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# Geothermal Energy in Nigeria: Assessing Its Potential and Environmental Impacts for Sustainable Development

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***Abstract***

*This study explores the possibility of using geothermal energy to address Nigeria's electricity generation issues sustainably. Significant potential for high-output power generation from geothermal resources is revealed by analyzing the geological features of the nation. Environmental issues including pollutant emissions and ecosystem damage are explored with the benefits of geothermal energy, such as its small land footprint and dependability. The purpose of the article is to identify possible geothermal energy sources in Nigeria, investigate their uses, and discuss the environmental risks related to geothermal power facilities. This research helps Nigeria and other countries develop a sustainable energy future by providing in-depth analysis and creative solutions.*

**Keywords:** Power plant efficiency, renewable resources, environmental impact, pollution emissions, geothermal energy, Nigeria, electricity generation, sustainable energy, and sustainable development

## INTRODUCTION

Climate change and global warming have emerged as pressing issues requiring mitigation [1]. Renewable energy is being developed to mitigate environmental pollution while supplying the energy required for the ecosystem. There are diverse sources of renewable energy such as geothermal, solar, hydro, and wind energy. Among these clean energy options, geothermal energy stands out because of its utilization of heat from the Earth's core. Nigeria, endowed with abundant natural resources, could potentially benefit from tapping into geothermal energy to address electricity generation challenges. An examination of the country's geological features suggests significant potential for high-output power generation from this untapped resource [2]. Geothermal energy harnesses heat energy from the Earth's crust and is often manifested in naturally occurring geysers, hot springs, and artificial wells [3]. One notable advantage of geothermal energy is its small land footprint and reliability compared with other renewable sources [4]. However, this energy source poses environmental challenges, including the production of pollutants that can adversely affect the surrounding ecosystem.

Therefore, this study aims to delineate potential geothermal energy sites in Nigeria, explore their applications, and address environmental hazards associated with geothermal power plants to foster a sustainable future.

## HISTORY OF GEOTHERMAL ENERGY

The development of geothermal followed successive events outlined below.

### Mechanisms of Geothermal Energy

Earth consists of four layers (Figure 1). These are the crust, mantle, outer core, and inner core [5].

The boundary between the mantle and the Earth's crust reaches a temperature of approximately 4000°C. Geothermal energy is generated by

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converting the thermal energy created inside the Earth's crust (i.e., heat source) and transporting it to the surface as a heat sink by conduction or convection of heat. The heat from the Earth's crust passes through the rock strata and heats underground aquifers [4]. Geothermal reservoirs are bodies of water heated by magma located beneath them [4]. To successfully extract this heated water, specific conditions must be met, including appropriate pH and temperature levels, along with the existence of pathways, such as fractures or faults, which facilitate fluid flow.

To maintain a geothermal reservoir under good conditions, geo-fluid recharge-discharge must be closely monitored. Electricity is generated from a geothermal well once the harvested geothermal fluid is converted into a power plant.

## Types of Geothermal Energy Plants

According to the U.S. Energy Information Administration [6], in 2022, the three basic types of geothermal power plants are:

1. *Dry steam power plants:* Dry steam power plants use steam directly from geothermal reservoirs to power generator turbines. This hot steam was extracted from the ground and channeled directly into the turbines.
2. *Flash steam power plants:* Flash steam power plants extract high-pressure hot water from deep within the Earth and transform it into steam, which then powers the generator turbines. Once the steam cools, it condenses back into water and is reinjected into the ground for reuse (Figure 2).
3. *The binary cycle power plant:* The binary cycle power plant is a type of geothermal power plant that transfers heat from geothermal hot water to a secondary liquid contained in a tank. As hot water flows through a conduit, it heats the secondary liquid, causing it to vaporize. The resulting steam is then used to drive the generator turbine (Figures 3 and 4).

## Geothermal Resources in Nigeria

According to Okolie et al. (2019) [3], the following are possible geothermal hotspots in Nigeria.

- *Volcanoes:* Jos Plateau and Biu Plateau are sites with volcanic records.
- *Hot springs and geysers:* The following are sites with hot springs and geysers in Nigeria.

