ENERGY ACCESS FOR SUB-SAHARAN AFRICA WITH THE FOCUS ON PV HYBRID MINI-GRIDS

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Introduction

Within the Sustainable Development Goal number 7 (SDG7) and UNs Sustainable Energy4All initiative it is targeted to achieve universal access to sustainable energy by 2030. Access to electricity enables social and economic development due to improved education, health care, agriculture and business opportunities [1, 2]. To reach this access enormous efforts have been and are undertaken globally. Nevertheless, still 1.3 billion people have no sufficient electricity supply [3].

Table 1: Number of people without access to electricity (in million) [3].

	Rural	Urban	Total	Share of population
Developing countries	1,081	184	1265	24%
Sub-Saharan Africa	475	114	590	57%
Developing Asia	556	62	628	18%
Latin America	23	6	29	6%
Middle East	16	2	18	9%
World	**1,083**	**184**	**1,267**	**9%**

Especially in sub-Saharan Africa (SSA) the majority of people lack access to electricity. The current actions of grid extensions in SSA are undermined by strong population growth in rural areas and by weak central grid and power generation infrastructure. The current central power supply infrastructure causes 8.8 percent of sales losses in SSA due to frequent power outages [4]. Connecting new customers to these supply systems without adding additional power generation capacities would even worsen this situation. Thus, to accelerate electrification in SSA it is recommended to not only focus on grid extension as electrification option, but also on decentralized hybrid mini-grids and stand-alone systems. IEA's New Policies Scenario suggests the generation of 26 TWh for only sub-Saharan Africa by mini-grids until the year 2040. The two most prominent technologies to achieve that are solar photovoltaic (PV) and oil, followed by hydro power [3]. Besides IEA’s findings on the overall numbers there exist still challenges on the geospatial planning of the electrification scenarios, e.g. precisely projecting investment costs of different electrification interventions.

Mentis et al. [5] provided a case study of Ethiopia to show the benefits of geospatial planning in energy access. This study compares the costs of grid extension, mini-grids and stand-alone systems for electrification [5]. Within our research work we compare these three main electrification options for all SSA countries to give an indication of the potential of decentralized electrification measurements based on population thresholds. By developing two different scenarios we show the boundaries of certain electrification pathways.

Methodology

To derive priority areas for the different electrification options we apply a GIS based approach. For each country the population distribution, night light imageries and grid infrastructure is analyzed. Due to high automation we can run our routine for all sub-Saharan countries following the algorithm shown in Fig. 1. With the help of this algorithm two electrification scenarios are developed. Scenario I is looking at the status quo of grid infrastructure while Scenario II takes into account the planned grid infrastructure.

To determine the number and location of people without access to electricity (non-electrified population) a global night light data set is applied. This data set illustrates significant light emissions indicating the availability of electricity in this area for e.g. street lights. After the determination of the non-electrified people the best matching electrification solution has to be applied. All people within a 20 km buffer around the existing / planned grids are suggested for grid connection. For the remaining regions the population density is the distinctive factor whether a mini-grid or a stand-alone system is proposed. Areas with high population densities are selected for mini-grid electrification as it is economically feasible to set up single distribution grids there. In the opposite case solar-home systems are suggested as stand-alone solution since sparsely populated regions bear too high costs for interconnecting the households to one mini-grid.

