Rural Electrification in Mozambique: Challenges and Opportunities

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Abstract. The International Energy Agency states that access to electricity is an essential condition for sustainable human development, however, it is estimated that approximately 22% of the world population (about 1.6 billion people) does not have access to electricity, a significant part of these people live in rural areas of developing countries in Sub-Saharan Africa, despite the fact that Africa has enormous potential in renewable and non-renewable energy sources. In Mozambique, approximately 50% of the population does not have access to electricity due to the fact that 66.6% of the population lives in rural areas, where the rate of access to electricity is even worse, paradoxically, Mozambique has a significant potential for renewable energy sources equivalent to 23 TW, this potential when combined with factors such as commitment to ensuring access to electricity for all, forecast of population growth and electricity demand, generates huge investment and long term business opportunities in the electricity sector, however, there are economic, social and cultural challenges that constitute uncertainties that should be considered in the decision-making process for investment in rural electrification infrastructure in the specific context of Mozambique and Sub-Saharan Africa in general. This article aims to discuss the possibilities that Mozambique has to guarantee access to electricity for all by 2030 (emanating from United Nations Sustainable Development Goal 7) emphasizing land use plans and education for rural electrification benefits through the use of renewable energy sources.

1. Introduction

Access to electricity is a fundamental and indispensable condition for ensuring the industrial and socioeconomic development of communities around the world, over 22% of the world population (corresponding to approximately 1.6 billion people) does not have access to electricity, [1–3]. According to [1, 4] it is estimated that 57% of the African population (approximately 630 million people) does not have access to electricity due to the fact that about 80% of the African population lives in rural areas without electricity infrastructure, despite the availability of a huge variety of renewable and non-renewable energy sources. For [5] the African continent is running against clock to increase access to electricity, which on the one hand is challenged by rapid population growth estimated to increase from approximately 1 billion in 2016 to approximately 2.4 billion in 2050, and on the other hand, challenged by large-scale investments and rapid growth of the extractive industry, modernization of the residential sector and socioeconomic development of African society, are just a few examples that challenge African leaders and governments to seriously invest in electricity infrastructure (generation, transmission and distribution systems).

The very low access to electricity in Africa is potentially critical in the sub-Saharan region where according to [6] less than 30% of the total Sub-Saharan African population has effective access to electricity due to a very low electrification rate, deficient conditions for the maintenance and operation of the existing infrastructure, the majority of the population resides in remote rural areas, of difficult access, with spatial heterogeneity, access paths with uneven pavement and without coverage by the infrastructure of electricity distribution.

It was within the global panorama of access to energy that the United Nations Organization defined the Sustainable Development Goal 7 (SDG-7) declaring access to affordable, reliable, sustainable, and modern energy for all by 2030, it is globally proven that without access to energy sources it is not possible to achieve sustainable industrial and socioeconomic development [2, 7]. Despite huge efforts to ensure access to electricity in sub-Saharan Africa, [6] say that from the point of view of current situation, trend of access to electricity by the populations of sub-Saharan Africa, new private and public investments in electricity infrastructure, there is no clear evidence that the SDG-7 defined by the United Nations will be effectively achieved in the region of sub-Saharan Africa by 2030.

The critical context of access to electricity in the in Sub-Saharan Africa extends to the Southern African Development Community (SADC) region comprising 15 member states with a total population of approximately

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341 million in 2017 (expected to reach more than half a billion by 2050) currently representing 33% of the total population of sub-Saharan Africa (more than 1 billion in 2017, [8]). In southern Africa (SADC region) the rate of access to electricity in 2013/2014 was around 37% of the total population of the region [9].

In Mozambique (a member state of the Southern African Development Community (SADC) with approximately 30 million inhabitants according to 2017 population census, published in 2019), access to electricity (or clean, sustainable and affordable sources of energy) for all is a huge and challenging task, despite the progressive trend, the rate of access to electricity is still very low as 6% in 2004, 7% in 2005, 17% in 2010, 20% in 2014, 24% in 2016, 25% in 2017 and 32% in 2019 [INE data, 2019] and [8–11] as illustrated in the graph 1 below:

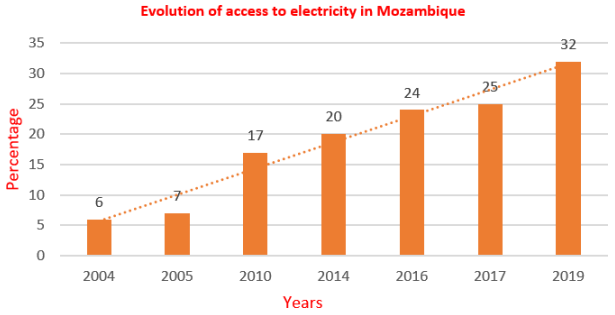

Figure 1. Evolution of access to electricity in Mozambique [INE data, 2019] and [8–11].

