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Original Article

Prospects, Challenges, Implementation Strategies, and General Outlook for Geothermal Energy Application in Nigeria

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ABSTRACT: *Nigeria's national development depends on energy security and sustainability because of the nation's expanding industrial base, growing population, and ongoing electricity shortages. The Earth's interior heat can be used to generate geothermal energy, a renewable resource that is yet mostly unexplored but has the potential to produce consistent, dependable, and eco-friendly power. Nigeria's Benue Trough, Sokoto Basin, Niger Delta, and portions of the basement complex all have geothermal potential, as shown by high geothermal gradients, increased heat flow, and surface manifestations such as the hot springs at Ikogosi, Wikki, and Nasarawa. Despite these signs, Nigeria's geothermal development is still restricted because of a lack of specific legal frameworks, high initial investment costs, poor institutional frameworks, a lack of geo-scientific exploration data, and a lack of public awareness. It will require a comprehensive and thorough evaluation of geothermal resources, capacity building, risk mitigation techniques, supportive regulatory frameworks, and stakeholder engagement to overcome these obstacles. Nigeria might increase energy security, diversify its energy sources, improve electricity reliability, lower greenhouse gas emissions, and promote industrial and rural development if geothermal energy is fully adapted into the country's energy mix. As a sustainable and workable solution to Nigeria's energy problems, this discussion paper emphasizes the strategic significance of geothermal energy and calls for systematic research, policy prioritization, and investment to realize its full potential. Thus, this paper examines the prospects, challenges, implementation strategies, and general outlook for geothermal energy application in Nigeria.*

KEYWORDS: *Nigeria's energy mix adaptations, Sustainability, SDG goals 9 and 13, Geothermal energy, Green energy, Associated issues.*

1. INTRODUCTION

National development is heavily reliant on energy security and sustainability, especially in countries like Nigeria that are expanding rapidly. In addition to intermittent sources like solar and wind, geothermal energy, which is produced from the Earth's interior heat, is a mostly unexplored renewable energy source that can produce consistent and dependable heat and electricity (Abubakar, 2024; Nwankwo, 2021). Geothermal energy accounts for a significant portion of global renewable energy generation. Countries such as Iceland and Kenya utilize geothermal resources to deliver a substantive portion of their electricity needs, highlighting the potential and benefits of its use in geologically suitable locations. Yet the largest economy in Africa, Nigeria, is still grappling with critical energy shortfalls encapsulated by grid inadequacies, persistent power blackouts, and overwhelming dependence on fossil fuels, especially natural gas, which accounted for over 70 percent of generated electricity (Abubakar, 2024; Reuters, 2026). As a consequence of these challenges, millions of Nigerians live without reliable electricity, and greenhouse gas emissions from gas and diesel generators have intensified environmental impacts. In response, the Nigerian government and energy stakeholders have emphasized a transition to sustainable energy sources as part of broader climate commitments (such as net zero greenhouse gas emissions by 2060) while also meeting renewable energy targets set in the National Renewable Energy and Energy Efficiency Policy (NREEEP). In this regard, geothermal energy is a promising but understudied alternative.

Geothermal resources available in parts of Nigeria for direct use or power generation – new research and preliminary geophysical analysis. Aeromagnetic studies show regions of high heat flow and significant geothermal gradients in sedimentary basins such as the Upper Benue Trough and northeastern parts of the Niger Delta. The results suggest that sub-surface factors are appropriate for geothermal exploration and development if validated by comprehensive exploration and subsurface drilling (Mohammed et al., 2019; Nwankwo, 2021). In addition, innovative studies indicate the utilization of Nigeria's Niger Delta gas and oil wells, which have been deserted for geothermal heat extraction that can reduce exploration cost whilst still tapping into pre-existing infrastructure to facilitate energy transition efforts (Usuolori et al., 2025). Remote sensing techniques have also been used in North-Eastern Nigeria to identify new geothermal prospective areas, suggesting the need for field work and exploration (Kehinde et al., 2025). However, despite such encouraging signs, the development of geothermal energy in Nigeria is still hindered by an absence of specific policy frameworks, insufficient exploration data, inadequate institutional coordination, and a lack of financial incentives to attract investors (Abubakar, 2024; Ajia, 2025). Despite the potential for geothermal energy as recognized by renewable energy policy, the realization of construction and commercialization on a larger scale has been impeded by governance issues, regulatory barriers, and technological inadequacy (Ajia, 2025). Such limits underscore the need for comprehensive national approaches that encompass geothermal within Nigeria's energy agenda but also strengthen institutional support as well as provide finances for systematic quests and development. This paper seeks to, therefore, exhaustively interrogate the prospects, challenges, implementation strategies, and the general outlook for geothermal energy application in Nigeria. This work would serve as a documented resource to meet the interests of policymakers and the government, as well as other interested parties.

