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Roll Out of Sustainable Solar Energy in Spatial Planning: A Focal Lens of Maseru, Lesotho

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1 ABSTRACT

The global energy crisis disproportionately affects Sub-Saharan Africa, with Maseru, Lesotho, facing rising urban energy demand, unregulated spatial growth, socio-economic inequalities, and reliance on imported electricity. Despite high solar potential, solar energy remains underutilized and poorly integrated into urban planning. This study employs a PRISMA-guided systematic review and VOSviewer bibliometric analysis to identify research trends, policy gaps, and best practices in solar energy and spatial planning. Findings highlight the potential of decentralized solutions, including rooftop solar and solar-powered public infrastructure, to enhance local energy resilience. The study offers evidence-based recommendations to inform policy frameworks aligned with SDG 7 and SDG 11, promoting renewable energy adoption and advancing a just and sustainable urban energy transition in Maseru.

Keywords: Climate change, State Owned Enterprises, Just Energy Transition, Fossil fuel Dependence, Public engagement

2 INTRODUCTION

Global energy demand is projected to increase by 56% by 2040, largely driven by industrial growth in developing regions (Muhammad et al., 2016; Kayima et al., 2023). Rapid population growth and urbanization in Sub-Saharan Africa are outpacing energy infrastructure development, leaving 568 million people without electricity (IEA, 2020). Urban areas contribute nearly 80% of global CO_2 emissions (IEA et al., 2022), and reliance on unsafe energy sources such as biomass disproportionately affects women and marginalized communities.

Maseru, the capital of Lesotho, illustrates these challenges. Only 57% of households are connected to the national grid, with national electrification at 33.7% (Energy Catalyst, 2020; Mpholo et al., 2021). High electricity tariffs encourage reliance on kerosene and biomass, increasing health risks and environmental degradation (WHO, 2016). The city shown below on diagram 2,depends heavily on imported electricity from South Africa and Mozambique, exposing it to supply vulnerabilities (Mpako & Ndoma, 2024).

Although renewable energy policies exist, implementation remains limited due to financial, institutional, and infrastructural constraints.Solar energy offers a strategic solution to Maseru's energy insecurity. However, adoption is hindered by fragmented urban planning, inadequate policy alignment, and limited technical capacity. This study investigates the potential of integrating solar energy into spatial planning to advance energy security, sustainability, and equity. By focusing on Maseru, the study contributes to achieving SDG 7 and SDG 11 through a just energy transition.

3 CONCEPTUALIZATION

3.1 Urban Energy Challenges

Spatial planning organizes land use to balance competing interests, promote sustainable development, protect the environment, and involve local communities (Nowak, 2022). Key elements include land use management, infrastructure development, environmental protection, public participation, and spatial justice. Historically, energy planning has emphasized techno-economic efficiency (Osorio-Aravena, 2020), but integrating spatial planning can enhance energy efficiency and fairness by mediating site development,

mitigating inequalities, and aligning energy infrastructure with urban growth (Kooij, 2025; Marsden et al., 2025).

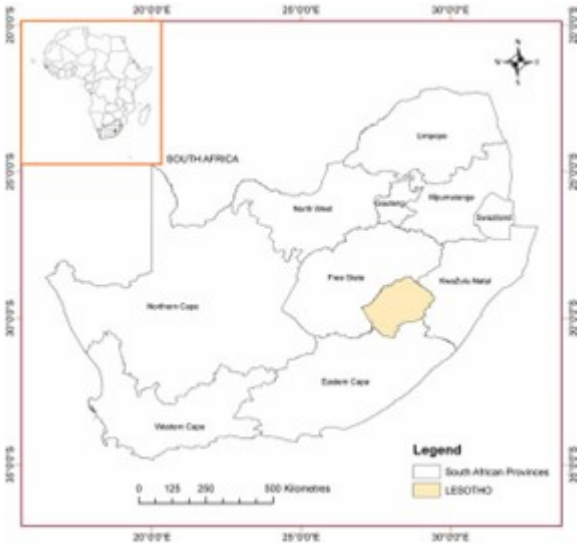

Diagram 1. Location Map of Lesotho (Source: Mukwanda 2020)