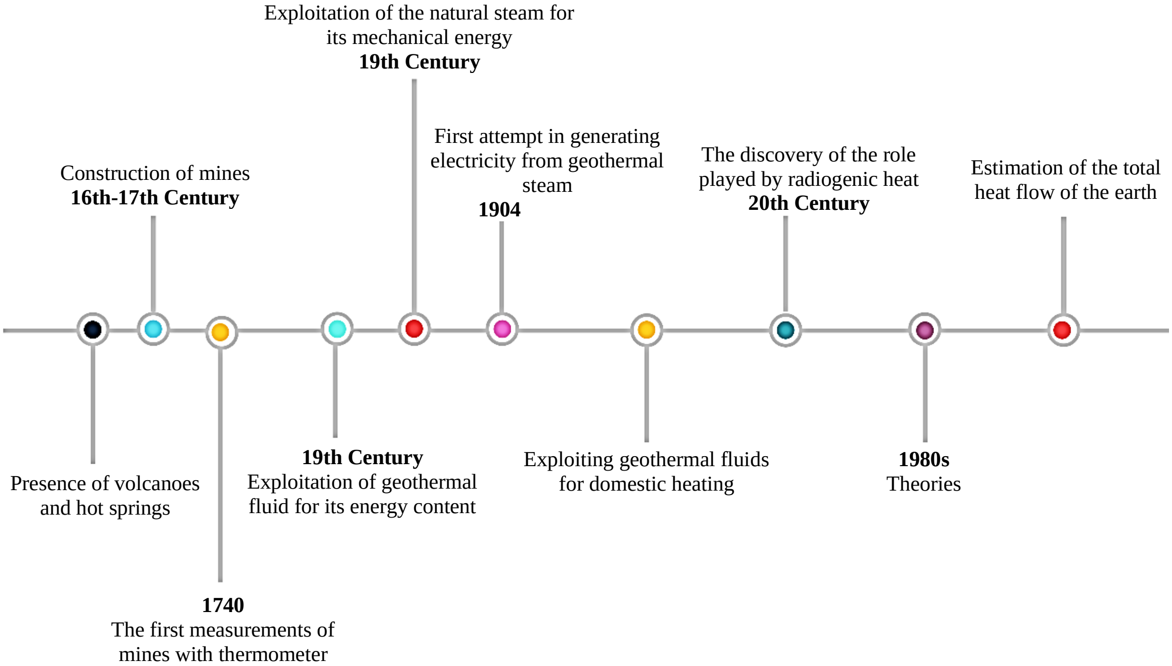


**Figure 1.** Historical timeline for the development of geothermal energy.
*Source: Abstracted from Dickson and Fanelli (2003) [5].*