2. ORIGIN AND APPLICABILITY OF GEOTHERMAL ENERGY IN NIGERIA

The Precambrian Basement Complex, sedimentary basins such as the Niger Delta and Benue Trough, and a few isolated volcanic formations make up Nigeria's geology. Various geological conditions govern the geothermal gradient and the potential of a country for exploitable geothermal energy. There are also thermal manifestations, such as hot springs, on the Jos Plateau, Nasarawa, and Bauchi, which evidence shallow geothermal systems and geothermal activity. According to fjs. fudutsinma. edu. (2022), this means that some areas in Nigeria would be suitable for geothermal energy. Geophysical studies have also shown large variations in geothermal gradients as well as heat transport within the Nigerian terrain. In certain areas of the Benue Trough, which exceed 35 °C/km in geothermal gradient, there is a high geothermal potential. In all other regions, the gradients are lower, and Curie Point Depths are deeper, which may restrict immediate exploitation (rans. nsps. org. ng, 2021).

Geothermal energy is applicable both for direct-use applications and for the generation or production of electricity. Geothermal resources may provide power plants in high-gradient areas with constant base load electricity for the sectors, both commercial, industrial, and residential, becoming a reliable replacement for renewable energy sources that can be intermittent and save the dependence on fossil fuels (rans. nsps. org. ng, 2021). Although geothermal energy can also be employed in direct application, such as greenhouse heating, soil warming, home and space heating, aquaculture, food drying, and industrial thermal needs (jpt. spe. org, 2022). In Nigeria, repurposing defunct oil and gas wells is an inspired alternative. They could still have remained underground, where there is still underground heat that can help power a facility, or heat an industrial plant, making them very viable and cost-efficient energy (Tayo, 2025). The development of geothermal energy also has significant financial and ecological benefits. It produces lower greenhouse gas emissions, reduces dependence on fossil fuels, increases the reliability of electricity, promotes long-term energy security, and creates jobs in its operation, maintenance, and construction (jpt. spe. org, 2022).

2.1. ADVANTAGES AND DISADVANTAGES OF GEOTHERMAL ENERGY

In the global search for low-carbon and sustainable energy solutions, geothermal energy, which is produced from the heat stored beneath the Earth's surface, has become a promising alternative energy source. Geothermal energy, in contrast to traditional fossil fuels, uses the Earth's inner heat to generate electricity and provide direct heating. Geothermal energy has a lot of potential, but it also has some drawbacks that should be carefully considered, particularly in developing nations like Nigeria.

2.1.1. ADVANTAGES OF GEOTHERMAL ENERGY

Renewable and Sustainable Energy Source: Due to the Earth's intrinsic radioactive decay and residual heat from formation, geothermal energy is naturally renewable. While fossil fuels are finite resources that will deplete over time, such as coal, oil, and natural gas (Lund & Toth, 2020), geothermal reservoirs can provide a sustainable source of energy that does not run out if properly managed. Geothermal energy is crucial to meeting long-term energy needs without degrading the environment because of its sustainability.

