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Geothermal Energy Development in Bangladesh: A Sustainable Solution to Mitigate Climate Change Impacts

Md.Mamun[1], Nayeem Md. Lutful Huq[2]*, Md. Ubaidur Rahman[3], Md. Zakir Hossain[1], Md Rakib Hossain[4], Shuvo Chandra Das[1], Minhaz Hossain[1]

[1] Department of Mechanical Engineering,
Dhaka University of Engineering & Technology, DUET, Gazipur.
[2] Professor, Department of Mechanical Engineering,
Dhaka University of Engineering & Technology, DUET, Gazipur.
[3] Department of Electrical & Electronics Engineering,
Dhaka University of Engineering & Technology, DUET, Gazipur.
[4] Department of Materials & Metallurgical Engineering,
Dhaka University of Engineering & Technology, DUET, Gazipur.
mamun193016@gmail.com, lutful@duet.ac.bd ubaidurduet@gmail.com,
zakirduet@gmail.com, rakibduet@gmail.com, shuvochandra05@gmail.com ,
hossainmdminhaz.92@gmail.com

Abstract

Geothermal energy may provide a dependable and sustainable answer to Bangladesh's increasing energy needs while mitigating the effects of climate change. This research emphasizes base-load supply, power output, and environmental advantages and explores Bangladesh's potential for geothermal energy development. A 200 MW project has already been approved in Thakurgaon and Habiganj. Titas, Shabajpur, and Thakurgaon are potential geothermal hotspots. In light of Bangladesh's distinct geological circumstances, the research examines the viability of geothermal power-generating methods such as binary cycles, flash steam, and dry steam. Additionally covered is the potential for enhanced geothermal systems (EGS) to have a lower environmental effect and greater efficacy. Geothermal energy can be critical in diversifying Bangladesh's energy mix, ensuring energy security, and supporting decarbonization efforts. However, careful management of environmental and social impacts is essential to fully harness geothermal energy's potential. This study provides a foundation for future research and policy development to optimize geothermal energy utilization in Bangladesh.

Keywords
Geothermal; Climate Change; Renewable energy; Electricity Generation; Sustainable Solution.

1. Introduction
Three significant issues impede sustainable growth: the world population is expanding quickly, there is a need for more energy, and environmental pollution is worsening. Several countries are researching alternative energy, particularly renewable energy, to reduce their dependency on traditional fossil fuels over time (Aikins & Choi 2012; Bahadori et al. 2013; Hepbasli 2004). Electricity from renewable sources could triple between 2010 and 2035. This

development would be a significant improvement, accounting for 31% of total energy generation ("WORLD ENERGY OUTLOOK 2022," 2022). In addition to space heating and cooling, geothermal energy is used in mineral extraction, aquaculture, agro-industry, recreation, and health. It is produced and stored underground as hot water or steam and is a renewable energy source that offers base-load power in an environmentally responsible manner (Darge et al. 2019; Li et al. 2012). Because geothermal resources are not affected by weather variations, they are more reliable than other sustainable energy sources such as solar and wind power. Geothermal power can create electricity around the clock, making it a dependable energy source (Samrock et al. 2015). Before 2041, Bangladesh is expected to experience economic prosperity ("PERSPECTIVE PLAN OF BANGLADESH 2021-2041," 2020). It also requires the constant and dependable production of electricity. There are numerous departments in Bangladesh where geothermal energy can be possible. Habiganj, Titas, Shabajpur, Bangora, Singra, and Saldanadi are some regions that show promise in aesthetics (M. Hassanuzzaman 2014). Under many kilometers of earth, the country's northwest region, in particular, shows great promise with a temperature gradient ranging from 20.8° to 48.7°C/km (M. T. Islam et al. 2022).

Despite its early stages, the Ministry of Power, Energy, and Mineral Resources approved the first geothermal project. It is being built at Thakurgaon by investor Anglo MGH. It can only currently hold 200 MW (Alam et al. 2024). Geothermal energy, with its vast potential, offers a possible answer to the fight against climate change. As a renewable energy source with low greenhouse gas emissions, it may replace fossil fuels by creating heat and power, promoting decarbonization. In areas where heating is a significant energy expenditure, geothermal energy may significantly reduce carbon emissions (Tester et al. 2021). However, to fully realize this potential, geothermal energy's environmental and social implications must be carefully managed (Ozcelik 2022). Geothermal energy is essential for meeting energy demands in sustainable manufacturing because of its steady and reliable supply (Ratnakar et al. 2022).

