Comparison of Off-Grid Electrification versus Grid Extension: Influencing Parameters and the Role of Renewable Energies from a Geographic Point of View

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Research Problem

- **Access to electricity is still a huge challenge in many remote, rural regions globally. Especially people in Sub-Saharan Africa and in South and South East Asia lack access to electricity.**
- **Insufficient power generation facilities in many regions are prevailing.**
- **Outdated infrastructure leads to unreliable grid electricity access.**
- **Dependence on fossil fuel imports leads to expensive power generation costs (high levelized costs of electricity [LCOE]).**
- **Renewable energies are necessary to reduce CO_2 emissions and mitigate climate change.**

Theoretical Background

Different electrification pathways are possible to provide access to electricity for rural areas.

Challenges are identified in the location-specific set-up: Depending on multiple objectives, namely

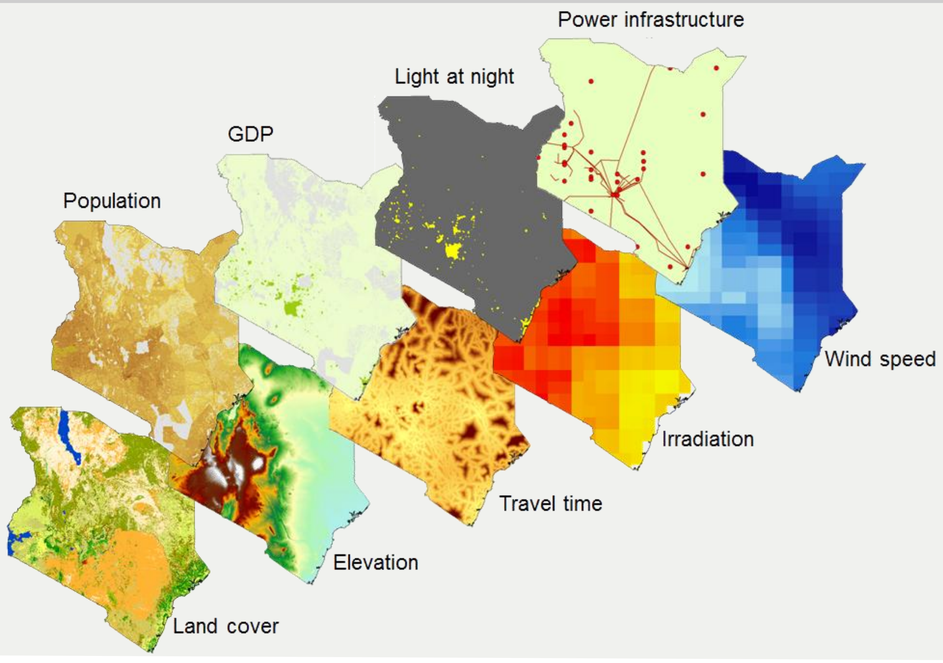
(1) sustainable electricity supply,
(2) usage of renewable energies,
(3) low electricity costs (LCOE-based), and
(4) various stakeholder interests (governments, communities, private industry),

the complexity of various alternatives requires a comprehensive analysis to develop the optimal solution.

Historical development, status quo and future opportunities need to be incorporated in the decision making process for electrification.

Location-specific resources and existing infra-structures as well as policies in place need to be considered.
A choice of different energy generation technologies, various initial situations (no electricity, insufficient grid electricity, diesel generators), and business models (public, private, PPP, microfinance) requires a broad decision matrix for the electrification strategy.