Low Carbon Emissions and Environmentally Friendly: Little greenhouse gas is generated by geothermal power plants. Geothermal plants emit significantly lower levels of carbon dioxide, methane, and nitrous oxide compared to coal and natural gas (IEA, 2021). This feature makes geothermal energy an attractive solution to tackle climate change and achieve low-carbon development goals. Modern geothermal facilities incorporate reinjection systems that return extracted fluids to the reservoir to further reduce their environmental impact.

Dependable Base-Load Energy Generation: Geothermal energy, or so-called base-load power, provides a constant and reliable source of energy as compared to solar or wind resources that are intermittent and dependent on weather (Hochstein 2018). This reliability provides a continuous supply of power for residential, commercial, and industrial applications, especially in regions with fluctuating energy demand.

Small Land Footprint: Compared to other renewable energy sources like solar or hydroelectric power, geothermal energy infrastructure needs comparatively less land. This compact geographical footprint permits dual land use, such as forestry or agriculture, in addition to energy generation, minimizing ecological disturbance and land-use conflicts (Barbier, 2002).

Energy Security and Utilization of Domestic Resources: By utilizing their own geothermal potential, nations can lessen their reliance on imported fuels, whose availability and price are frequently subject to fluctuations. Geothermal energy could be a locally accessible, dependable energy source for Nigeria, since the country's electrical supply is erratic and mostly reliant on fossil fuels, enhancing national energy security.

Direct Use Applications Outside of Electricity: Due to its adaptability, geothermal energy may be utilized directly for heating in a variety of settings, such as greenhouses, aquaculture, industrial processes, spa resorts, and spaces. In addition to having positive effects on the environment, these direct applications are energy-efficient and less dependent on fossil fuels or electricity (Lund & Toth, 2020).

2.1.2. DISADVANTAGES OF GEOTHERMAL ENERGY

High Initial Capital and Development Costs: The high initial costs associated with exploration, drilling, and plant construction are one of the main drawbacks of geothermal energy. Finding promising geothermal resources necessitates deep drilling and sophisticated geophysical surveys, both of which are costly and technically demanding (DiPippo, 2016). For underdeveloped nations like Nigeria that have limited financial resources, these hefty upfront costs might be a major obstacle.

Site-Specific Restrictions: Geological conditions have a significant impact on geothermal energy. Tectonically active regions, volcanic zones, or areas with substantial heat flow close to the Earth's surface are typically suitable locations (Barbier, 2002). Compared to solar or wind power, which may be built in a number of sites, geothermal energy is less versatile due to its site specificity, which restricts its widespread deployment.

The Sustainability and Reservoir Depletion Risk Concerns: Over time, improper management of geothermal reservoirs may result in a drop in reservoir temperature and pressure, which would lower energy output. In order to sustain long-term output, sustainable practices like the reinjection of geothermal fluids are crucial. Even renewable geothermal systems may experience transitory depletion if they are not managed carefully (Hochstein, 2018).

Environmental Issues and Gas Emissions: While geothermal energy emits significantly fewer greenhouse gases than fossil fuels, geothermal operations may release certain emissions, such as hydrogen sulfide (H_2S). Furthermore, trace levels of hazardous substances, including arsenic, mercury, and boron, may be present in geothermal fluids; these must be handled carefully to avoid contaminating the soil and water (DiPippo, 2016).

Induced Seismicity: This phenomenon refers to the ability of geothermal activities, especially improved geothermal systems that incorporate fluid injection, to cause small earthquakes. Despite the fact that these earthquakes are usually minor, they raise questions about the safety of communities in the vicinity and necessitate close observation and risk assessment (USGS, 2020).

Technical Difficulties: High mineral concentrations in geothermal fluids can lead to corrosion and scaling in turbines, pipes, and other machinery. These technological difficulties can shorten the operating lifespan of geothermal facilities, raise maintenance costs, and decrease efficiency (Lund & Toth, 2020).

Limited People Awareness and Acceptance: Policymakers and the general people in many developing nations lack a thorough understanding of geothermal energy. The adoption and growth of geothermal projects may be slowed by a lack of knowledge, high upfront costs, and perceived hazards.

