Proceedings World Geothermal Congress 2026, Calgary, Canada, June 8—11, 2026

From Ground to Grid: Strategic Geothermal Development for Nigeria's Resource Ranking and Net Zero Pathways

Ovye Musah Yohanna[1]*, Aaron Cahill[1], Nathaniel Forbes-Inskip[1], David Egya[2]
Lyell Centre, Heriot Watt Univeristy[1], Petronas[2] Edinburgh United Kingdom
omy4000@hw.ac.uk*

1. INTRODUCTION

Nigeria faces a dual challenge of **energy shortage** and **net-zero commitments** with 2060 target. 40% lack access to electricity , frequent grid collapses, and a fossil fuel dominated energy mix. Government policies encourages cleaner options including geothermal as evidence from elevated heat flow zones, warm springs and good hydrogeology.

Existing studies is still at infant stage, often fragmented and site-specific with no national scale assessment of potential.

This work assess and rank the shallow geothermal potential of Nigeria in all 36 states (plus Abuja) employing a hybrid-MCDA approach.

We adopt a multi-criteria approach informed by technical and non-technical factors. The criteria included:

a. **Thermal Regime:** Heat flow data within a state.
b. **Hydrogeology:** Spatial extent of aquifer types.
c. **Surface Manifestation:** Warm-spring presence and temperature.
d. **Energy in Demand:** Prioritising development for heating from energy deficiencies.

2. METHODS

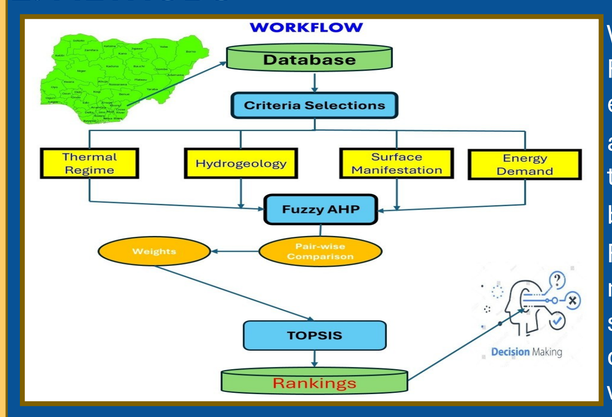


Figure 1: Workflow showing the Approach

We adopted a hybrid-MCDA approach (similar to Qu et al.,2025) combining Fuzzy-Analytical Hierarchical Process (FAHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) in 2 steps:

a. **Data collection:** Quantitative data were gathered for the 4 criteria using National dataset, literature and GIS tools.

b. **Ranking Techniques:** Hybrid FAHP & TOPSIS

FAHP was used to weight criteria through pairwise comparison and expert judgment, using fuzzification following Buckley et al. (1985) with Triangular Membership Functions and Geometric Mean, ensuring reduced bias via consistency checks. TOPSIS ranked Nigeria's 37 states by geothermal proximity using these weights.

3. RESULTS

The ranking of geothermal potential across Nigeria's 37 states was conducted using the TOPSIS method, incorporating weighted criteria derived from Fuzzy AHP in table 1. The performance scores (Pi values) reflect each state's relative suitability for geothermal development and the highest-ranked states mostly align within regions influenced by magmatism (after Obaje, 2009).