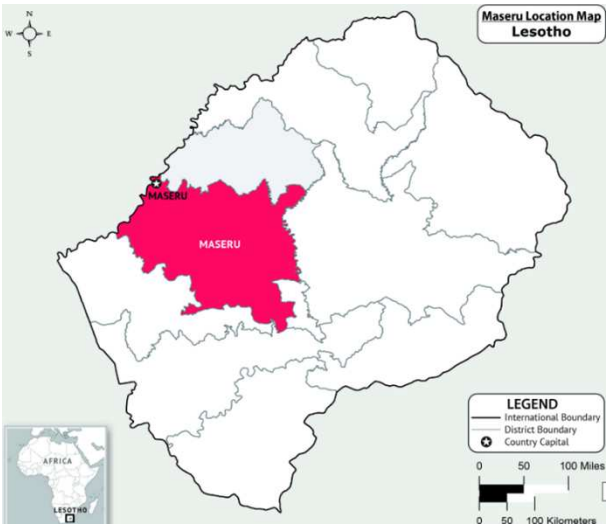

Diagram 2. Location Map of Maseru

3.1.1 Energy as a Planning Concern

Energy production, distribution, and consumption are shaped by urban form, land use, and infrastructure. Recognizing energy as a spatial governance challenge allows for strategic urban design that supports renewable energy deployment, energy-efficient buildings, and resilient public infrastructure (Rydin & Turcu, 2019).

3.2 Energy Demand and Supply

Global energy consumption has increased nearly twentyfold since 1850, driven by economic activity, urbanization, and technology adoption (Al-Yasiri, 2021). Developing countries face challenges in forecasting demand due to grid limitations and diverse consumption patterns (Arnob et al., 2023). In Maseru, supply fails to meet growing demand, leaving informal and peri-urban areas underserved. Aging infrastructure, low investment, and weak governance exacerbate access disparities (Moturi et al., 2024).

3.2.1 Just Energy Transition (JET)

A Just Energy Transition involves a fair, inclusive shift from carbon-intensive to low-carbon energy, emphasizing social equity, job protection, and community welfare alongside environmental goals (Yang et al., 2024). Global reliance on fossil fuels has driven climate change, compelling nations to adopt renewable energy under frameworks such as SDG 7. By 2030, SDG 7.1 targets universal access to reliable energy,

while SDG 7.2 promotes the global share of renewables. Yet, nearly 3 billion people still depend on fossil fuels for cooking and heating (Patrick et al., 2025).

3.2.2 Theoretical Underpinnings

Dependency Theory

Prebisch and Singer's framework explains how historical and structural inequalities limit local autonomy in energy development (Romaniuk, 2017). Lesotho exemplifies this dependence through reliance on imported electricity and donor-driven renewable projects, often prioritizing external interests over local needs. Addressing this requires investment in local capacity, policy reform, and domestically driven solar projects.

Smart City Theory

Smart City Theory frames cities as data-driven systems integrating ICT, human capital, and governance for sustainability (Liu & Wu, 2023). Smart energy systems – smart grids, IoT, and AI – can optimize solar adoption, enhance energy reliability, and reduce emissions (Gracius et al., 2023). For Maseru, smart city strategies offer a pathway to affordable, carbon-neutral solar energy deployment.

4 METHODOLOGY

This study employs a mixed-method research design combining a systematic literature review with bibliometric analysis. A PRISMA-guided systematic literature review was conducted using the Scopus database to ensure transparency, replicability, and academic rigour. Peer-reviewed literature published between 2015 and 2026 was screened based on relevance to spatial planning, solar energy, energy demand, and sustainability transitions. The diagram depicts how PRISMA protocol was followed in the study.