3. GEOTHERMAL ENERGY ZONES OF NIGERIA

3.1. SURFACE GEOTHERMAL MANIFESTATIONS IN NIGERIA

3.1.1. IKOGOSI WARM SPRING (SOUTH-WEST NIGERIA)

The most notable geothermal surface manifestation in Nigeria is the Ikogosi Warm Spring, which is situated at the border of Ekiti and Ondo States. The spring is thought to be the result of deep groundwater circulation along fault zones and releases warm water via fractured foundation rocks. Ikogosi is a recognized geothermal resource location. According to geological studies, the thermal anomaly there is related to structural controls within the basement complex (Babalola, 1984; Ojo et al., 2011). A portion of the Ikogosi warm spring's surface manifestation in Nigeria's Ekiti State is depicted in Figure 1.

3.1.2. WIKKI WARM SPRING (NORTH-EAST NIGERIA)

Wikki Warm Spring, with warm water and continuous outflows, is located in Bauchi State within the Upper Benue Trough. Recent geophysical studies indicate that the spring is associated with the deepening of geothermal sources related to tectonic activity in the Benue Trough, as suggested by shallow Curie point depths and relatively high heat flow of that region (Nwankwo et al., 2011; Anakwuba et al., 2016). Figure 2 shows the surface expression of part of the Wikki Warm Spring in Nigeria's Bauchi State.

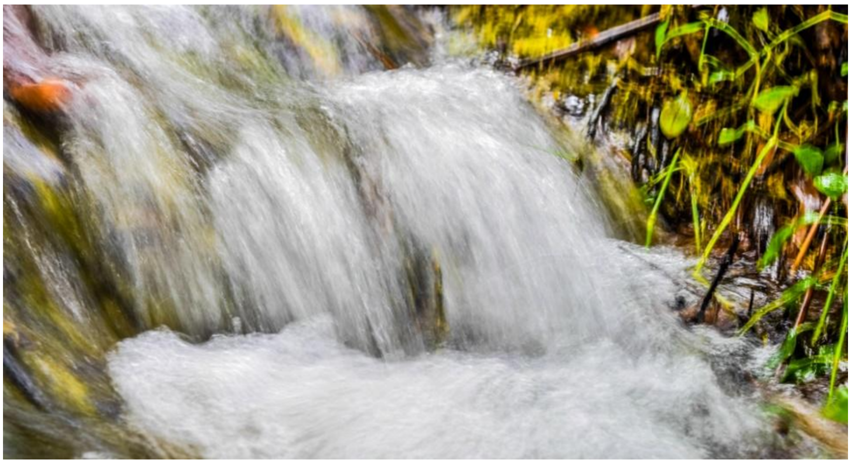

FIGURE 1 A plate showing a part of the Ikogosi warm spring in Ekiti State, Nigeria

FIGURE 2 A plate showing tourists enjoying the warmth of the Wikki warm spring situated in Bauchi State, Nigeria.

3.1.3. OTHER WARM AND THERMAL SPRINGS

The Nike Lake thermal anomaly, the Lamurde (Ruwan Zafi) Warm Spring in Adamawa State, the Keana-Awe thermal springs in Nasarawa State, and the Rafin Rewa Warm Spring are other examples of geothermal manifestations in Nigeria. Despite their limited research, these locations lend support to the notion that geothermal anomalies are common in Nigeria's basement and sedimentary terrains (Bello et al., 2017).

3.2. SUBSURFACE GEOTHERMAL ZONES IDENTIFIED THROUGH GEOPHYSICAL STUDIES

The Benue Trough: One of Nigeria's most important geothermal provinces is the Benue Trough. In portions of the Upper and Middle Benue Trough, aeromagnetic spectral analysis has revealed higher heat flow values, significant geothermal gradients, and shallow Curie point depths. These traits point to anomalous thermal regimes that are advantageous for the development of geothermal energy, especially for applications with low to medium enthalpies (Nwankwo & Ekine, 2009; Anakwuba et al., 2016).

