MEASURING ENERGY POVERTY IN MOZAMBIQUE: IS ENERGY POVERTY A PURELY RURAL PHENOMENON?

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Abstract

Mozambique is one of the largest energy producers in the Southern African Development Community. Substantial efforts have been undertaken in recent years to increase energy access in the country; however, almost 70% of the Mozambican population still lives without modern energy services. The study assesses the extent of energy poverty and the impact of the different dimensions of energy poverty in Mozambique using the multidimensional energy poverty index approach and Mozambican demographic and health surveys data for households. It concludes that Mozambique has improved from acute energy poverty in 2009 to moderate energy poverty in 2015. Increased inequalities, however, accompanied this improvement. Energy poverty is a rural issue and an urban phenomenon since 34% of urban households are energy poor, suggesting that energy poverty in the country is a lack of access and a lack of capacity to afford energy services to fulfill basic needs. Therefore, coordinated political actions between the various economic sectors and policies that focus on meeting the population´s basic needs, on technical, financial, and infrastructural issues may enable income generation and upgrade the use of electricity and its impacts on human development. Finally, we propose changes to the method to highlight the relevance of productive uses of energy for energy poverty alleviation. We also suggest the introduction of energy affordability measure in the MEPI framework to identify the causes of energy poverty.

Keywords: Energy poverty, poverty alleviation, Development

1. Introduction

Modern energy services[1] are granted in developed countries and remain unavailable to many world populations in developing countries. In these countries, basic needs such as food, lighting, appliances, water, sanitation, essential health care, and communication are challenging (Nussbaumer et al., 2013).

Mozambique has significant renewable and non-renewable energy resources, and it is one of the largest energy producers in the Southern African Development Community – SADC, (ALER, 2017; Cuvilas et al., 2010; Mahumane & Mulder, 2019; WEC, 2016). However, more than 90% of the energy sources (natural gas, coal, hydro) produced in the country are for export (Cuvilas et al., 2010; Mahumane & Mulder, 2019). Despite the wealth in energy sources, Mozambique is the sixth poorest country (with a Human Development Index of 0.446 in 2018), ranking 180 out of 185 classified countries and suffers from acute energy poverty (Nações Unidas, 2019; Nussbaumer et al., 2013). About 66.7% of its population lives in rural areas, of which 77.8% are women and children under 16 years old, 66% of the active population works in agriculture, fisheries, and forestry, of which 87.8% are rural women (INE, 2019). Traditional solid biomass (charcoal and firewood) is the principal energy source for most Mozambicans. Projections expect that solid biomass will remain responsible for 60%-50% of total final energy consumption by 2030, with insipient use of modern forms of energy for cooking (electricity, natural gas, PG) (Mahumane & Mulder, 2016, 2019). In 2018 total natural gas final consumption was 5360.0TJ-gross, IEA (2020)[2].

The lack of access to modern and clean energy disproportionally affects the population by intensifying the inequalities of social positions, economic capacity, and the roles defined by gender (Daly & Walton, 2017; Practical Action, 2012). Women and children in rural areas walk several kilometers and hours to collect firewood for cooking and get to the nearest water well or manual water pump. According to (INE & MISAU, 2018), 40% of rural households walk at least 30 minutes to get to the water source for drinking water. Women and children spend hours processing cereals for cooking (for instance, when there are no electric or diesel mills/grinders, women and children spend hours grinding) and cooking, exacerbating gender inequalities. Estimation in (Daly & Walton, 2017) suggests that the households relying on biomass for cooking spend around 1.4 hours/day collecting firewood and several hours cooking.

[1] Such as transportation, warm/cold room, light, cooking, communication, entertainment, education.
[2] https://www.iea.org/data-and statistics?country=MOZAMBIQUE&fuel=Energy%20consumption&indicator=Natural%20gas%20final%20consumption, accessed on September 29, 2020.

