reach 48°C in the next 10 years. Hence there are some factors that geothermal wells will work in favor.

$$T_f = T_s + (G \times D) \quad (1)$$

Figure 5 graphically represents the temperature gradient and the required depth to produce steam for different wells in Bangladesh.

Existing production wells and abandoned wells are listed in the figures. Even though the northwestern part of the country has a high geothermal gradient, all the wells mentioned have a good potential to be modified as geothermal wells and serve the power sector of the country. Strong aquifer regions are our primary focus for the initial stage.

8. Conclusion

Bangladesh has now come across a viable solution in geothermal energy in a view to overcome the energy crisis which can be a struggle as natural gases become a rare factor in Bangladesh. The prospect of geothermal energy extraction is viable economically as well. There is much potential to generate geothermal energy from exhausted wells; it may be globally revealed that by rehabilitating many important wells the output is around 150 MW only, which reduces the use of fossil fuels. According to the economic analysis the use of infrastructure can cost up to 40% less than the new drilling operations that are already existing. Moreover, the technologies for low to middle-temperature resources can generate electricity at an affordable cost of \$05 per kWh thus making geothermal a favorable solution for environmentally friendly power generation. The environment is promising; a shift to geothermal power may bring the ability to decrease more than 1 million tons of CO₂ emission per year. With the advent of geothermal power to its energy resource basket, Bangladesh has the predisposition to avail of energy without having scarcity as a hindrance further can act as a seminal force in combating climate change at the international level. This could be useful as a model for other nations with similar geology and energy problems. From the paper, it can be established that Bangladesh has the potential capability to acquire and use geothermal energy.

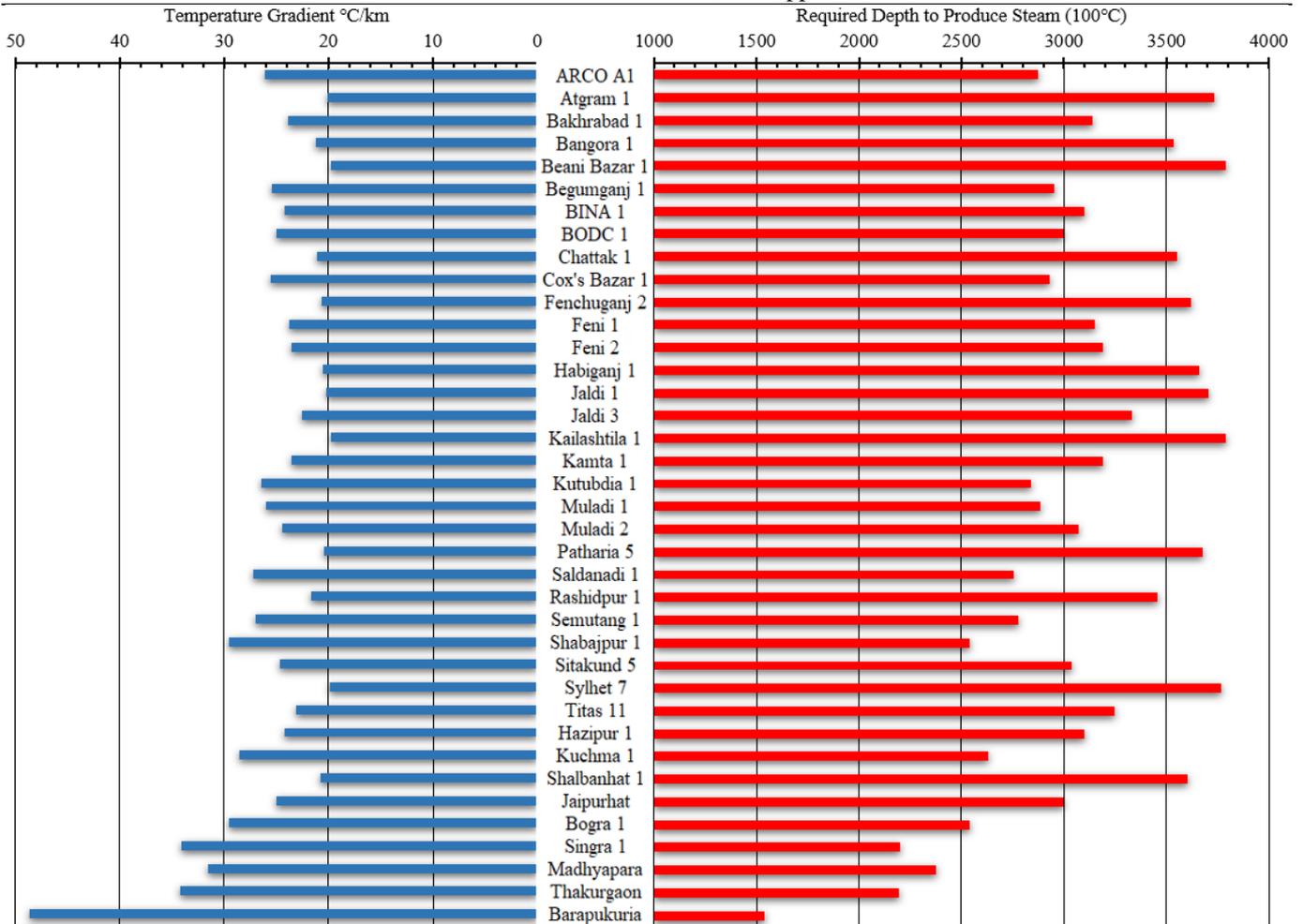


Figure 5: Temperature Gradient and Required Depth to Produce Steam for Different Wells in Bangladesh [3,9,12]