The Sokoto Basin: One of the main geothermal anomaly zones in North-Western Nigeria is the Sokoto Basin. According to studies, deep tectonic features and crustal thinning are responsible for geothermal gradients and heat flow levels that are much higher than the norm for the entire continent. According to these thermal parameters, one of Nigeria's most promising areas for geothermal development is the Sokoto Basin (Nwankwo et al., 2011; Bello et al., 2017).

The Niger Delta Basin: Although it is best recognized for its hydrocarbon buildup, the Niger Delta Basin also has geothermal potential. High subsurface temperatures are caused by the basin's thick sedimentary cover, which acts as an insulating layer. Geothermal fluids appropriate for the combined exploitation of geothermal and hydrocarbon energy may be found in geopressured strata within the basin (Obaje, 2009; Aigbogun et al., 2018).

The Bida Basin in Central Nigeria: Geothermal gradients and modest Curie point depths are found in the Bida Basin, according to geophysical studies. Despite having less geothermal potential than the Sokoto Basin and Benue Trough, the area might be able to accommodate low-temperature geothermal uses such as drying, agricultural processing, and space heating (Bello et al., 2017).

South-West and South-South Basement Complex Areas: Moderate geothermal anomalies linked to basement faults and cracks have been observed in portions of the states of Ondo, Ekiti, Edo, Osun, Kogi, and Delta. If further research is conducted, these regions may be suitable for small-scale geothermal or direct-use applications due to localized increases in heat flow (Ojo et al., 2011; Anakwuba et al., 2016). Nigeria's geothermal energy zones are depicted in Figure 3 along with the locations of the country's various basins and basement complexes.

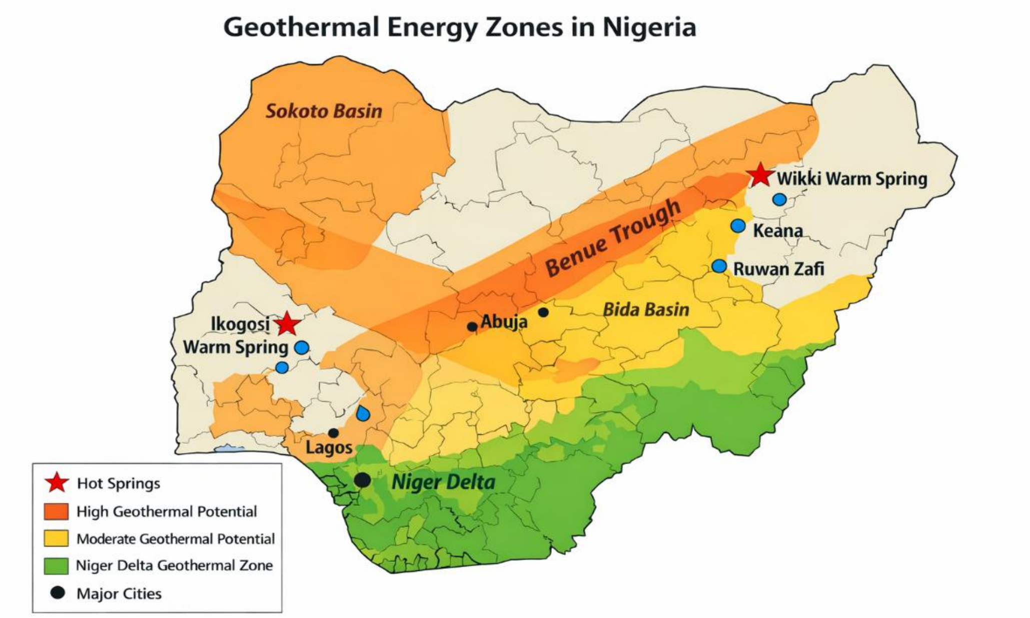

FIGURE 3 The geothermal energy zones of Nigeria in relation to the geographical positioning of the different sedimentary basins and basement complexes within Nigeria

4. CHALLENGES MILITATING AGAINST GEOTHERMAL ENERGY APPLICATION AND ADAPTATION IN NIGERIA

4.1. INADEQUATE GEOTHERMAL RESOURCE DATA

The absence of comprehensive and reliable geothermal resource data is one of the main issues. The majority of Nigeria's subsurface temperature and heat-flow data comes from oil and gas exploration operations, which aren't made with geothermal assessment in mind. Investment risk is raised by the lack of specialized geothermal drilling, magnetotelluric surveys, and temperature gradient wells, which raise uncertainty about reservoir depth, temperature, and sustainability (Nwankwo & Ekine, 2009; Bello et al., 2017).