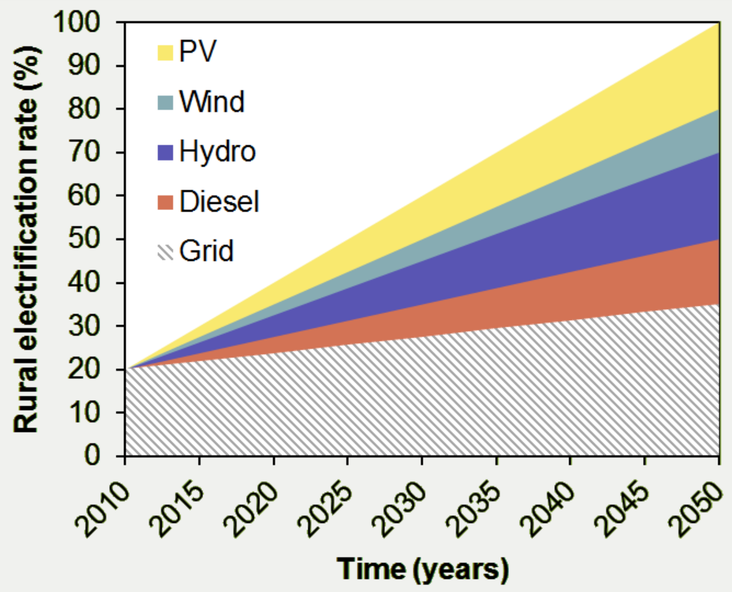
Methods - GIS Modelling



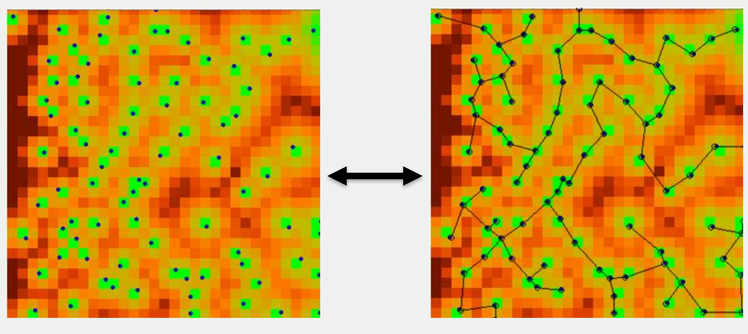
◄ Figure 1: Spatial data availability for the example of Kenya.

Information on a spatially resolved basis are available for natural and anthro-pogenic parameters.
Natural parameters include elevation (e.g. mountain ranges) and renewable resource availability (e.g. wind speed, solar irra-diation or hydro power potential).
Anthropogenic factors are reflected in the parameters population distribution, gross domestic product (GDP), night lights and power infrastructure.
A combination of anthropogenic and na-tural factors is given in land cover datasets (human influence on nature) and travel time data.