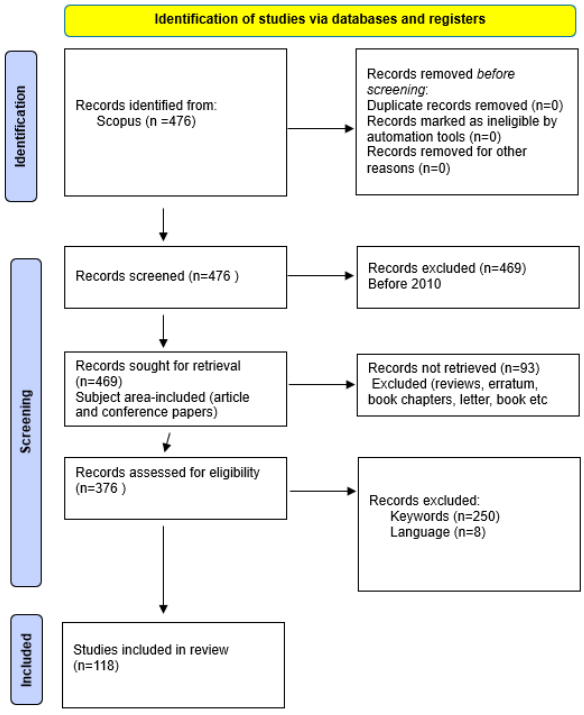

Diagram 3. PRISMA flow diagram (Source: Author: 2025)

Complementing the review, a bibliometric analysis using VOSviewer mapped keyword co-occurrences, thematic clusters, and geographic research trends. This approach enabled the identification of dominant research themes, policy gaps, and the relative absence of African urban case studies particularly from smaller cities such as Maseru within the global renewable energy planning discourse.

5 RESULTS AND DISCUSSION

5.1 Global and Regional Research Trends

The bibliometric analysis identified 761 publications related to renewable energy planning and energy transitions, with 394 English-language sources meeting the inclusion criteria. Research output is heavily concentrated in Europe, Asia, and North America, with comparatively limited representation from African cities. Thematic clusters reveal a shift from narrowly focused technical energy modelling toward more integrated approaches encompassing governance, spatial planning, infrastructure, and social justice.

Key clusters include carbon emissions and energy infrastructure, smart cities and digital innovation, clean energy transitions in developing countries, micro-grids and disaster resilience, and solar energy deployment in urban areas. These trends reflect growing recognition that renewable energy transitions are not solely technological processes but deeply embedded within planning, governance, and socio-spatial systems.

5.2 Energy Insecurity and Planning Constraints in Maseru

Findings indicate that Maseru's energy insecurity is shaped by a combination of ageing infrastructure, limited generation capacity, high electricity tariffs, and continued reliance on coal-powered imports. Weak spatial planning practices characterised by unregulated settlement growth, infrastructure backlogs, and fragmented sectoral policies further constrain the integration of renewable energy.

Picture 1. An Informal Settlement in Maseru

Picture 2. Old Electrical poles destroyed by extreme weather

Despite high solar irradiation and substantial rooftop photovoltaic potential across residential, commercial, and public buildings, the absence of mandatory planning guidelines for example-in the picture 1 shown

above, financial incentives, and technical standards limits systematic adoption. Additional barriers include limited technical expertise, low public awareness of solar benefits, weak governance structures, and insufficient private-sector investment.

5.3 Decentralised Solar Systems and Urban Resilience

Decentralised solar systems emerge as a critical pathway for addressing energy access and equity gaps, particularly in peri-urban and informal settlements where grid connectivity remains limited. Rooftop solar installations and solar-powered public infrastructure such as street lighting, clinics, schools, and transport interchanges offer opportunities to improve service delivery, enhance safety, and reduce pressure on the national grid.

