



Research Paper

Long-term energy demand modeling and optimal evaluation of solutions to renewable energy deployment barriers in Benin: A LEAP-MCDM approach

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ARTICLE INFO

Keywords:

Benin
LEAP
sustainable development
GHG emissions
energy demand

ABSTRACT

Approximately 60 % of Beninese lack access to electricity, relying heavily on traditional energy sources, electricity imports, and low renewable energy integration. This study aims to forecast the energy demand for Benin while reducing greenhouse gas (GHG) emissions and propose alternative solutions to clean energy deployment barriers. The Low Emissions Analysis Platform (LEAP) is used to explore the future energy demand for Benin and associated GHG emissions. Four scenarios have been developed, namely Business as Usual (BAU), High Economic Development (HED), Electrification and Urbanization Growth (EUG), and High Efficient Energy Application (HEEA). In addition, the Fuzzy AHP and TOPSIS techniques have been employed to rank and prioritize alternative solutions to Renewable Energy (RE) deployment barriers in the country. A total of eighteen sub-barriers were identified and classified into five main categories under the four pillars of sustainability (technical, social, economic, and environmental), and nine strategies were identified and proposed to overcome the barriers. The results show that under the BAU scenario, the total energy demand is expected to reach 445 PJ in 2050 from the current demand of around 164 PJ. A total GHG emission of 21 MtCO_{2e} is estimated under the BAU scenario in 2050. However, the HEEA scenario indicates that energy demand would considerably decrease resulting in low GHG emissions from the energy sector. The findings from the Fuzzy AHP ranking show that technical barriers, political and regulatory barriers, and financial and economic barriers, are the top three barriers hindering RE deployment in Benin. Moreover, adequate policy and regulatory framework emerges as the most weighted solution to eliminating barriers to RE deployment in the country. These results encourage the application of effective policy to support sustainable energy transition. The study's approach is applicable to other developing countries outside Benin, offering insights into RE barriers and potential alternative solutions.

List of abbreviations and acronyms: ABERME, Beninese Agency for Rural Electrification and Energy Control; BAU, Business As Usual; CO₂, Carbon dioxide; CSP, Concentrated Solar Power; DGRE, Directorate General Energy Resources; EUG, Electrification and Urbanization Growth; GDP, Gross Domestic Product; GDEX, Gbê-Djigbê Industrial Zone; GHG, Greenhouse Gas; HEEA, High Efficient Energy Application; HED, High Economic Development; HH, Household; IEA, International Energy Agency; IRENA, International Renewable Energy Agency; INSAH, National Institute of Statistics and Economic Analysis; INSTAT, National Institute of Statistics and Demography; LEAP, Low Emission Analysis Platform; LPG, Liquefied Petroleum Gas; MCVDD, Ministry of Living Environment and Sustainable Development; MESSAGE, Model for Energy Supply Strategy Alternatives and their General Environmental Impacts; MtCO_{2e}, Million metric tonnes of CO₂ equivalent; NEMO, Next Energy Modeling System for Optimization; NDC, Nationally Determined Contribution; OPENMODSYS, Open Source Energy Modeling System; PJ, Petajoules; PHODERE, Renewable Energy Development Program; PROVES, Solar Energy Promotion Project; PONADER, National Renewable Development Policy; PANED, National Energy Efficiency Action Plan; PV, Photovoltaic; SSEE, Beninese Company of Electrical Energy; SIMFACTS, Simplified approach to estimating electricity generation's external costs and impacts; SDG7, Sustainable Development Goal 7; SSA, Sub-Saharan Africa; SEB-Benin, Energy Information System of Benin; UNDP, United Nations Development Programme; AHP, Analytic Hierarchy Process; TOPSIS, Technique for Order of Preference by Similarity to Ideal Solution; MCDM, Multi-criteria Decision Making; OC_{2e}, Closeness Coefficient.

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Received 20 April 2024; Received in revised form 16 July 2024; Accepted 27 July 2024

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Monitoring Long Term Energy Technology An Evaluation Efnreport

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