It is, however, about creation and the prudent handling of its social and economic consequences. Analyses of land-use changes and their effects on nearby populations are included (Jiang et al. 2017). Geothermal power plants are being built quickly in places like Buyuk Menderes Graben, Turkey, which emphasizes the need for constant observation to avoid negative social and environmental impacts (Ozcelik 2022). Continuous observation would affect the industry's commitment to reducing negative consequences. Geothermal power facilities can use various technologies, such as Organic Rankine cycles, which use an organic fluid instead of water to reinject non-condensable gases and improve environmental efficiency (Desideri et al. 2021). The environmental effects of geothermal power generation may be predicted using simplified Life Cycle Assessment (LCA) models, which can also help choose appropriate technologies (Paulillo et al. 2022). The selection of a power fluid, such as carbon dioxide, is necessary when using decommissioned wells for energy production, and it may impact the thermal output and feasibility of geothermal projects (Ratnakar et al. 2022).

This research highlights the use of geothermal energy as a sustainable means of mitigating climate change while examining its untapped potential in Bangladesh. Analyzing site-specific geothermal potential and utilizing state-of-the-art power generation technologies, this study provides new information on renewable energy development.

2. Demand And Scenario of Energy in Bangladesh

Energy is the entire quantity of electrical power that is accessible. This power can be produced from various sources, including biomass from organic matter, biogas from organic waste, concentrated solar energy, renewable wind, fossil fuels, and water-driven hydroelectric sources. Both power generated for broad consumption and power generated for a single, particular use fall under this category. The estimated electricity demand in the Power System Master Plan (PSMP) 2010 is contingent upon a GDP growth rate of 7% ("People’s Republic of BangladeshPower & Energy Sector Master Plan (PSMP2016),"). As indicated by the results shown in Figure 1, the highest possible needs are projected to be roughly 10283 MW in the economic year of 2015, 17304 MW in the fiscal year of 2020, 25199 MW by the end of 2025, and 33708 MW by the year 2030 ("বাংলাদেশ বিদ্যুৎ উন্নয়ন বোর্ড,"). The most significant amount of power produced was 4890 MW in the fiscal year 2010–11; however, in the fiscal year 2022–23, there was a notable increase to 15604 MW. Figure 1 displays the maximum generated and utilized capacity for the fiscal years 2010 through 2023 ("Finance Division, Ministry of Finance,"). Naturally occurring gas accounts for about 44.50% of the energy produced; liquid fuel, coal, and hydropower comprise the remaining percentage. Currently, renewable energy barely makes up 3.75% of the total. The figure illustrates the assets that are helping Bangladesh produce power. The primary energy source for the sector is fossil fuel, which will run out soon. Due to their degradation, conventional power generation based on fossil fuel methods is expected to become less viable in the upcoming years. Scientists, engineers, and communities are turning to renewable energy sources due to the growing world population and the resulting spike in energy consumption. Work began in November 2017 on Bangladesh's first nuclear reactor, the Rooppur Nuclear Power Station, initiating the nation's journey toward nuclear plant ownership. Rooppur 1 reactor is anticipated to begin operations by 2024 (Islam Md. Shafiqul 2020). Most public-sector power plants use degraded, old equipment to run their operations. As a result, they cannot operate to their full potential, which lowers the power produced nationally. Figure 2 illustrates the electricity generation capacity (MW) from various energy resources, highlighting their contributions to the overall energy mix.

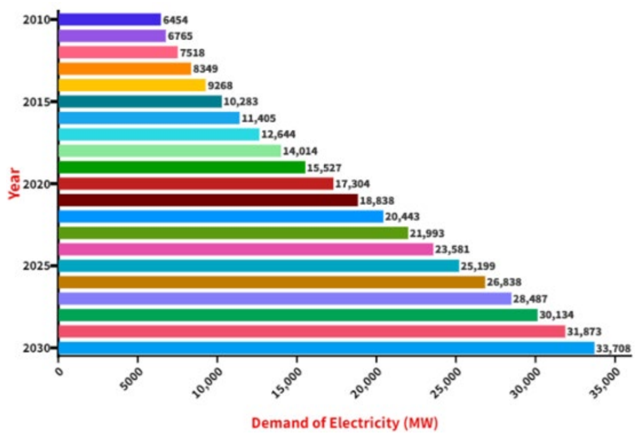


Figure 1. Year-wise peak demand forecast.