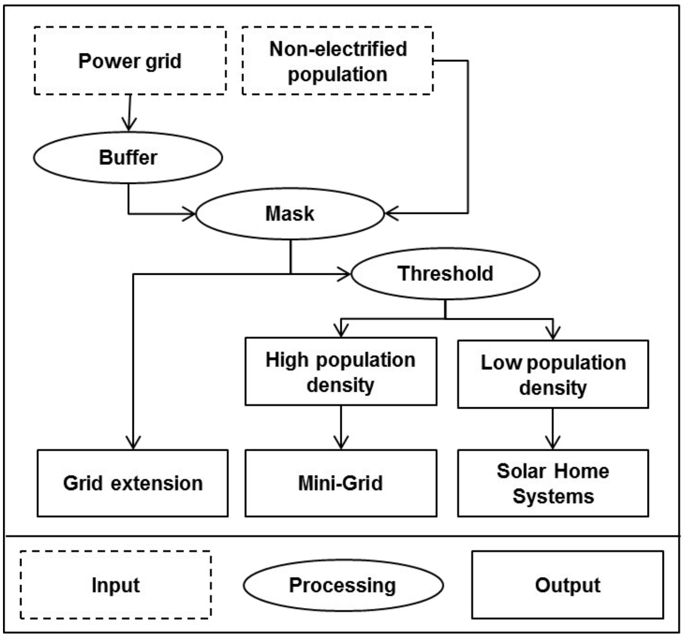

Figure 1: Approach for electrification modelling.

Results

The algorithm was applied for all SSA countries by adjusting population density and night light thresholds respectively. Power grid infrastructure was derived from the African Development Bank and various local sources.

The night light analysis revealed that 620 out of 951 million people have no access to electricity which matches quite well with the global statistics on Table 1. The advantage of the night light analysis is that not only the number of people without access to electricity but also their location could be detected. After the detection of the non-electrified population the most suitable electrification options were assigned.

Scenario I: Existing grid

For scenario I only the existing grid infrastructure is taken as baseline. Figure 2 and 3 reveal the results of the modelling for each SSA country. The number of people assigned to grid connection, mini-grids and stand-alone systems as electrification option is shown as well as the overall share of mini-grids as electrification option.

The countries in Fig. 2 are ranked according to the highest share of mini-grids as suggested electrification option. Countries with very weak infrastructure are leading this ranking, namely Somalia (75 %), Liberia (39 %), and Chad (35 %). Nevertheless, the countries with the highest overall number of people assigned for mini-grid electrification are Nigeria (22 M), Democratic Republic of Congo (11 M), and Somalia (6 M). Taking out the extreme case of Somalia shows that the range of mini-grid electrification varies from 40 % to 0 % with the majority of countries between 10 and 5 %. For these countries only few high populated areas cannot be reached via grid extension and therefore most people gain access to electricity either by solar-home systems or grid connection. In total 12 % of the non-electrified population in the SSA countries could be best electrified by mini-grids and 47 % by solar home systems and 41 % by grid extensions, respectively.

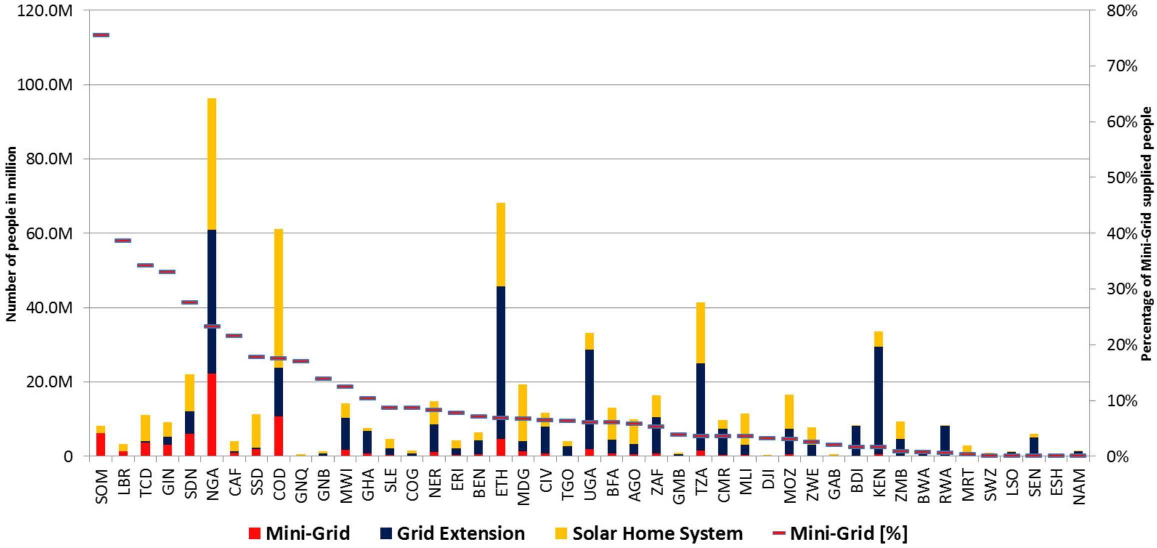

Figure 2: Results of electrification modelling for Scenario I.