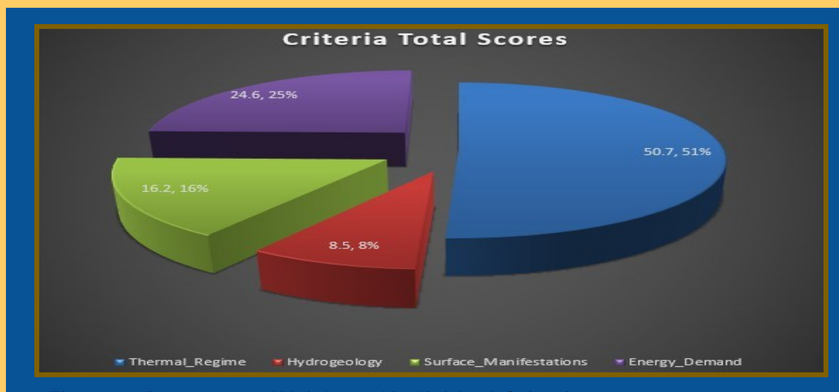


Figure 2: Percentage Weights of Individual Criteria

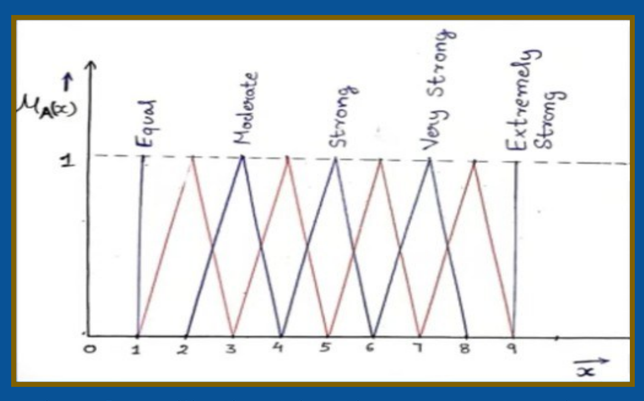


Figure 3: Fuzzification Using Triangular Membership Function where μÃ(x) or membership degree = Ã= (lower, middle, upper)

Table1: Performance Indices of State's Geothermal Resources

Rank	States	Pi
1	Nassarawa	0.6432
2	Bauchi	0.6139
3	Benue	0.4961
4	Cross River	0.4498
5	Borno	0.4309