References

[1] B. Imam, "Energy crisis and potential in Bangladesh," *Strategic Analysis*, vol. 35, no. 2, pp. 248–264, Mar. 2011,

[2] M. B. Imam and M. Hussain, "A Review of Hydrocarbon Habitats In Bangladesh," 2002.

[3] A. S. M. M. Hasan, "Energy Demand & Prospect of Geothermal Energy as the Solution of Energy Crisis of Bangladesh – an Approach to Green Energy Solution," *International Journal of Renewable and Sustainable Energy*, vol. 2, no. 6, p. 217, 2013

[4] C. Small *et al.*, "Spectroscopy of sediments in the Ganges-Brahmaputra delta: Spectral effects of moisture, grain size and lithology," *Remote Sens Environ*, vol. 113, no. 2, pp. 342–361, Feb. 2009.

[5] S. M. Kabir and B. Imam, "Geological factors contributing to high-heat in part of Barapukuria Underground Coal Mine," 2013. [Online]. Available: <https://www.researchgate.net/publication/313979710>

[6] S. J. Zarrouk and H. Moon, "Efficiency of geothermal power plants: A worldwide review," Jul. 2014.

[7] M. Tessema Abisa, "Geothermal Binary Plant Operation and Maintenance Systems With Svartsengi Power Plant as A Case Study."

[8] J. Wan *et al.*, "Development and technology status of energy storage in depleted gas reservoirs," *Int J Coal Sci Technol*, vol. 11, no. 1, Dec. 2024.

[9] M. Hassanuzzaman, Al-Shahriar, and S. T. Faisal, "Geothermal energy and its scope in Bangladesh," in *Proceedings of 2014 3rd International Conference on the Developments in Renewable Energy Technology, ICDRET 2014*, Institute of Electrical and Electronics Engineers Inc., Jul. 2014.

[10] K. Khan, M. Ahmed, M. S. Parvez, and M. M. Hossain, "Scope of geothermal potential of Bangladesh: A review," in *2015 International Conference on Green Energy and Technology, ICGET 2015*, Institute of Electrical and Electronics Engineers Inc., Nov. 2015.

[11] M. Masum, "Low-Temperature Geothermal Systems in Sedimentary Basin and Their Prospect in Bangladesh," 2015. [Online]. Available: <https://www.researchgate.net/publication/329175220>

[12] "Geothermal Energy and The Prospect Of Bangladesh' Hasnat Nayem Univertsiti Putra Malaysia".

[13] J. Jello and T. Baser, "Utilization of Existing Hydrocarbon Wells for Geothermal System Development: A Review," 2023.

- [14] A. P. Davis and E. E. Michaelides, "Geothermal power production from abandoned oil wells," *Energy*, vol. 34, no. 7, pp. 866–872, 2009.
- [15] X. Bu, W. Ma, and H. Li, "Geothermal energy production utilizing abandoned oil and gas wells," *Renew Energy*, vol. 41, pp. 80–85, May 2012.
- [16] J. Jello and T. Baser, "Utilization of Existing Hydrocarbon Wells for Geothermal System Development: A Review," 2023.
- [17] S. M. Watson, R. Westaway, and G. Falcone, "A Review of Deep Geothermal Energy and Future Opportunities in the UK," pp. 11–14, 2019.
- [18] L. Santos, A. Dahi Taleghani, and D. Elsworth, "Repurposing abandoned wells for geothermal energy: Current status and future prospects," 2022.
- [19] A. Mehmood, J. Yao, D. Fan, K. Bongole, J. Liu, and X. Zhang, "Potential for heat production by retrofitting abandoned gas wells into geothermal wells," *PLoS One*, vol. 14, no. 8, Aug. 2019.
- [20] P. Szűcs *et al.*, "Innovation in assessment of the geothermal energy potential of abandoned hydrocarbon wells in the southern and southeastern foreground of the Bükk Mountains, northeast Hungary," *Hydrogeol J*, vol. 30, no. 8, pp. 2267–2284, Dec. 2022.

NOMENCLATURE

- D : the depth
 E : electricity generated (kWh)
 G : the geothermal gradient
 h_{in} : enthalpy of the steam entering the turbine (kJ/kg)
 h_{out} : enthalpy of the steam exiting the turbine (kJ/kg)
 $h_{resource}$: enthalpy of the geothermal resource (kJ/kg)
 \dot{m} : mass flow rate of the steam (kg/s)
 Q_{in} : heat input from the geothermal source
 T_f : the formation temperature
 T_s : the surface temperature
 W : work output (electricity generated)