4.2. EXPENSIVE DRILLING AND DISCOVERY

Developing geothermal energy requires significant investment, especially in the discovery and drilling phases. The majority of the specialized tools and technology needed to drill deep wells in order to reach geothermal resources must be imported into Nigeria. Both the public and private sectors are deterred from investing in geothermal projects by these high upfront costs and the possibility of drilling unproductive wells (Obaje, 2009).

4.3. LOW HUMAN CAPACITY AND TECHNICAL EXPERTISE

Nigeria's indigenous knowledge of geothermal science and engineering is somewhat low. Specialized expertise in reservoir engineering, geothermal drilling, and power plant design is needed for the development and operation of geothermal systems. The lack of qualified workers hinders the transfer of technology and skills to local professionals, increases reliance on foreign specialists, and raises project costs.

4.4. LACK OF A DEDICATED POLICY AND REGULATORY FRAMEWORK

The absence of a precise and well-defined policy framework for geothermal energy in Nigeria is another significant obstacle. Geothermal resources receive little to no attention in current renewable energy plans, which place greater emphasis on solar, wind, and hydropower. Investor confidence is lowered, and sectoral expansion is constrained by the lack of geothermal-specific laws, incentives, feed-in tariffs, and licensing processes (Obaje, 2009; Federal Ministry of Power, 2015).

4.5. WEAK INSTITUTIONAL AND GOVERNANCE STRUCTURES

Geothermal growth is further hampered by institutional inefficiencies such as inconsistent regulatory enforcement, bureaucratic bottlenecks, and inadequate coordination among government agencies. Disjointed duties between environmental and energy organizations frequently cause delays in project approval and execution, which raises doubts among possible investors (Bello et al., 2017).

4.6. INADEQUATE ENERGY INFRASTRUCTURE

In Nigeria, a large number of geothermal opportunities have been found in isolated or rural locations with poor access to transmission lines, roads, and grid infrastructure. The poor condition of the national electrical system also hinders the integration of additional power generation sources. According to Nwankwo et al. (2011), these infrastructure issues significantly increase development costs and reduce the commercial viability of geothermal projects.

4.7. LIMITED FINANCING AND INVESTMENT RISKS

Although geothermal projects need a significant amount of long-term funding, Nigerians have limited access to reasonably priced credit. Because geothermal projects have long payback periods, substantial exploration risks, and no government-backed risk-sharing arrangements, financial institutions are frequently hesitant to support them. As a result, geothermal energy is seen as a riskier investment than other renewable energy sources.

4.8. LOW STAKEHOLDER ENGAGEMENT AND PUBLIC AWARENESS

In Nigeria, there is still a lack of knowledge and comprehension regarding geothermal energy. The advantages of geothermal technology are not well known to many local populations, investors, and governments. This ignorance may hamper project development by leading to poor community engagement, insufficient advocacy, and a lack of political will (Bello et al., 2017).

4.9. COMPETITION FROM CONVENTIONAL AND OTHER RENEWABLE ENERGY SOURCES

Fossil fuels, especially natural gas, which have the advantages of established infrastructure and regulatory support, dominate Nigeria's energy market. Furthermore, because of its simple implementation and reduced start-up costs, solar energy has attracted significant interest. Interest in developing geothermal energy is diminished by fierce competition from conventional and alternative renewable energy sources (Federal Ministry of Power, 2015).