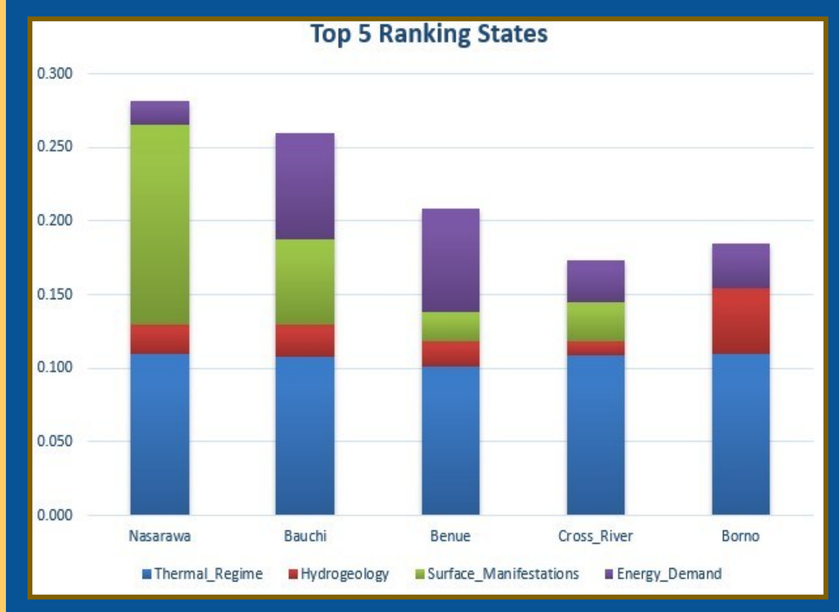


Figure 4: Top Ranked States Individual Criteria Scores

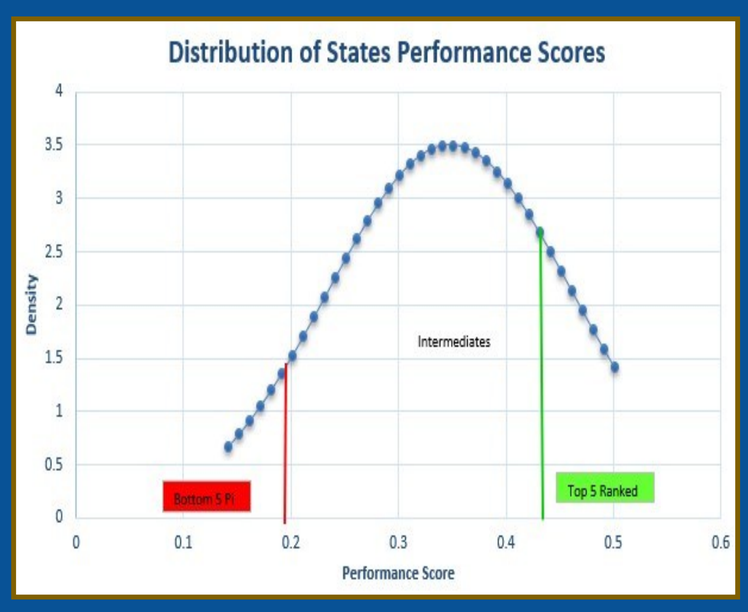


Figure 5: The Distribution of State Performance Scores



Figure 6: Map of Nigeria showing the State's Performances Ranking

4. DISCUSSION

- The study applied multi-criteria decision analysis (MCDA) to evaluate the low-enthalpy geothermal development potential across Nigerian states.
- CPD–derived heat flow values, corrected by reducing them by 30%, following established studies after Ross et al. (2006)
- Our findings are :
  1. Nasarawa (Pi = 0.643) and Bauchi (Pi = 0.614) ranked highest due to strong geothermal indicators such as temperature regime, surface manifestations, and hydrogeology.
  2. Most of the highest-ranked states for geothermal potential align within regions influenced by the most recent magmatic episodes in Nigeria, which occurred during the Tertiary period
- Energy demand, weighted 0.246 in the FAHP model, significantly influenced rankings; states like Nasarawa and Benue show potential for localized and regional energy support.
- Low-ranking states such as Lagos and Gombe exhibit high energy needs but poor geothermal indicators, emphasizing the need to align exploration with both geological potential and energy planning for sustainable development.
- Although future improvements in data availability and adjustments in socioeconomic conditions may boost the geothermal potential of states currently in the intermediate group, those in the bottom tier may need to acquire specific data or focus on alternative renewables such as solar and wind.

5. CONCLUSION

This research demonstrates the feasibility of a nationwide, integrated geothermal assessment for Nigeria, offering a pathway toward sustainable, low-carbon energy development

The leading states, Nasarawa, Bauchi, Benue, Cross River, and Borno, exhibit significant thermal and hydrogeological potential, particularly Nasarawa, which possesses a surface score of 0.839.

Lagos, Gombe, and Ogun ranked lowest, while states such as Rivers, Katsina, and Niger showed moderate potential.

This research supports further targeted geothermal exploration and provide a strategic tool for policymakers and investors.

Acknowledgements

This research was conducted as part of my PhD studies within the Geo-Energy Group at the Lyell Centre, which is part of the School of Energy, Geoscience, Infrastructure and Society (EGIS) at Heriot-Watt University. I gratefully acknowledge the Petroleum Technology Development Fund (PTDF), Nigeria, for sponsoring my doctoral programme. I also extend my appreciation to the Nigerian Upstream Petroleum Regulatory Commission (NUPRC) and the Nigerian Geological Survey Agency (NGSA) for providing access to valuable geothermal and subsurface data, and to the authors of published geological surveys.

REFERENCES

Buckley, J., Feuring, T., & Hayashi, Y.: Fuzzy hierarchical analysis. Fuzzy Sets and Systems, 17(3), 233–247, (1985).
Obaje, N., G.: Geology and Mineral Resources of Nigeria. Springer-Verlag Berlin Heidelberg, (2009).
Qu, W., Qian, H., Yang, C., Xu, P., Gao, Y., Wei, L., & Long, Q.: A comprehensive multicriteria decision analysis framework for shallow geothermal energy suitability evaluation in Yinchuan Area, China. Scientific Reports. (2025).
Ross, H. E., Blakely, R. J., & Zoback, M. D. (2006). Testing the use of aeromagnetic data for the determination of Curie depth in California. Geophysics, 71(5), L51–L59.