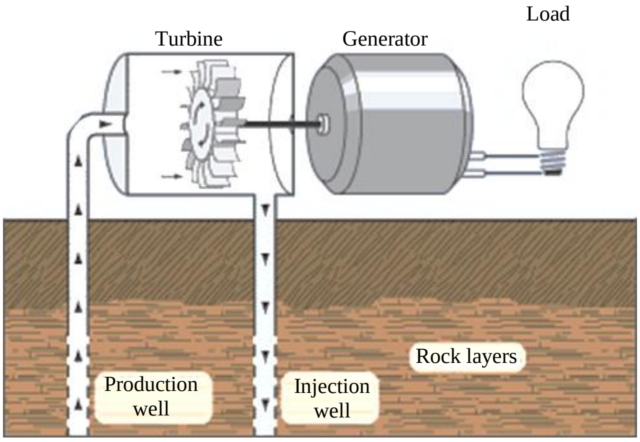


**Figure 2.** Dry steam power plant.
*Source: U.S. Energy Information Administration, 2022.*

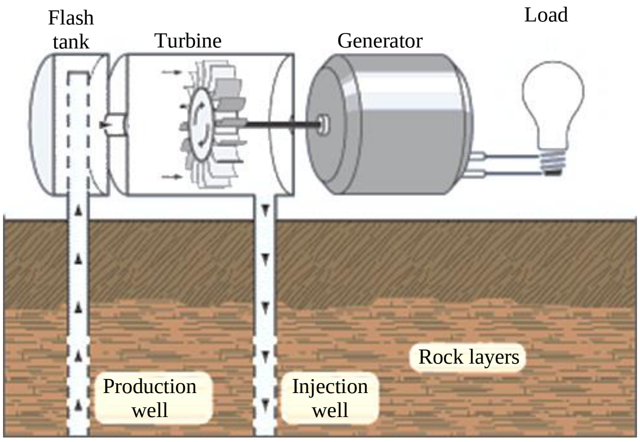


**Figure 3.** Flash steam power plant.
*Source: U.S. Energy Information Administration, 2022.*

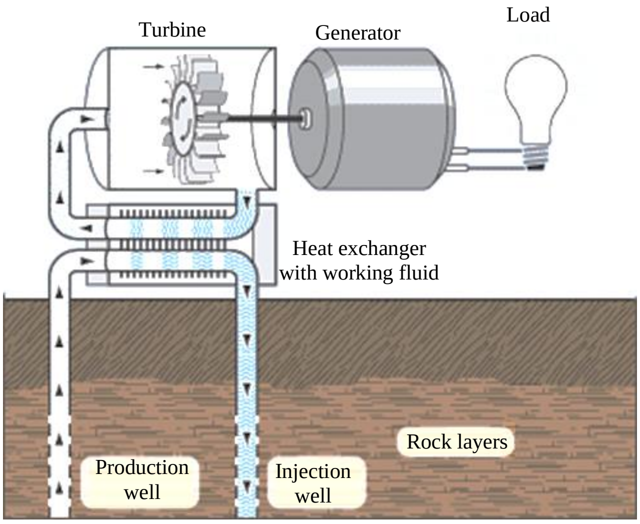


**Figure 4.** Binary cycle power plant.
*Source: U.S. Energy Information Administration, 2022.*

According to Gorthy et al. (2023) [4], one method of finding a potential site for geothermal energy involves collecting samples from surface wells and searching for high helium 3 to helium 4 ratios. A higher ratio suggests the possibility of using a geothermal heat source that might be used to produce electricity (Table 1).

**Applications for Geothermal Energy**

The avenue for utilizing geothermal energy, according to Lund and Toth (2020) [7], includes.

1. Geothermal heat pumps
2. Space heating
3. Greenhouses and covered ground heating
4. Aquaculture pond and raceway heating
5. Agricultural crop drying
6. Industrial process heat
7. Bathing and swimming
8. Snow melting and space cooling
9. Electricity, etc.

## LITERATURE REVIEW

Okoli et al. studied the feasibility, manufacturing process, and consumer distribution of Nigeria's geothermal resources in 2019. Dickson and Fanelli (2003) [5] analyzed the significance, background, and application of geothermal energy. Scion et al. (2011) [8] developed simulations and a model for a typical combined-cycle geothermal power plant to aid in improved optimization. Barbier (2002) [9] investigates the evolution, use, and production processes of geothermal energy and geological landforms. Zira (2013) [10] was used to explore Nigeria's geothermal system and emphasized the use of geophysical methodologies. Compared to other renewable energy sources, Fridleifsson (2001) [11] emphasized the value, applications, and uses of geothermal electricity, as well as its effects on the ecosystem.

**Table 1.** Hot springs and geysers sites in Nigeria.

| Location | State |
|---|---|
| Essie | Kwara State |
| Madalla | Abuja State |
| Ijebu-Ode | Ogun State |
| Akampa | Cross River State |
| Minna | Niger State |
| Lokoja | Kogi State |
| Jos | Plateau State |
| Kwali | Abuja State |
| Onitsha | Anambra State |
| Obudu | Cross River State |
| Bauchi | Bauchi State |
| Enugu | Enugu State |
| Idanre | Ondo State |
| Abaji | Abuja State |
| Jalingo | Taraba State |
| Ijebu-Jesa | Osun State |
| Ikogosi | Ekiti State |
| Ile-Ife | Osun State |
| Gurara | Bauchi State |
| Kabba | Kogi State |

*Source: Okolie et al. (2019) [3].*

Abraham and Nkitnam (2017) studied the energy potential of certain geothermal sites in Nigeria and their geothermal gradients [12]. Lund and Toth (2020) [7] investigated and measured the use of geothermal energy in several nations worldwide. DiPippo (2012) [13] investigated geological landforms, geothermal energy production, and the associated processes. In their study of the effects of geothermal energy on the environment, Gorthy et al. (2023) proposed a solution to the pollution caused by geothermal pollution [4]. Geothermal energy was researched by Sahdarani et al. (2020) as a potential alternative energy source for Indonesia [1].