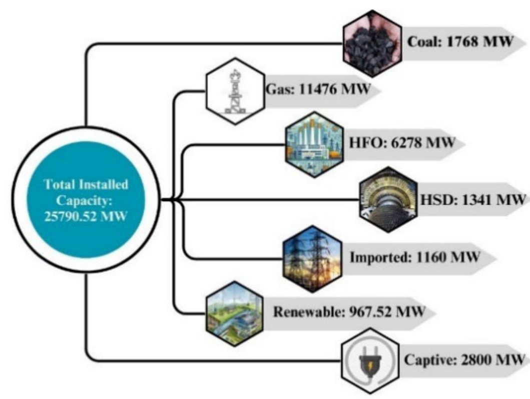


Figure 2. Electricity generation from different resources (MW).

The problem is made worse by the scarcity of natural gas, which is these power plants' primary fuel source and limits their ability to generate electricity. In addition to natural gas-powered plants, additional power facilities exist, such as the Katapai Hydro Electric Plant, the Barapukuria coal-based plant, and other diesel and burner oil-based plants across the nation (Kibria et al. 2024). However, the lack of gas supply has dramatically reduced the country's capacity to generate electricity. Regrettably, to produce the most power possible, the nation has been unable to exploit its resources completely (S. Islam & Khan 2017).

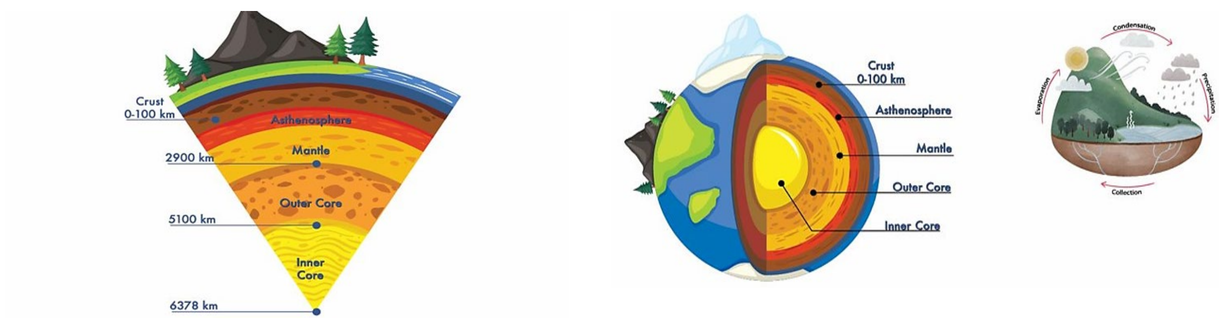
3. Geothermal Energy

The heat from within the Earth gradually rises to the surface. It is both environmentally friendly and hygienic. About 80% of the heat generated by radioactive decay and 20% from gravitational binding energy comes from the Earth's interior ("পাওয়ার সেল,"). A potential hotspot, the planet's core can achieve pressures of 360 GPa and temperatures of up to 6,000°C (10,830°F) (Alfè 2007). From shallow ground to hot rock and water located kilometers below the surface of the Earth, geothermal energy resources are a varied and intriguing variety. The three temperature ranges for the materials are low (below 90°C or 194°F), moderate (90°C to 150°C or 194°F to 302°F), and high (above 150°C or 302°F). Temperature also has an impact on how these resources are used. Table 1 presents expert-assessed values gathered through consultations to support geothermal energy development analysis.

Table 1. Collection of expert values.

Depth (km)	Component Layout	Density (gm/cm^3)
0-60	Lithosphere	2.7-3.3
0-35	Crust	2.2-2.9
35-60	Upper Mantle	3.4-4.4
60-2890	Mantle	3.4-5.6
100-700	Asthenosphere	3.5-3.6
2890-5100	Outer core	9.9-12.2
5100-6378	Inner core	12.8-13.1

Figure 3 illustrates the Earth's chemical and physical layer organization, highlighting compositional and mechanical properties (not to scale).



(a) (b)

Figure 3. The chemical and physical organization of the Earth's layer (representation is not proportionate).

3.1 Determination of Ergonomic Factors

This study first investigated the existing literature on ergonomic factors affecting productivity in the garment industry. This review aims to establish a basic understanding of ergonomic problems that may affect employee performance and productivity. In addition to data analysis, a statistical package (SPSS) is used for statistical analysis to collect meaningful comments and primarily to observe the definitive results. Experts' feedback helped improve and optimize the unique content of the readymade garments sector in Bangladesh.