2. Penalizing factors for electrification in Mozambique

According to data from the *Intituto Nacional de Estatistica-Mocamique (INE, 2017)* resulting from the 2017 population census, rural areas have a very low access rate (17.43%) when compared to urban areas (82.57%), the rural areas are deeply penalized due to a combination of several factors such as, rural communities located in remote areas, difficult to access, far from electricity infrastructure (generation, transmission and distribution), spatial heterogeneity, access roads with rough and irregular pavement, low population density, significantly low electricity demand, low ability to pay the electricity bill as a result of low purchasing power, high risk of low (or no) return on investment, high costs of operating and maintaining the power grid due to extension as locations are remote [12]. There is no doubt that access to electricity is a fundamental element for sustainable industrial and socioeconomic development for communities [2], however for the investment to be economically and financially viable, it is important to ensure sustainability, affordability, proximity between the power generation point and the power demand and consumption market [12].

3. Challenges of rural electrification in Mozambique

Electrification and massive access to electricity generate business opportunities, create value chains, develop economies and local communities. This article intends to discuss the real possibilities that Mozambique has to achieve access to electricity for all taking into account that Mozambique is a country in Sub-Saharan Africa, a member state of the United Nations, committed to the Sustainable Development based on electricity access, the discussion considers four factors:

(i) Rapid population growth and rural electrification (Forecast for Mozambique);
(ii) Power demand and consumption (Forecast for Mozambique)
(iii) Land use planning and electrification (Mozambican reality)
(iv) Education for rural electrification benefits (Mozambican context)

3.1 Population growth and rural electrification in Mozambique

The number of population in Mozambique grows steadily, successive population censuses recorded 12.1 million in 1980, 16.1 million in 1997, 20.6 in 2007, 27.9 in 2017, 30.1 million in 2021, expected to reach 48.2 million in 2042 (Source: INE-Mozambique, 2017 population census and JICA Study team).

Forecasts indicate that by 2030, 45% of the Mozambican population will not have access to electricity, this forecast challenges the government authorities of Mozambique and Sub-Saharan Africa in general and their private investment partners, to redouble efforts, race against time, ***act and think for tomorrow*** to ensure access to electricity for all by 2030 as recommended by SDG-7. The curves in figure 2 show forecasts for population growth and electrification rates in Mozambique until 2042.

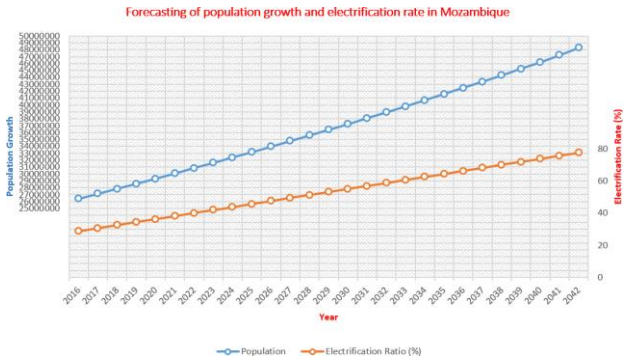

Figure 2. Forecast curves for population growth and electrification rate in Mozambique (data from INE-Mozambique, 2017 population census and JICA study team).

Total electrification (100% electrification rate) and access to electricity for all in Mozambique, is deeply challenged by the accelerated population growth which is expected to reach approximately 48.3 million inhabitants in 2042, however electrification is expected to reached just 77.5%. In this sense, if the electrification rate increases in accordance with the forecasts, there is no guarantee that

the goal of access to electricity for all will be achieved by 2030, anticipatory action is strongly recommended.

3.2 Power demand and consumption (forecast data for Mozambique)

In Mozambique, 66.6% of the population resides in rural areas, which less than 20% have effective access to electricity [INE, 2017], despite multiple challenges, constraints and limitations, electricity demand is expected to grow rapidly as result of several factors such as rapid population growth, development and modernization of the extractive and mining industry, emergence of new urban residential areas and expansion of existing ones, improvement of living conditions and modernization of the residential sector, development and modernization of the agro processing sector, development of the manufacturing, trade and services sector [11].