## METHODOLOGY

Some processes must be undertaken to generate electricity from potential sites. This can be summarized as follows:

1. *Geochemical surveys* including isotopic geochemistry play a crucial role in various aspects of geothermal system analysis. They help determine whether the system is water- or vapor-dominated, estimate minimum depth temperatures, assess water supply uniformity, infer deep fluid chemistry, and pinpoint recharge water sources. These surveys also offer insights into potential challenges during reinjection and plant operation, such as fluid composition changes, corrosion, pipe scaling, and environmental impacts. The process involves sampling and analyzing water and gas from geothermal features, such as hot springs and wells in the study area. Because of their cost-effectiveness compared to more complex methods, such as geophysical surveys, geochemical techniques should be extensively employed before resorting to other costly approaches [14].
2. *Geophysical surveys* aim to indirectly gather the physical parameters of deep geological formations from the surface or shallow depth intervals. Geophysical surveys include thermal surveys, electrical conductivity measurements, seismic surveys, gravity surveys, and magnetic surveys [13]. Although techniques such as seismic, gravity, and magnetics provide valuable insights into potential geothermal reservoir characteristics such as shape, size, and depth, they offer limited information on fluid presence. Geophysical methods are better suited for refining details in the later stages of exploration before drilling exploratory wells. Electrical and electromagnetic prospecting, particularly the magnetotelluric method (MT) and controlled source audiomagnetotelluric method (CSAMT) offer deeper structural insights and are sensitive to the presence of geothermal fluids and temperature changes. Thermal surveys can provide reliable estimates of reservoir temperatures.
3. Drilling exploration wells mark the final phase of geothermal exploration and provide crucial data on reservoir characteristics and potential.

### Negative Environmental Impacts

According to Gorthy et al. (2023) [4], the primary environmental issues with geothermal plants include the following.

1. Surface disturbances
2. The physical effects of fluid withdrawal
3. Noise
4. Thermal effects
5. Chemical pollution
6. Biological effects
7. Disruptions in the preservation of natural features.

However, the activities in geothermal plants may lead to further hazards. This includes.

1. *Drilling:* Drilling is initially required to set up the plant. Drilling can influence nearby species and ecosystems, even if the area utilized for a drill site is usually small, and the terrain might be altered.
2. *Fumaroles:* Fumaroles have the potential to cause additional harm and can occur as a result of the physical effects of fluid withdrawal and surface disturbances.
3. *Hazardous chemicals:* hazardous chemicals such as hydrogen sulfide, arsenic, boron, mercury, lead, cadmium, iron, zinc, manganese, lithium, ammonia, and aluminum, are other chemicals that

make up the liquid fraction of geothermal fluids [4]. These substances are toxic to a variety of plants and animals; therefore, if water seeps into other areas, it could have negative consequences.

4. *Toxic gases:* Gases discharged into the atmosphere during the extraction of geothermal energy are another significant source of pollution. They include.
   - *Carbon (IV) oxide:* One significant environmental impact of geothermal energy generation is the emission of greenhouse gases, particularly carbon dioxide ($CO_2$), into the atmosphere. Because $CO_2$ can absorb energy across a wide range of wavelengths, it is extremely harmful to ecosystems.
   - *Hydrogen sulfide (sulfur dioxide):* Hydrogen sulfide is another harmful waste that is released from geothermal power facilities. Hydrogen sulfide is slightly soluble in water and can create sulfhydric acid, which poses a threat to both humans and the environment. It is corrosive to metals and can intensify the effects of acid deposition in soil and water.

**Solution to Reduce Hydrogen Sulfide Pollution**

According to Gorthy et al. (2023) [4], two primary methods concentrate on eliminating hydrogen sulfide both prior to and during its arrival at the turbine.

1. *First approach:* this involves letting hydrogen sulfide and hot water steam come into contact with copper sulfate, which causes a reaction that produces elemental sulfur.
2. *Second approach:* Using an alkaline solution such as sodium hydroxide is the second method. After steam enters the turbine, hydrogen sulfide can be eliminated in a variety of ways, including off-gas techniques, condensate water techniques, and hybrid systems.
   a. *Condensate water technique:* This method involves using waste steam treatment or hydrogen peroxide treatment to remove hydrogen sulfide from the gas [4].
   b. *Off-gas methods:* use a non-condensable gas removal device.
   c. *Hybrid systems:* Finally, hydrogen sulfide can be eliminated from the steam leaving the condenser or condensate steam using hybrid systems.