4. Geothermal power generation technology

The technologies of Geothermal Power Productions are dry steam technology, flash steam technology with single-flash or double flash, and binary power plants.

4.1 Dry steam technology

Critical technologies in geothermal power generation include dry steam technology, which utilizes superheated or saturated vapor directly from the underground as the working fluid (Aziz & Juangsa 2021). This method enhances energy output and system efficiency, supported by advancements like honeycomb-structured dry steam generation devices that improve heat exchange efficiency (Leon Clarke 2021). Figure 4 illustrates the working principle of dry steam geothermal technology, where steam directly drives a turbine to generate electricity.

4.2 Flash Steam Technology

One popular approach to effectively using geothermal energy is using flash steam cycles in geothermal power generation technology. Improving design parameters and higher energy efficiency are two examples of how research has shown that integrating single-flash geothermal cycles with trans-critical carbon dioxide cycles can significantly improve system performance (Aryanfar et al. 2023; Huang et al. 2023). Furthermore, it has been discovered that adding recuperators to recover heat loss in geothermal power-generating systems increases energy efficiency, energy efficiency, and net power output, demonstrating the possibility of significant system efficiency gains (Hao Wang et al. 2023). The latter can achieve an efficiency of up to 48.5% in energy production and electricity generation (Farsi & Rosen, 2022)**.** Moreover, the application of depleted geothermal energy in combined cycles for heating and cooling has demonstrated remarkable overall efficiencies of up to 73%, suggesting low heat loss and optimal geothermal energy usage (Kishore Rawat et al. 2022). Figure 5 representation of flash steam geothermal technology, highlighting the separation of high-pressure hot water into steam to power turbines.

4.3 Binary Power Plant

Using geothermal fluids to transfer energy to a second fluid with a low boiling point, such as n-pentane, isopentane, or isobutane, without flashing is the process of producing geothermal power using binary power plants (Panggabean & Siregar 2022; Абдлахатова & Жанпейісова 2022). Like conventional thermal power plants, Geothermal Power Plants (GPPs) use the binary cycle, in which a second fluid evaporates, travels through a turbine, condenses in a condenser, and is then used by a pump to complete the cycle (Başoğul et al. 2021). Research has demonstrated that binary power plants help utilize geothermal energy. Novel applications, such as the Kalina cycle, have been proven to improve energy and energy efficiency in Double-Flash Geothermal Power Plants (Rostamzadeh et al. 2021). Furthermore, Indonesian research has looked into improving binary systems using organic Rankine cycles for increased energy efficiency and usage, demonstrating the ongoing advancement and refinement of geothermal power generation technology (Kumolosari et al. 2020). Figure 6 represents binary power geothermal technology, showcasing the heat transfer to a secondary working fluid to drive turbines in a closed-loop system.

4.4 Enhanced Geothermal System (EGS)

Enhanced Geothermal Systems (EGS) circulate water via injected, well-created fissures to produce energy from underground warm rock. Proppants and chemical additions are used as backfill materials to improve energy extraction and water circulation (Kumar et al. 2023). Geothermal production in EGS has been effectively predicted using deep learning models, especially the Transformer algorithm, which has considerably reduced prediction time compared to numerical simulations (Xue & Chen 2023).

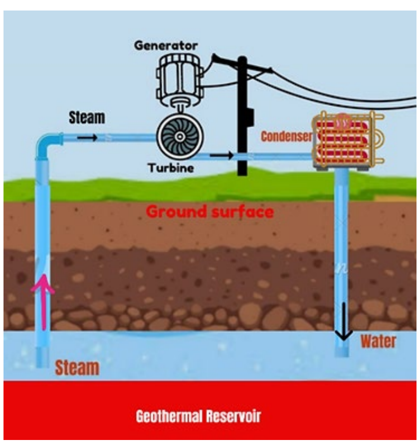


Figure 4. Dry steam technology schematic diagram.

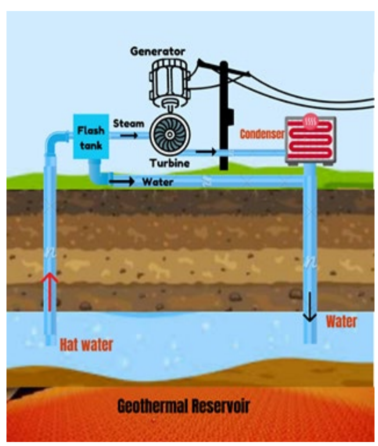


Figure 5. Flash steam technology schematic diagram.