The graph 3 below shows demand and consumption fore- cast curves in Mozambique up to 2042 [Source: INE, 2017 and JICA study team].

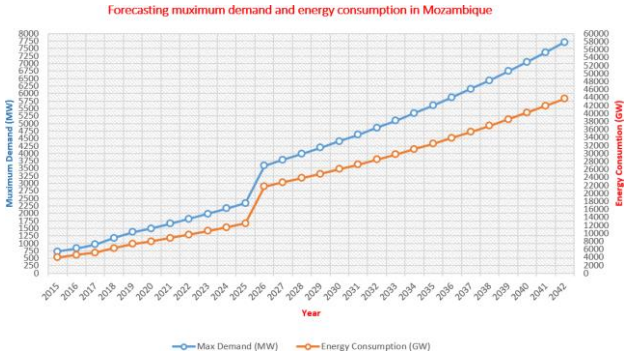

Figure 3. Electricity demand and consumption forecast in Mozambique [Souce: INE-Mozambique, 2017 population census and JICA study team].

The demand and consumption curves have an obviously growing trend, this reality challenges leaders, private partners and decision makers for serious investments in electricity infrastructure (generation, transmission and distribution systems), otherwise the number of people without access to electricity will certainly grow with the rapid growth of the population in accordance with the forecasts discussed previously.

According to the International Energy Agency, access to electricity is a fundamental and indispensable condition for sustainable human development [2], access to electricity is closely related to investment in infrastructure, government authorities and private partners recognize the strategic value of investments in electricity infrastructure [11]. In the global context, it is known that approximately 1.6 billion people do not have access to electricity, the vast majority of these people live in Sub-Saharan Africa [2], if serious investments in electricity infrastructure are not made, [13] predicts that the number of people without access to electricity worldwide will be around 1.4 billion by 2030, contrary to the commitment to the SDG-7 targets.

3.3 Land use planning and electrification (Mozambican rural reality)

In any context, land occupation and population distribution is influenced by physical and human factors such as soil fertility, geographic location, existence of essential resources, climate conditions and its variations, temperature, rainfall, cultural heritage, terrain conditions [14]. In the current context (of the modern era), sustainable human development cannot be addressed without the provision of basic services and resources such as water, electricity, telecommunications, domestic gas, the road and transport network and other social equipment of public utility, however supplying these resources requires large investments in specific infrastructures that are expected to be technically, economically and financially viable, therefore land use plan is a fundamental condition.

In rural areas of Mozambique, where 66.6% of the Mozambican population lives, land occupation and population settlements have adverse factors that discourage investments in public utility infrastructures, are normally areas of very low population density, the land is occupied in a disorderly and informal way, the settlements have a random dispersion configuration, land occupation does not follow any structured land use plan, as illustrated in the figures 4 and 5 below.

Figure 4. Peripheral area of the city of Lichinga, Province of Niassa, North of Mozambique [15].

Figure 5. Rural area of Cabo-Delgado province, Northern Mozambique [Source: Photo by EVANDRO HOLZ, published on *Perfil do Setor de Habitação Moçambique 2018, UN Habitat Moçambique* [16].]

In this configuration of land occupation and use, it would be difficult to find a model (configuration or

topology) suitable for an electrification project that ensures viability, the lack of land use plans discourages investments in electricity infrastructure, thus rural communities live without access to electricity, trapped in a vicious circle of chronic poverty, underdevelopment, social instability and rural exodus looking for better living conditions.

According to [17] Morris Cooke head of the Rural Electrification Authority (REA) in the USA stated in 1935:

> "[...the promise of continued drudgery and the absence of modern comforts have helped drive from the farm to the city those who were most needed in the farm- the young people]."

Electrification and increased access to electricity in rural areas create conditions for sustainable, balanced human development, in harmony with the environment, generates employment and business opportunities, absorbs and maintains the workforce and avoids rural exodus.

In this sense, Mozambican government authorities are challenged to implement massive territorial planning programs for structured land occupation, as one of the basic conditions for safe and profitable investment in power grids with known topologies for easy optimization.