The traditional burn of biomass for cooking generates high levels of indoor air pollution. (Daly & Walton, 2017) estimated that 2.8 billion people die prematurely each year because of the indoor pollution caused by the traditional burn of biomass in inefficient stoves or from the combustion of kerosene or coal for cooking, and about 2.5 million of the annual premature death will still be attributable to household air pollution by 2030.

Mozambique lacks electricity and water infrastructures and has problems with roads network and transports that affect citizens' mobility. Without private vehicles, people depend on public transport (if it exists), semi-public/semi-collective and rented transport, or even walking to move from one area to another. In rural areas, adults and children walk for hours to get to the nearest road where semi-public transports stop or to get to the nearest hospital or school. In urban areas, as in Maputo, most adults and children rely on the shared and overcrowded public transports to move from home to work, hospital, school, and vice-versa, facing traffic congestion and hike segments at the beginning or end of the journey in unsafe areas without public lighting. According to (Mikou et al., 2019), only 17.8% of the Mozambican rural population live within two kilometers of the nearest primary and secondary roads. 55.7% of the country´s population live the nearest primary, secondary, tertiary, and track roads, meaning that the remaining rural population in the country walk more than 30 minutes to find the nearest road.

Access to clean, affordable, reliable, safe, and modern energy sources might reduce indoor air pollution, poverty, deforestation, the hardship of daily activities improving Education, health, employment, gender equality, transport, communication, production, commerce. This, in turn, will promote human Development, see for example (Bergasse et al., 2013; Bouzarovski, 2014; Carley et al., 2011; Nussbaumer et al., 2012; Reddy, 2003; Sher et al., 2014; Toman & Jemelkova, 2003). Hence, (Barron & Torero, 2017; Daly & Walton, 2017; Dinkelman, 2011; ECREE, 2015; Grogan & Sadanand, 2013; O´Dell Kathleen & Sophia, 2014; WEC, 2016) consider access to modern energy services as a fundamental social right and a critical element for the Development of societies It is also considered by (Sher et al., 2014) as the first step for the Development of any country.

Access to clean, affordable, reliable, safe, and modern energy services act as input for income generation and productive activities such as industries, agriculture, and commerce (one of the primary sources of self-employment in developing countries) small and medium-sized enterprises (one of the primary sources of job creation in developing countries), and thus, poverty alleviation. Additionally, access to modern and clean energy services reduces the time spent by women and children gathering fuelwood and processing cereals for cooking. It also enables them to engage in income-generating activities (women empowerment) and Education, contributing to the reduction of inequalities and health risks from exposure to pollution driven from the traditional burning of fuelwood.

The empirical literature on poverty relates it to production and income. (Nussbaumer et al., 2012) relates poverty with energy and emphasizes the multidimensional nature of energy poverty and the need to capture a range of its various elements to effectively reflect the complexity of the existing relationship between access to modern energy services and human development.

The United Nations Sustainable Development Goals (SDGs) recognized that access to affordable, reliable, sustainable, and modern energy is fundamental to achieve many of today´s global development challenges[3]. i.e., poverty is also related to insufficient access to affordable, reliable, sustainable, and modern energy (Daly & Walton, 2017).

Therefore, knowning the importance of energy access in achieving Sustainable Development, the Mozambican Government adopted the United Nations Sustainable Development Goals and committed itself to ensure universal access to electricity by 2030 (WORLD BANK, 2019).

Since the adoption of de UN Sustainable Development Goals, the Mozambican Government makes, significant efforts through projects carried out by Ministry of Land, Environment and Rural Development (MITADER); Energy Fund (FUNAE); Mozambican Government´s Five-year Plan for 2015-2019; and National Development Stragtegy for 2015-2053, to provide electricity access across the country, which caused the electrification rate to increase from 24% in 2015 to 39% (ALER, 2017; FUNAE, 2019; REN21, 2018).

However, all the Governments efforts on achieving sustainable development trough access to electricity are concentrated in rural areas see for example (ALER, 2017; FUNAE, 2019) ignoring the possibility of existence of houeholds in urban areas that can not afford for a minimal quantity of energy to fulfill their very basic needs in energy services.