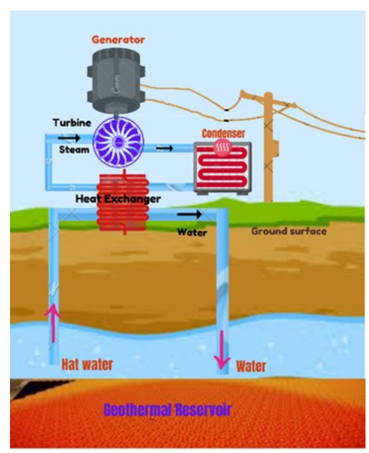


Figure 6. Binary power technology schematic diagram.

Hydraulic stimulation is a popular technique for increasing reservoir permeability and heat exchange area in EGS to maximize efficiency and minimize induced seismicity through accurate site identification and sound design (Jia et al.

2022). The performance of an EGS reservoir is greatly influenced by the way fractured zones are represented and the working fluid used, such as supercritical CO2 (Zhou,2022), which has longer service lifespans and higher heat generation rates than water. While other parameters like thermal conductivity and injection temperature have less impact, matrix permeability and injection flow rate are critical to the heat generation performance of EGS geothermal reservoirs (Haitao Wang et al. 2022).

5. Tectonic & Geological Settings

Sandstone, siltstone, shales, and claystone beds alternate, punctuated from time to time by conglomerate bands of differing thickness, indicating the Neogene sedimentary sequence that was penetrated in the Bangladeshi portion of the Bengal Basin. Here, the cap rock will serve as argillaceous beds to stop the loss of geothermal heat from the sandy reservoir beds, and the reservoir rocks are arenaceous sediments with porosity ranging from 12 to 30 percent with acceptable permeability (Bhuiyan et al. 2024).

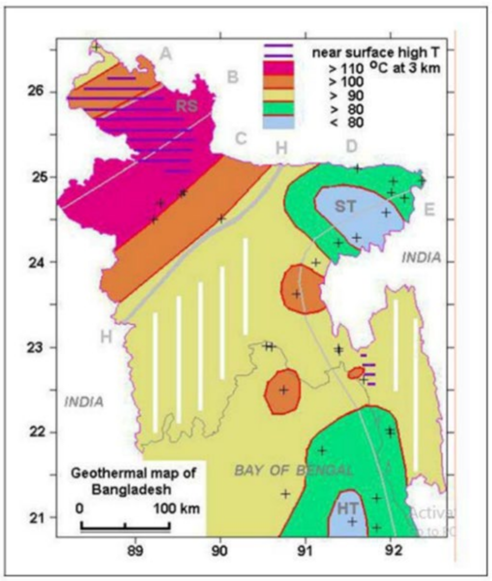


Figure 7. Geothermal Map of Bangladesh

The majority of Bangladesh is made up of flat alluvial flood/delta plains, except the Eastern Folded Belt, which is morphologically represented by a series of parallel sub-meridional hill ranges and valleys formed by anticlines and synclines in the eastern part. These plains are formed by the sediments carried by the mighty rivers Ganges (Padma), Brahmaputra (Jamuna), and Meghna, as well as their numerous tributaries and distributaries, which annually transport over 2.5 billion tons of sediments to the Bay of Bengal ("Abandoned on-shore deep wells : a potential for geothermal energy resource for rural Bangladesh," 2005). The basement dips fairly gently (2 to 3 degrees) along the Bogra Slope towards the southeast, as sequence stratigraphy on the Eocene Sylhet/Bogra Limestone surface shows. This dips steeper (15 to 30 degrees) near the Hinge Zone (Guha, 1978) (Nayem 2019). The local environmental factors directly impact continental hot springs' microbial function and composition. For instance, communities supported by light energy (i.e., photosynthetic) are restricted to temperatures <73°C10 in circumneutral to alkaline hot springs in Yellowstone National Park (YNP), USA, but <57°C in acidic and high-sulfur environments. Beyond these temperature thresholds, chemical energy produced by breaking down disequilibrium in readily available oxidants and reductants sustains life (Boyd, Fecteau, Havig, Shock, & Peters, 2012; Brock, 1967; Colman et al. 2019; Colman et al. 2019; "Frontiers in Microbiology," ; Shock et al. 2010).