3.4 Education for rural electrification benefits

The race against the clock to achieve the SDG-7, can trap developing countries in simple statistics of an increasing number of people with access to electricity, without substantial results from the point of view of sustainable human development, each context has its specificities to be taken into account, socioeconomic and cultural factors can be pitfalls (uncertainties). No electrification model will perfectly fit all rural contexts in Sub-Saharan Africa due to behaviors, attitudes and practices based on the cultural heritage of each rural community.

In Mozambique, the 2017 general population census recorded 39% of the illiterate population (approximately12 million people) of which 62.4% are residents of rural areas, in addition, only 6.6% of the Mozambican population has access to the internet, 4.4% with access to a computer and 26.4% have a cell phone [source: INE,2017]. Furthermore, the prevalence of poverty has significantly high rates despite the decreasing trend, according to [18] the proportion of Mozambicans living below the poverty line was 60% in 2002/03, 58% in 2008/09 and 48.4% in 2014/15.

The aforementioned data clearly indicate that the rural Mozambican environment has very high levels of illiteracy, a very low rate of access to Information and Communication technologies, high rates of poverty, and a very high rate of poverty prevalence.

Reflection question: In this context (of illiteracy, lack of information and poverty) what are the real possibilities that rural electrification in Mozambique will not only be a statistical growth of people with access to electricity, but that electrification will truly be reflected in sustainable human development of rural communities?

3.5 Leveraging successful experiences

According to [17] in 1930, rural communities in the United States of America created a cooperative movement for rural electrification throughout the country, at that time, President Flanklin D. Roosevelt created the Rural Electrification Agency (REA) through an executive order that was promulgated by Congress in 1936. In addition to providing funds for investment in electricity infrastructure, the Rural Electrification Agency (REA) systematically provided logistical support by sending qualified and specialized technical personnel to train, educate and dialogue with rural communities about electricity, its use and its socioeconomic impact, support with technical, managerial, legal and accounting issues. In addition, the REA interceded with manufacturers to design equipment that fits the needs of rural areas.

The successful experience of the United States of America alerts Sub-Saharan Africa and particularly Mozambique to an important issue: ***It is not enough to electrify, it is necessary to educate.***

The lack of education of rural communities for the socioeconomic benefits of electrification has the potential to reduce electricity to the perspective of lighting only, so the objectives of sustainable human development would not be achieved despite the electrification.

3.6 Rural electrification and cultural factors

About 2.4 billion people worldwide use biomass as an energy source for cooking and heating, developing countries account for 99% [2]. Biomass is an organic material of plant and animal origin (such as plant and animal remains, waste from agricultural and industrial products) that can be used as an energy source, converting biomass energy to a usable form of energy has multiple benefits for the environment, contributes to producing energy and eliminating discarded waste products at the same time [19].

In Mozambique, the use of biomass energy is directly linked to the direct burning of firewood and charcoal as the only natural source of energy available to rural communities for several centuries, resulting in the indiscriminate felling of trees, deforestation, with considerable negative environmental impact, the direct burning of firewood is part of many cultural, traditional and gastronomic practices of rural communities in Mozambique (such as certain types of food consumed on a daily basis that are enjoyed when cooked over wood burning stoves, meal preparation for popular events and traditional ceremonies) are some examples of the massive use of firewood as an energy source.

Despite the recognized importance of access to energy sources, we should not solve a problem (access to energy sources) by creating another (environmental degradation), the exploitation of natural resources as a source of energy in rural communities, must be done in a balanced and sustainable way. If there is significant environmental

damage due to the felling of trees to obtain firewood for cooking and heating, it should not be assumed that this is an efficient way of extracting energy from nature. Therefore, there are significant socio-cultural aspects based on cultural heritage that determine the practices and way of life of rural communities, representing the risk and uncertainty that trees can continue to be felled, causing deforestation and environmental degradation, even after electrification and increased access to electricity.

Public or private investments in rural electrification projects for the sustainable development of rural communities should consider socio-cultural aspects as existing and observable uncertainty factors.

3.7 Electrification and transformation of communities

Based on the International Energy Agency, access to electricity is indispensable for sustainable human development, electrification and massive access to electricity in rural areas is a factor of social transformation that directly impacts the way of life of rural communities. To achieve the transformation based on sustainable human development through access to electricity, rural communities must be the primary agents of their own transformation process, nobody should develop them, they must develop on their own, it is necessary to educate rural communities [2] on a dialogue basis to avoid being passive receivers (or simple observers) without understanding the socioeconomic value and impact of electrification, with the risk of reducing access to electricity just for lighting.