## CONCLUSION

Geothermal energy is a promising renewable resource that serves as a better alternative to fossil fuels (U.S. Energy Information Administration, 2022) [15]. However, several modifications are required to mitigate the environmental hazards associated with their production. Although geothermal energy offers significant benefits and can effectively replace nonrenewable sources, attention must be given to the impacts on local ecosystems and land formations, as well as the pollutants released that can indirectly affect the environment. Additionally, it is essential to develop methods for locating heat sources without encroaching on sensitive areas. Further research should focus on enhancing the efficiency of power plant construction, reducing the environmental impact of drilling, eliminating pollutants from exhaust emissions, and exploring alternative isolation methods. Identifying geothermal heat sources while minimizing ecosystem disruption is also a critical area for improvement.

## REFERENCES


1. Sahdarani DN, Ponka MA, Oktaviani AD. Geothermal energy as an alternative source for Indonesia’s energy security: The prospect and challenges. J Strateg Glob Stud. 2020;3(1):Article 1. DOI: 10.7454/jsgs.v3i1.1024.
2. Kurowska E, Schoeneich K. Geothermal exploration in Nigeria. Proceedings of the World Geothermal Congress, Bali, Indonesia; 2010, Apr 25–29.
3. Okolie STA, Ozuor O, Fakehinde O, Ongbali SO, Fayomi OSI, Agu FA. Study of Nigeria geothermal energy resources’ viability, brief production techniques and transportation. Energy Procedia. 2019;157:1475–85. doi: 10.1016/j.egypro.2018.11.312.
4. Gorthy A, Tran N, Pierre-Louis L. Geothermal energy and its impacts on the environment. Mako: NSU Undergrad Student J. 2023;2023(1):article 4. Available from: https://nsuworks.nova.edu/mako/vol2023/iss1/4.


 

5. Dickson MH, Fanelli M. Geothermal Energy. London, United Kingdom: Routledge; 2013. DOI: 10.4324/9781315065786.
6. U.S. Energy Information Administration (EIA). (2024). Geothermal explained: Geothermal power plants. [online] U.S. Energy Information Administration (EIA). Available from: https://www.eia.gov/energyexplained/geothermal/geothermal-power-plants.php.
7. Lund JW, Toth AN. Direct utilization of geothermal energy 2020 worldwide review. Geothermics. 2021;90:101915. DOI: 10.1016/j.geothermics.2020.101915.
8. Scion MI, Sellier M, Krumdieck S. An adaptive design approach for geothermal plant with changing resource characteristics. In: World Renewable Energy Congress. Linköping; 2011.
9. Barbier E. Geothermal energy technology and current status: An overview. Renew Sustain Energy Rev. 2002;6:3–65. doi: 10.1016/S1364-0321(02)00002-3.
10. Zira AM. Challenges and prospects of geophysical exploration of geothermal system for national development. Acad J Interdiscip Stud. 2013;2. doi: 10.5901/ajis.2013.v2n12p137.
11. Fridleifsson IB. Geothermal energy for the benefit of the people. Renew Sustain Energy Rev. 2001;5:299–312. doi: 10.1016/S1364-0321(01)00002-8.
12. Abraham EM, Nkitnam EE. Review of geothermal energy research in Nigeria: The geoscience front. Int J Earth Sci Geophys. 2017;3:1–5.
13. DiPippo R. Geothermal power plants: Principles, Applications, Case Studies and Environmental Impact. 3rd ed. Oxford, United Kingdom: Butterworth-Heinemann; 2012.
14. Kagel A, Bates B, Gawell K. A Guide to Geothermal Energy and the Environment. Washington, D.C.: Geothermal Energy Association; 2005.
15. U.S. Energy Information Administration (EIA). (2024). Geothermal explained: Geothermal energy and the environment. [online] U.S. Energy Information Administration (EIA). Available from: https://www.eia.gov/energyexplained/geothermal/geothermal-energy-and-the-environment.php.

 