The known magmatic-hydrothermal systems connected to active arc volcanoes are not directly linked to the springs under investigation in this work. The subduction zone geometry in this area controls the mantle-to-surface flux of volatiles, according to previous research employing hot spring helium and carbon isotope geochemistry (Hiett, Newell, & Jessup, 2021; Hiett et al. 2022). Localized little negative gravity anomalies make it clear that Permian Gondwana coal deposits (sub-bituminous) are found in the shallow fractured basement grabens at several locations, including

Barapukuri, Khalashpir, Phulbari, Dighirpar, etc. (Petrobangla, 1977). The initial pair of underground coal mines, Barapukuria (coal) and Madhyapara (hard rock) are encountering unanticipated issues related to flooding caused by water, particularly in Barapukuria, which has caused delays in meeting their aim for several years. Even though the 300 MW thermal power plant infrastructure at the Barapukuria mine head has already been completed, its future is now unknown (Hasan, 2013).

6. Geothermal energy in climate change

Geothermal energy has much to offer the environment, especially in lowering carbon emissions and improving energy sustainability. Compared to other renewable sources, the life cycle analysis shows a favorable ecological profile with a lower environmental effect per kilowatt-hour generated (Basosi et al. 2020). About 20% of the energy in the United States comes from geothermal energy, which may drastically reduce carbon footprints by replacing fossil fuels in heating applications. The technology is a dependable alternative to intermittent renewable sources like solar and wind since it can supply baseload energy (Tester et al. 2021). Geothermal installations exert environmental consequences, including land utilization and potential induced seismicity, which can be alleviated through careful planning and monitoring (Ozcelik 2022). Efficient models for assessing geothermal impacts indicate that the technology can substantially alleviate climate change effects, aligning with established life cycle assessments (Paulillo et al. 2022). Geothermal energy might help the shift to a low-carbon economy by producing up to 150 GWe of sustainable energy by 2050 (Jolie et al. 2021). To safeguard the community, geothermal power plant (GPP) installation may have negative environmental effects, such as altered land use, air pollution, and induced seismicity, which need to be managed (Buijze et al. 2020; Ozcelik, 2022).

Optimized models for assessing environmental impacts indicate that geothermal energy has a lower carbon footprint than fossil fuels, making it a viable option for decarbonization (Paulillo et al. 2022). A study indicated that a shift to renewable energy, including geothermal sources, can yield a 0.5% decrease in CO_2 emissions for every percentage point rise in renewable energy usage (Y. Huang et al. 2021). Geothermal fluids may contain heavy metals such as arsenic (As), boron (B), and lead (Pb). Inadequate management of these elements may lead to their release into the environment. At the Cerro Prieto geothermal facility, these metals are in the geothermal fluids, either reinjected or channeled to evaporation ponds. To avoid contaminating the air and soil, effective soil management and reinjection techniques are essential (Ramos et al. 2021). Non-condensable gases like carbon dioxide (CO_2) and hydrogen sulfide (H_2S) may be released by geothermal plants, particularly those that use high enthalpy resources. To drastically cut these emissions, creative plant designs with integrated flash-binary technology have been created.

These systems achieve H2S and CO_2 reduction efficiencies of up to 99% and 90%, respectively, by reinjecting non-condensable gases into the reservoir, thereby alleviating air pollution (Manente et al. 2019). Geothermal heat pump systems effectively reduce low-emission pollutants in specific areas, such as health resorts. These systems can reduce dust and other pollutant emissions by up to 99% compared to traditional coal-fired systems, illustrating geothermal energy's ability to alleviate air pollution in sensitive environments (Sayegh et al.2019). Advanced geothermal systems, such as Organic Rankine Cycles (ORCs) and poly-generation designs, aim for zero emissions. With little harm to the environment, these systems generate energy, cooling, hydrogen, and desalinated water. By integrating these systems, air pollution may be greatly decreased, supporting the objectives of sustainable energy (Afshari et al. 2022; Bahrami & Rosen 2024). Although geothermal energy is typically thought of as being ecologically friendly, improper management might have negative consequences. Inappropriate use may lead to chemical contamination, ground subsidence, and temperature effects, as demonstrated in the Seferihisar geothermal system in Türkiye (Alacali 2024).