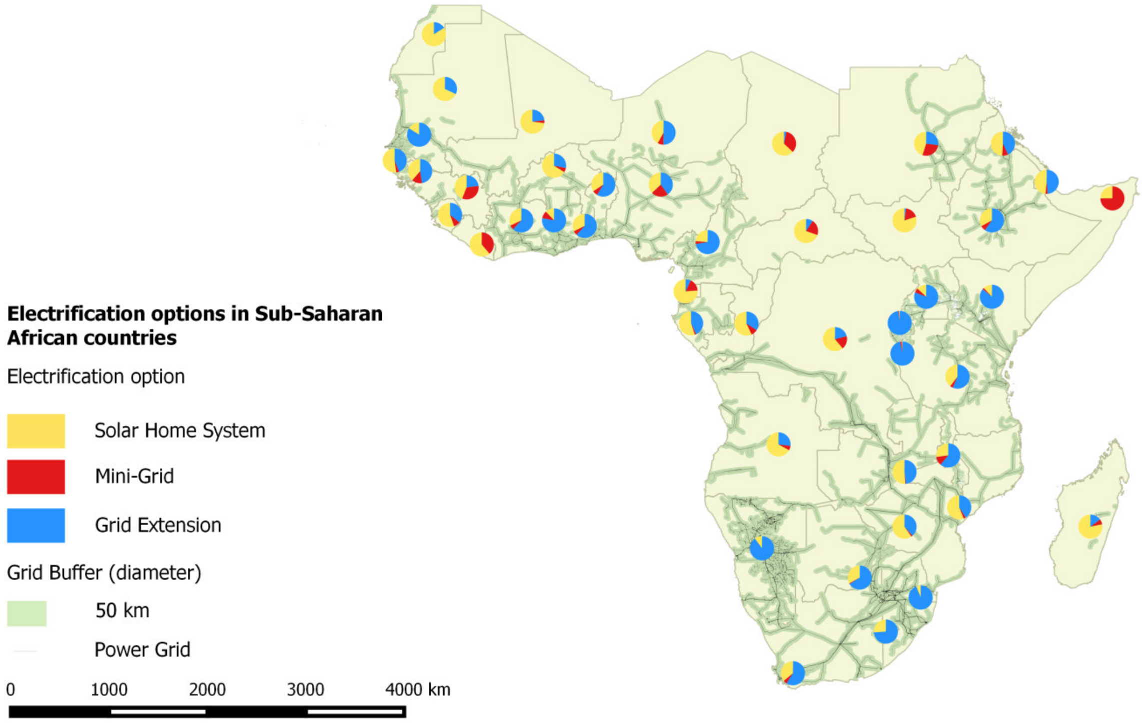

Figure 3: Map of modelling results for each country.

Scenario II: Planned grid

The same modelling as for scenario I was conducted for scenario II just changing the grid infrastructure data. For scenario II the planned grid lines are taken into account as well. Results are shown in Fig. 4 and again the countries are ranked according to the share of mini-grids as electrification option.

The overall share and total numbers of mini-grid electrification decreases as more high populated areas are assigned for grid electrification. The three countries with the highest mini-grid shares are Somalia (44 %), Chad (30 %), and Sudan (25 %). In terms of total population assigned for mini-grid electrification Nigeria is again leading the ranking with 16.7 M, followed by Sudan (5.5 M) and Somalia (3.6 M). The Senegal is joining Namibia and Western Sahara as countries without any mini-grid electrification.