5. STRATEGIES FOR OVERCOMING THE CHALLENGES OF GEOTHERMAL ENERGY DEVELOPMENT IN NIGERIA

Nigeria has observable geothermal resources; however, the development of geothermal energy has been hampered by several obstacles. Coordination of technical, institutional, financial, and policy-driven measures is necessary to overcome these obstacles. The main obstacles preventing the development of geothermal energy in Nigeria are discussed in this section along with workable, fact-based solutions (Obaje, 2009; Bello et al., 2017).

5.1. COMPREHENSIVE GEOTHERMAL RESOURCE ASSESSMENT

Nigeria has to make investments in methodical geothermal exploration and assessment programs in order to tackle the issue of insufficient data. This includes conducting extensive heat-flow studies, magnetotelluric surveys, temperature-gradient drilling, and seismic investigations in geothermal zones such as the Benue Trough, Sokoto Basin, and Bauchi State. A national geothermal database will support evidence-based decision-making, boost investor confidence, and reduce uncertainty (Nwankwo & Ekine, 2009; Bello et al., 2017).

5.2. CAPACITY BUILDING AND TECHNICAL EXPERTISE DEVELOPMENT

Building up domestic technical capability is crucial to the growth of geothermal energy in a sustainable manner. This can be accomplished by:

i) Training courses focused on geothermal science and engineering.
ii) Geothermal studies are being incorporated into university curricula.
iii) International collaborations and programs for information sharing with nations having geothermal development expertise.

Developing local knowledge will reduce long-term project expenses and dependency on outside consultants (Obaje, 2009).

5.3. REDUCTION OF EXPLORATION AND DRILLING RISKS

Government-led risk-sharing programs can help reduce the high expense and danger of geothermal drilling. These could include the utilization of subsidies from foreign development organizations, public financing of initial test wells, and insurance programs for exploration risk. These policies can significantly boost private-sector involvement and have been effectively implemented in other geothermal-developing nations (Bello et al., 2017).

5.4. ESTABLISHMENT OF A DEDICATED GEOTHERMAL POLICY AND LEGAL FRAMEWORK

Nigeria's renewable energy system requires a well-defined, precise geothermal energy policy. For geothermal projects, this policy should specify licensing processes, environmental requirements, financial incentives, and operational instructions. Geothermal investments would become more appealing with the implementation of incentives, including import duty waivers, feed-in tariffs, and tax holidays for geothermal equipment (Obaje, 2009; Federal Ministry of Power, 2015).

5.5. FORTIFYING GOVERNANCE AND INSTITUTIONAL FRAMEWORKS

Reducing bureaucratic bottlenecks requires better collaboration among government departments responsible for the environment, energy, and mineral resources. A centralized geothermal development unit or agency would guarantee efficient monitoring and execution of geothermal projects, expedite approvals, and enhance regulatory clarity (Bello et al., 2017).

5.6. ENHANCEMENT OF TRANSPORTATION AND ENERGY INFRASTRUCTURE

It is crucial to address the lack of infrastructure in possible geothermal zones. Enhancing the commercial feasibility of geothermal projects will need investments in transmission lines, access roads, and grid expansion. In remote locations where a grid connection is not immediately possible, off-grid and mini-grid geothermal applications may also be encouraged (Nwankwo et al., 2011).

5.7. IMPROVED AVAILABILITY OF FUNDING AND INVESTMENT ASSISTANCE

The government should make low-interest loans, green financing options, and international climate funding more accessible in order to address financial difficulties. PPPs, or public-private partnerships, can also be very important for sharing project risks and raising funds. Bankability and investor trust will be further enhanced by long-term power purchase agreements (PPAs) (Obaje, 2009).

5.8. ENGAGEMENT OF STAKEHOLDERS AND PUBLIC AWARENESS

It is crucial to educate local populations, investors, and legislators about geothermal energy. Initiatives for community participation, stakeholder workshops, and public education campaigns can raise awareness of geothermal energy's advantages and increase social acceptance. According to Bello et al. (2017), informed communities are more likely to support geothermal projects and take part in their sustainable management.