In rural Mozambican communities, with an education and way of life strongly influenced by cultural values, to achieve sustainable human development, it is important to dialogue, educate, train and influence, taking into account the natural tendency of humanity to resist changes and the fact that these communities are not familiar with the regular use of electricity.

The advantage of education after electrification is that rural communities actively participate and take ownership of the process of their own development, which accelerates development and economic gains.

4. Availability of renewable energy sources

In addition to mineral coal and natural gas, Mozambique has a variety of renewable energy sources, with emphasis on hydro, wind, solar, biomass, geothermal and waves, is one of the largest producers of renewable energy in the Southern African Development Community (SADC) region, a study carried out by Mozambican government authorities in the Renewable Energy Atlas of Mozambique revealed a potential equivalent to 23.000 GW distributed throughout the country as illustrated in the table 1 below [Source: Renewable Energy Atlas of Mozambique, 1st edition, 2000/14].

The potential for renewable energy equivalent to 23 TW identified in Mozambique is a huge investment and long-term business opportunity, offering gains for investors, rural communities and government authorities, for sustainable and balanced development in complete harmony with the environment competing for the achievement of SDG-7.

Table 1. Renewable Energies in Mozambique (in GW) [Source: Renewable Energy Atlas of Mozambique, 1st edition, 2000/14].

Solar	Hydro	Wind	Biomass	geothermal
23000	19	5	2	0.1

5. Conclusion

5.1 Industrial and socioeconomic perspective

The debate on electrification and increasing access to electricity in rural areas of Mozambique should not be restricted to investment in electricity infrastructure (generation, transmission and distribution), the International Energy Agency argues that electrification and access to electricity must allow sustainable human development, in this sense, in addition to the others, we consider only three players, in a win-win-win relationship, or triple benefit based on, 1. **Investors** (with return on investment-RoI); 2. **Communities** (with sustainable human development- SHD) and; 3. **Environment** (balance and sustainability), as illustrated in the figure 6 below.

Understanding the benefits of electrification and access to electrification in rural communities is a complex process, the high rates of illiteracy and poverty in communities deeply influenced by cultural habits and traditional practices, are just a few examples of uncertainties to take into account, thus the role of government authorities and private partners is so extensive that it should not be restricted to the availability of investment funds only, educating, training, dialoguing and influencing should be the commitment after the investment, so that rural communities in Mozambique can quickly understand the economic value of electricity and the transformation it can cause in their lives. It is also the role of government authorities to ensure formal land occupation by promoting land use planning programs so that electrification is technically feasible.

In general, land occupation in rural communities in Mozambique is characterized by random, informal and disorderly occupations forming low density population settlements, thus land occupation without observing land use plans does not ensure technical feasibility for electricity infrastructure, low population density does not ensure sufficient demand to ensure return on investment, these are just a few examples of factors that discourage investment in electricity infrastructure