Effective land use monitoring, incorporating machine learning techniques like Support Vector Machine (SVM) and Random Forest (RF), can improve sustainable water management in geothermal fields. It is crucial for harmonizing renewable energy production with environmental preservation (Utama et al. 2024). The efficiency and sustainability of geothermal power plants may be greatly increased by integrating cutting-edge technology, such as the innovative multi-generation geothermal cycle that uses LNG cold energy recovery. This method shows the possibility for optimal land use in geothermal projects by increasing net production power and economic and environmental efficiency (Mardan Dezfouli et al. 2024). Ambient noise tomography techniques have been employed in geothermal regions like the Los Humeros geothermal field in Mexico to monitor subsurface phenomena while reducing further noise pollution. This method employs existing ambient noise to mitigate the auditory effects of geothermal activity (Martins, Obermann, Verdel, & Jousset). Geothermal energy systems, particularly those employing Geothermal Heat Pumps (GHP), demonstrate a reduced visual impact compared to renewable energy sources like wind or solar. Geothermal installations are often underground, reducing their visibility and preserving the aesthetic quality of the landscape (Xu et al. 2022).

The significance of acknowledging public sensitivity to visual changes is shown by research conducted in Great Britain on the visual impact of renewable energy systems. The results of this study, which concentrated on wind energy, highlight the significance of visual effects in the development of renewable energy projects, including geothermal projects (Price et al. 2022). Geothermal power facilities frequently use closed-loop systems, which reduce usage and recycle water. They differ from specific biomass and solar thermal systems because they need much water for processing and cooling. To eliminate the requirement for an external water supply, geothermal systems frequently use water from subterranean reservoirs to continuously refill. Unlike solar photovoltaic and wind energy, which require less water during operation, geothermal energy mainly utilizes water during the initial installation and maintenance phases.

Nevertheless, this application still needs to be improved still needs to be improved for solar thermal and biomass systems, requiring water for cooling and processing (Basosi et al. 2020; K.A.Khan, Uddin, Islam, & Mondol, 2019). Geothermal energy is a feasible alternative to more water-intensive renewable sources in dry places due to its capacity to supply baseload electricity with minimal water use (Tester et al. 2021). Geothermal energy systems have a lower environmental impact because of their localized characteristics, which mitigate the ecological effects of waste disposal and water use [84]. Geothermal energy's low operating water costs increase its viability and put it on par with other renewable energy sources, such as the sometimes water-intensive hydroelectric power (Ebadollahi, Seyedmati, Rostamzadeh, Ghaebi, & Amidpour, 2020). The immense and constantly replenishing heat found inside the Earth is the source of geothermal energy. In contrast to renewable resources that rely on erratic natural conditions like wind or sunshine, it is a very sustainable resource. Permeable strata and robust crustal heat flow are two geological features that are essential for effectively locating and using geothermal resources.

Compared to other intermittently problematic renewable sources, these characteristics offer a consistent and reliable energy supply, which is a significant benefit (Jolie et al., 2021). Compared to the national energy portfolio, geothermal power plants have a better environmental profile and have less of an ecological effect. Geothermal energy is adequate and a good alternative to renewable energy sources, even if wind energy has more obvious environmental advantages. Geothermal plants' life cycle study highlights its sustainability benefit by showing a lower environmental effect than fossil fuels (Basosi et al. 2020). Geothermal energy systems may become economically feasible with efficient resource management and equilibrium between extraction and recharge rates. This is a major benefit as it guarantees a longer operating lifespan of 100–300 years in comparison to other renewable sources (Hackstein & Madlener 2021). By providing a variety of outputs, including purified water and power heating, the improvement of multi-generation systems boosts the efficiency of geothermal plants and improves resource utilization and financial returns (Ebadollahi et al. 2020). By offering dependable energy sources and lowering dependency on fossil fuels, the development of geothermal energy can improve societal welfare. Acknowledging and mitigating socio-cultural consequences is essential to sustainable growth (Jiang et al. 2017). While geothermal energy offers numerous benefits, it is essential to recognize the potential challenges and limitations. Significant initial capital investments and the necessity for site-specific geological conditions may hinder extensive deployment. Strict control is necessary to sustain growth and address environmental effects, such as induced seismicity and land subsidence (Jiang et al. 2017; Zhao et al.2021).