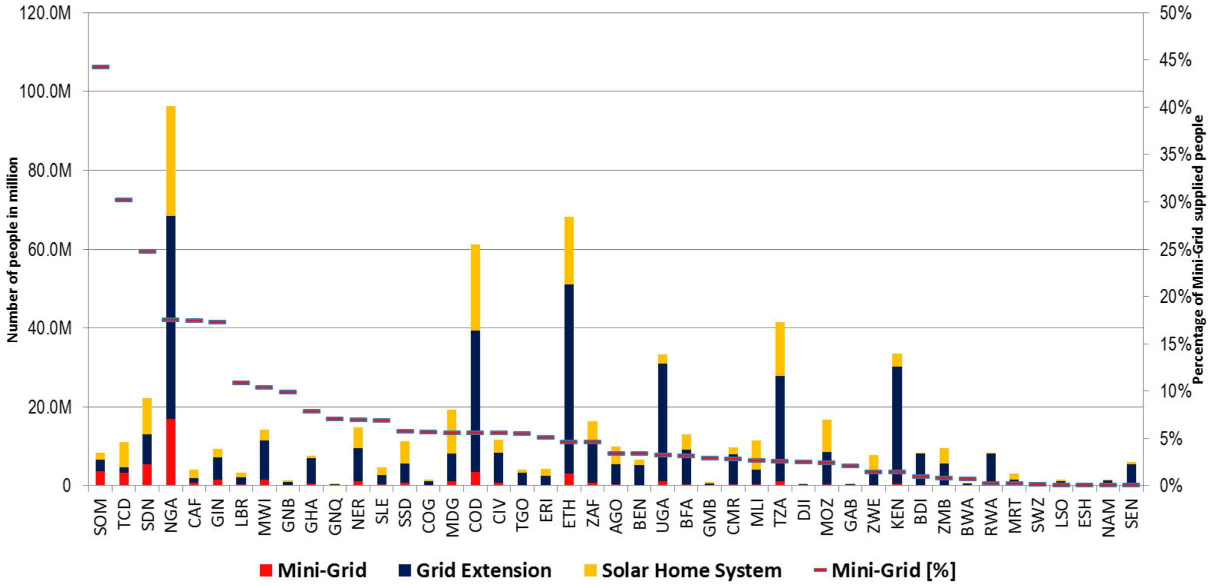

Figure 4: Results of electrification modelling for Scenario II.

Total results

Modelling two scenarios allows understanding the effects of future grid extension plans. In the following Tab. 2 both scenarios are compared.

Table 2: Total results of electrification modelling for all SSA countries.

	Mini-Grid	Grid Extension	Solar Home System
Scenario I	76.6 M ppl (12 %)	290.3 M ppl (47 %)	252.7 M ppl (41 %)
Scenario II	50.5 M ppl (8 %)	381.5 M ppl (62 %)	187.6 M ppl (30 %)

While mini-grid electrification remains more stable the highest shift is from solar-home systems towards grid extension comparing scenario I and II. This means investments into solar-home systems might become unviable if the planned grid connection is conducted. As stated mini-grids are less affected by the planned extension and they bear a second advantage. Once an implemented mini-grid project is connected to the central grid it can still generate electricity and feed into to the central power supply system. This can increase the quality of supply by reducing outages and therefore sustain revenues for the mini-grid operator.

Discussion and Conclusion

The developed methodology allows a comprehensive overview on the potential of different electrification options. By that, all three possible ways of electrification can be compared. It is important to translate electrification targets in total numbers assigned to certain electrification options. Current experience has shown that grid extension is a rather slow and unreliable pathway of electrification due to huge investment needs in grid and power generation capacities mainly conducted by the local governments. Especially mini-grids, which allow private sector involvement, are seen as a viable electrification option to leap frog the centralized power generation system and accelerate the electrification process [6, 7]. Thus, it makes sense not only to target the 76.6 million people of Scenario I as potential mini-grid customers, but also other regions assigned for grid extension which are underserved due to weak grids. Future research on modelling electrification options should therefore include the options of interconnected mini-grids as transition technology towards universal access to electricity.

However, the electrification strategy favoring mini-grids requires substantial capital investments and stable business conditions for private investors. Access to capital, matching amortization expectations and the required stable conditions are not always given. The key advantage of solar home systems is that people can finance such systems on their own, even without access to micro-credit schemes or by taking advantage of pay-as-you-go (PAYG) as shown in several SSA countries. Thus, this should also be taken into account when developing holistic electrification strategies.

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