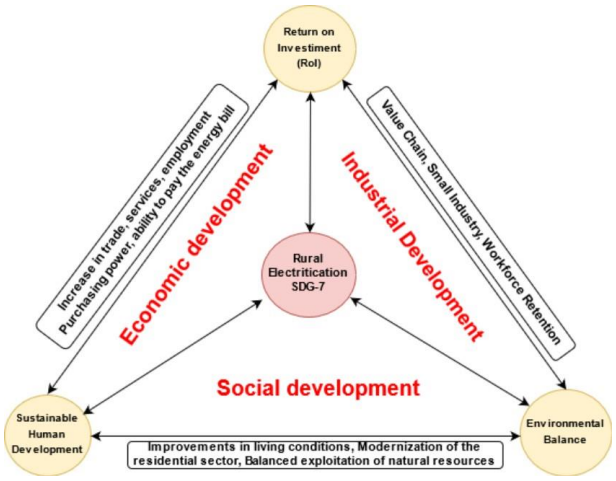

Figure 6. Triple benefit (win-win-win) relationship for rural electrification

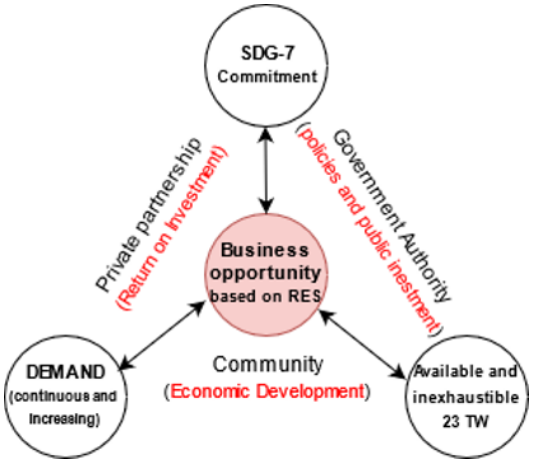

Figure 7. Favorable factors for investment in the use of RES in Mozambique

5.2 Investment opportunities perspective

The current situation and trends from the standpoint of electrification and massive access to electricity in Mozambique, based on the recommendations of the SDG7 is a possible and achievable task but far from being an effective reality, therefore, the use of renewable resources of which Mozambique has a vast potential has been pointed out as viable and sustainable solution, in this article, the authors identify three pillars that underpin the investment opportunity in the renewable energy sector in Mozambique as illustrated in figure 7, namely:

(i) The urgent need for electrification and of massive access to electricity (Commitment to achieve SDG-7).

(ii) The existence of a significant identified renewable energy potential equivalent to 23 TW (available and inexhaustible).

(iii) The existence of a huge and promising electricity demand market (continuous and growing demand).

The combination of the three pillars requires strong coverage from government authorities to create policies to attract, facilitate and make more flexible the participation of private investment, the expansion of business opportunities in the renewable energy sector should not be restricted to large-scale investments, it is important to involve local cooperatives in the management of small power generation systems, ensuring training in management, operation and maintenance, for the economic and financial empowerment of rural communities and boosting the local economy as a direct benefit of electrification through the use of available and abundant Renewable Energy Sources.

References

1. Z. Ding, M. Liu, W.J. Lee, D. Wetz, *An autonomous operation microgrid for rural electrification*, in *2013 IEEE Industry Applications Society Annual Meeting* (IEEE, 2013), pp. 1–8
2. T. Mohn, IEEE Power and Energy Magazine **11**, 46 (2013)
3. R. Nyakudya, T. Chikowore, S. Mhlanga, L. Nyanga, *A decision support tool for rural electrification grid design*, in *2013 IEEE International Conference on Industrial Technology (ICIT)* (IEEE, 2013), pp. 1443–1449
4. A. Medinilla, B. Byiers, K. Karaki (2019)
5. B. Graeber, *Generation and transmission expansion planning in southern Africa*, in *1999 IEEE Africon. 5th Africon Conference in Africa (Cat. No. 99CH36342)* (IEEE, 1999), Vol. 2, pp. 983–988
6. M. Kanagawa, T. Nakata, Energy policy **36**, 2016 (2008)
7. M.M. Uamusse, Ph.D. thesis, Lund University (2019)
8. S. RENO (2018)
9. B. Nhamire, J. Mosca, *Electricidade de Moçambique: mau serviço, não transparente e politizada* (CIP, Centro de Integridade Pública Moçambique, 2014)
10. P. Mulder, J. Tembe, Direção Nacional de Estudos e Analise Politica (2006)
11. D. Salite, M. Cotton, J. Kirshner (2020)
12. O.M. Longe, L. Myeni, K. Ouahada, *Renewable energy solution for electricity access in Rural South Africa*, in *2019 IEEE International Smart Cities Conference (ISC2)* (IEEE, 2019), pp. 772–776
13. S.R. Connors, *Providing Electricity Services to Rural Africa*, in *2007 IEEE Power Engineering Society General Meeting* (IEEE, 2007), pp. 1–3
14. R.C. Muanamoha, Master's thesis, Universidade Federal de Minas Gerais (1995)
15. J.M. Maloa, urbe. Revista Brasileira de Gestão Urbana **11** (2019)
16. M. Guarneri, E. Holz, T. Ramalho, in *Developing National Urban Policies* (Springer, 2020), pp. 319–333
17. A. Sebitosi, P. Pillay, R. Ramakumer, *Electrification of sub-Saharan Africa*, in *IEEE Power Engineering*

Society General Meeting, 2004. (IEEE, 2004), pp. 2098–2100

18. World Bank, Tech. rep., The World Bank, Washington, DC (2018), http://documents1.worldbank.org/curated/en/600731554132409626/pdf/Overview.pdf
19. B.K. Blyden, W.J. Lee, *Modified microgrid concept for rural electrification in Africa*, in *2006 IEEE Power Engineering Society General Meeting* (IEEE, 2006), pp. 5–pp