5.9. INTEGRATION OF GEOTHERMAL ENERGY INTO NATIONAL ENERGY PLANNING

Nigeria's long-term national energy planning and renewable energy goals ought to incorporate geothermal energy. Long-term energy security and balanced energy diversification can be achieved by acknowledging geothermal energy as a base-load renewable source that complements solar and hydropower (Federal Ministry of Power, 2015).

6. GENERAL OUTLOOK FOR NIGERIA'S ENERGY MIX WITH COMPLETE INTEGRATION AND ADOPTION OF GEOTHERMAL ENERGY

Fossil fuels, especially oil and natural gas, dominate Nigeria's energy sector and provide more than 80% of the country's electricity. Geothermal energy is largely unexplored, while renewable energy sources such as solar and hydropower are still underdeveloped. Full integration of geothermal energy into the national energy mix might increase sustainability, diversify energy sources, and improve electricity reliability (Bello et al., 2017; Obaje, 2009).

6.1. DIVERSIFICATION OF ENERGY SOURCES

Nigeria's reliance on fossil fuels will be lessened by using geothermal energy, lowering the hazards brought on by unstable oil and gas markets. In contrast to intermittent sources like solar or wind, geothermal energy is a base load renewable energy source that produces power continuously. This would enhance current solar and hydropower projects, resulting in a more resilient and balanced energy mix (Nwankwo & Ekine, 2009).

6.2. IMPROVING ENERGY SECURITY

Complete adoption of geothermal energy would enhance energy security by providing a locally accessible, domestic source of electricity and heat. Geothermal reservoirs provide consistent energy year-round, especially in areas such as the Niger Delta, Sokoto, and Bauchi. This lessens the demand for fossil fuel facilities or the importation of electricity. Rural electrification and industrial expansion depend on this dependability (Bello et al., 2017).

6.3. DECREASE IN EMISSIONS OF GREENHOUSE GASES

Compared to traditional thermal power plants, geothermal energy emits fewer greenhouse gases. Geothermal energy integration would help Nigeria meet its climate change mitigation goals and Paris Agreement obligations by drastically lowering CO_2 and methane emissions. Additionally, the environmental advantages would promote sustainable development and enhance public health (Obaje, 2009).

6.4. ENCOURAGEMENT OF INDUSTRIAL AND RURAL DEVELOPMENT

Direct-use uses of geothermal energy could include heating for small-scale industrial operations, aquaculture, and agro-processing. This is especially important in rural areas near geothermal zones, such as Ikogosi in Ekiti and Wikki Warm Spring in Bauchi. These kinds of applications would boost regional industries, reduce post-harvest losses, and open new economic opportunities (Bello et al., 2017).

6.5. PRICE STABILIZATION FOR ELECTRICITY

Widespread use of geothermal energy would help stabilize electricity prices due to its dependable base-load output and low operational costs. Lower production costs would result from reduced reliance on volatile fossil fuel markets, benefiting businesses and people alike and spurring additional investment in Nigeria's energy industry (Nwankwo & Ekine, 2009).

6.6. COMBINING RENEWABLE ENERGY WITH OTHER SOURCES

In order to construct hybrid renewable energy networks, geothermal energy could be combined with solar, hydroelectric, and biomass systems. For instance, solar and wind might provide peak-load capacity, while geothermal could supply base-load electricity. According to Bello et al. (2017), this multi-source integration would increase national energy reliability, optimize resource usage, and stabilize the grid.

7. CONCLUSION

This discussion paper thoroughly addressed the prospects, challenges, implementation strategies, and the general outlook for geothermal energy application in Nigeria. This work now serves as a documented resource to meet the interests of policymakers and the government, as well as other interested parties. It is pertinent to state here that the complete incorporation of geothermal energy into Nigeria's energy mix has the potential to increase national energy security, diversify energy sources, improve electricity reliability, lower greenhouse gas emissions which contributes directly to the attainment of United Nations SDG goal 13 (SDG 13), and promote industrial and rural development which promotes the attainment of United Nations SDG goal 9 (SDG 9).

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