7. Strategic Solutions for Renewable Energy Challenges Especially Geothermal Energy

Geothermal energy development in Bangladesh offers an environmentally friendly way to minimize climate change by addressing the critical challenges of renewable energy connectivity, simplifying energy policy, updating energy contracts, and improving infrastructure through grid modernization, energy storage systems, and smart grid deployment. Financial support from foreign direct investment and green money can contribute to the growth of geothermal energy during climate change by diversifying the energy mix and increasing adaptation strategies. Ensuring sustainability through life assessment and compliance with sustainability standards will strengthen the energy sector in the long term and benefit the country’s power needs. The Bangladeshi government's efforts focus on the Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy). Figure 7 illustrates the following usual topics to cover in a research paper on how Bangladesh may enhance renewable energy development and solve related obstacles:

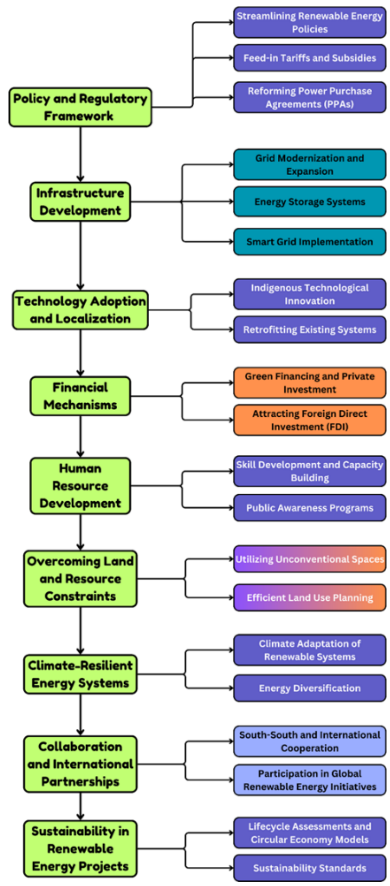


Figure 8. Strategic Solutions

By 2025, 10% of its power generation mix will come from renewable sources. Reducing carbon emissions, guaranteeing energy security, increasing solar and wind power, and providing electricity to rural regions are all crucial strategies to meet SDG 13 (Climate Action).

8. Conclusion

As a competitive alternative to fossil fuels, geothermal energy presents an excellent opportunity to combat climate change because of its sustainability and reliability. Despite the high initial costs, its reduced environmental impact makes it an excellent option for meeting long-term energy demands. With the country's favorable geological conditions, particularly in the Bengal Basin and Chittagong Hill Tracts, advanced geothermal technologies can harness this potential. The study identifies several important findings, including the following: geothermal energy uses subterranean heat to generate power continuously, needs to be managed carefully to minimize environmental effects, lessens reliance on fossil fuels, provides base-load energy production potential, and emits fewer carbon emissions than other renewable energy sources. By investing in geothermal development, Bangladesh can reduce carbon emissions, enhance energy security, and support its transition to a low-carbon economy.

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Biographies

Md. Mamun
Md. Mamun, a Mechanical Engineering graduate from DUET, Gazipur, focuses on renewable energy, materials science, and sustainable technologies. He has contributed to international conferences and publications on geothermal energy, biogas, and advanced air conditioning systems.

Dr. Nayeem Md. Lutful Huq
Dr. Nayeem Md. Lutful Huq is a professor of Mechanical Engineering at DUET, Gazipur. He is an expert in renewable energy, advanced materials, and sustainable engineering. He has supervised numerous research projects and is key in promoting innovative energy technologies in Bangladesh.

Md. Ubaidur Rahman
Md. Ubaidur Rahman is an Electrical & Electronics Engineering researcher at DUET, Gazipur, specializing in innovative grid technologies, renewable energy integration, and sustainable electrical systems.

Md. Zakir Hossain
Md. Zakir Hossain is a graduate of the Department of Mechanical Engineering at DUET, Gazipur. He is passionate about renewable energy and mechanical systems, focusing on geothermal energy and energy efficiency.

Md. Rakib Hossain
Md. Rakib Hossain is affiliated with the Department of Materials & Metallurgical Engineering at DUET, Gazipur. His research interests include advanced materials, sustainable energy technologies, and the development of innovative energy storage systems.

Shuvo Chandra Das
Shuvo Chandra Das is a graduate of the Department of Mechanical Engineering at DUET, Gazipur. His research interests include thermal engineering, renewable energy technologies, and sustainable design.

Minhaz Hossain
Minhaz Hossain is a graduate of the Department of Mechanical Engineering at DUET, Gazipur. He specializes in mechanical systems and renewable energy applications, with a focus on geothermal energy development and climate change mitigation.