Electrification Planning

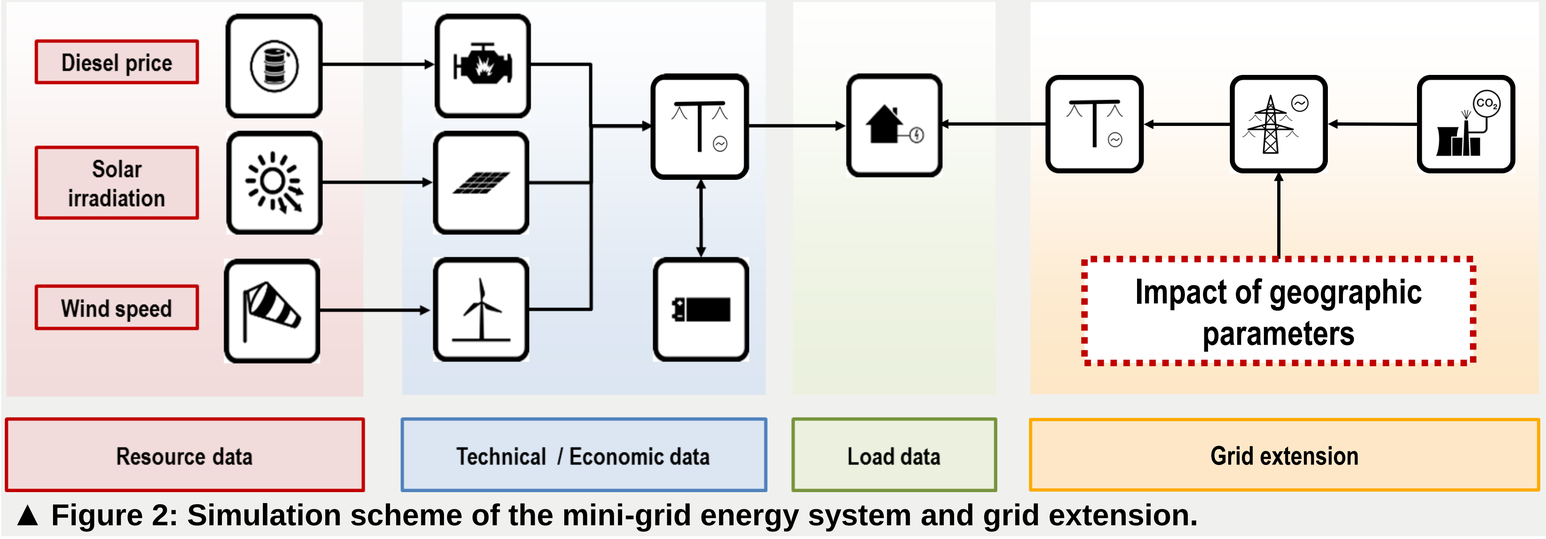


▲ Figure 3: A location specific electrification pathway requires a distinction between decentralized options and grid extension. The renewable energy share as well as the electrification level of a region are distinguished within this planning.



▲ Figure 4: Spatial planning of electrification options for scattered villages. Decentralized approaches (left side) have to be considered in addition to grid extension (right side).

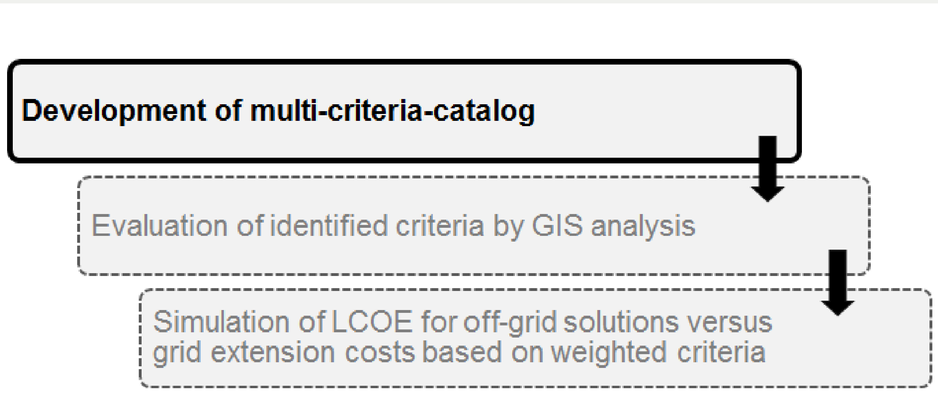
Methods – Simulation of Mini-Grid and Grid Extension Costs



▲ Figure 2: Simulation scheme of the mini-grid energy system and grid extension.

Future Course of Research

1. Development of the grid extension cost simulation to compare the electrification options.
2. Multi Criteria Decision Analysis (MCDA) to include non-spatial parameters (policies, regulations) into the comparison framework.
   a) Definition of the methodology
   b) Establishing a weighting scale
3. Validation with empirical data.



▲ Figure 5: Next research steps to calculate the cost comparison of electrification alternatives.

Final objective:

Development of a **Decision Support Tool** for the design of **Electrification Strategies** with consideration of climate neutral **Renewable Energies** in decentralized electrical systems.

Conclusion

Providing electricity to remote, rural locations remains a great challenge. Focusing on infrastructure development, the choice between decentralized energy systems and extension of the national or international grid system has to be carefully evaluated.
The performance of technical feasible, sustainable, reliable, and affordable electrification pathways significantly depends on local characteristics and defined policies and regulations.
GIS analysis of location specific spatial characteristics, such as renewable resources, combined with cost simulations of decentralized and centralized electrification options provide a detailed assessment of the attractiveness of both options.

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