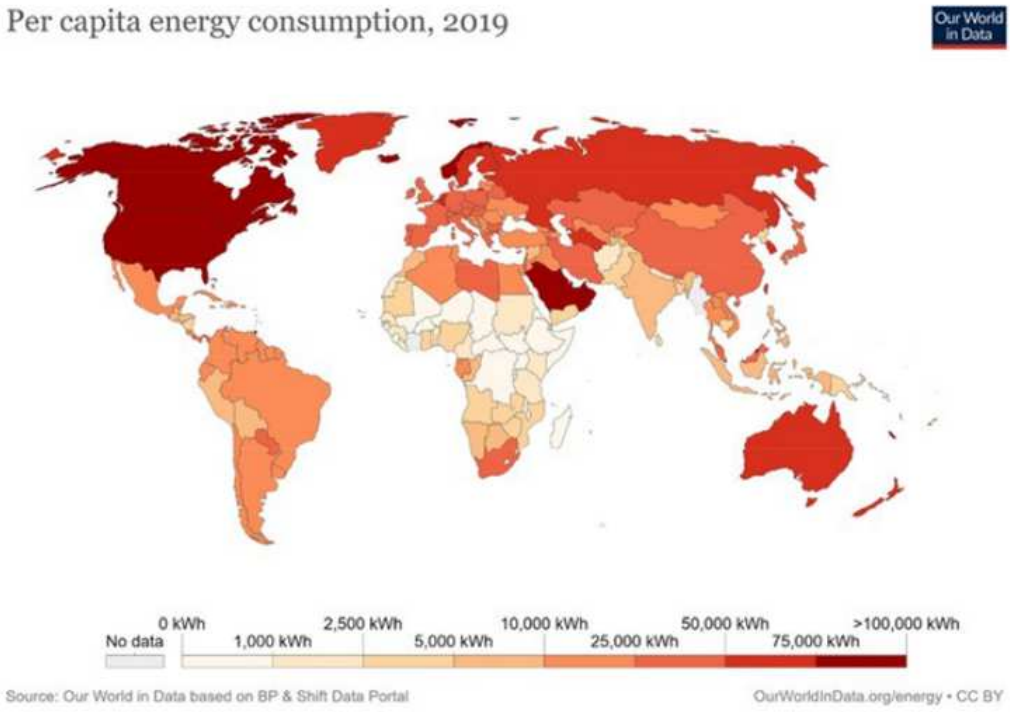

Figure 1: Global Distribuion of solar energy (Our World in Data, 2020)

International experience demonstrates that cities which align spatial planning instruments with renewable energy policies through zoning regulations, building codes, and incentive frameworks achieve faster and more inclusive solar adoption. In Maseru, adopting similar approaches could significantly strengthen urban energy resilience while supporting broader sustainability objectives.

6 TOWARD SOLAR-INTEGRATED SPATIAL PLANNING

Based on the findings, the study proposes a planning-led framework for integrating solar energy into Maseru's urban development processes. Key pathways include:

- Updating building regulations to mandate solar-ready design in new developments;
- Designating renewable energy zones and micro-grid innovation hubs within urban and peri-urban areas;
- Introducing targeted financial incentives, including subsidies and feed-in tariffs, to encourage household and commercial solar adoption;
- Strengthening public-private-community partnerships aligned with SE4ALL, UNDP, and World Bank frameworks;
- Piloting solar-powered public infrastructure as demonstration projects to build institutional and public confidence.

7 CONCLUSION

This study demonstrates that Maseru possesses substantial untapped potential for integrating sustainable solar energy into its spatial planning frameworks. While technical feasibility is high, institutional fragmentation, weak policy alignment, and limited planning-led incentives continue to constrain progress. Addressing these challenges requires a deliberate shift toward integrated urban energy planning that prioritises decentralised solar solutions, social equity, and environmental sustainability.

By embedding renewable energy within spatial governance processes, Maseru can reduce dependence on imported fossil-fuel-based electricity, enhance urban resilience, and advance a just energy transition aligned with global development goals. The findings contribute to the limited body of Global South urban energy planning literature and offer transferable lessons for similarly positioned cities across Sub-Saharan Africa.

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