The lack os inclusion of the sustainable development strategies for rural and urban areas inhabited by low income households is olso acoumpaigned by lack off policies focused on access to clean, affordable and modern energy sources for cooking.

[3] poverty, inequalities, climate changes, food security, health, unemployment, and human and sustainable development

Therefore, on can ask: is Energy Poverty a puraly rural phenomenon? What is the magnitude and intensity of energy poverty in the country?

Therefore, the objective of this work is to measure the level of energy poverty in Mozambique by updating and refining the calculation of the MEPI and the impact of the different dimensions of energy poverty at national, provincial, and regional levels using the 2015 Mozambican demographic and health surveys data for households[4]. However, although we recognize the importance of access to all forms of energy (electrical and mechanical) for poverty reduction, due to lack of data on the use of mechanical power for daily activities and mobility/transport, our analysis focuses on access to electricity, and modern fuels for cooking.

(Nussbaumer et al., 2012) relates poverty with energy and emphasizes the multidimensional nature of energy poverty and the need to capture a range of its various elements to effectively reflect the complexity of the existing relationship between access to modern energy services and human development. Their method, based on the Multidimensional Energy Poverty Index (MEPI), was applied to different regional areas, identifying countries where energy poverty is a more significant challenge (Ashagidigbi et al., 2020; Bensch, 2013; Endoumiekumo et al., 2013; Nussbaumer et al., 2013; Ogwumike & Ozughalu, 2016; Olang et al., 2018; Sher et al., 2014).

Little has been done in the literature on energy poverty in Mozambique. (House et al., 2011; Nussbaumer et al., 2012, 2013) showed that, at the time, Mozambique was a country suffering from acute energy poverty. These studies provided cross-country comparisons but not giving detailed information about the different dimensions that compose the MEPI, nor information at the provincial and regional (rural and urban areas) levels.

The study provides detailed information about the magnitude and intensity of energy poverty in the country. The information on the extent and intensity of energy poverty can help policymakers and social planners design policies, regulatory and financial strategies that target those affected by multiple energy deprivations in the country and monitor the progress and effectiveness of implemented response policies to SDGs. Furthermore, a detailed multidimensional analysis of energy poverty can be used to support integrated and multisectoral coordinated policies. The study results might help to allocate the public budget at national,

[4] https://dhsprogram.com/data/dataset/Mozambique_Standard-AIS_2015.cfm?flag=1

regional, and provincial levels targeting those affected by multiple deprivations in energy services. Finally, the study raises concerns about the issue of energy poverty in the country.

2. Literature review

2.1. Defining Energy poverty

Most literature considers energy poverty as fuel poverty; however, (Li et al., 2014) assume that they are two different concepts with some similarities. However, both concepts are related to low incomes and energy consumption of the residential sector.

Energy poverty focuses on access to modern energy services (a problem that occurs mostly in developing countries or Global South). Fuel poverty focuses on affordability, inefficient housing, heating systems issues, or thermal comfort problems that occur in developed countries or Global North (Bouzarovski, 2014; Bouzarovski et al., 2012; Hills, 2011; Li et al., 2014; Liddell et al., 2012; Moore, 2012; Recalde et al., 2019; Schuessler, 2014; Ürge-Vorsatz & Tirado Herrero, 2012; Viggers et al., 2013).

Developing countries understand energy poverty from the perspective of the relationship between access to energy services and socio-economic Development, well-being, or quality of life (Bazilian et al., 2012; Day et al., 2016; Endoumiekumo et al., 2013; Kaygusuz, 2011; Nussbaumer et al., 2012; Okushima, 2017; Schuessler, 2014; Sher et al., 2014).

Decades before the adoption of the UN Sustainable Development Goals, fuel poverty was already an issue of concern in England (Bollino & Botti, 2017; Bradshaw Jonathan, 1983; Day et al., 2016; Liddell et al., 2012; Maxim et al., 2016); however, it was only in 2002 that energy poverty emerged as a concept with (IEA, 2002). Both gained importance in global research and political agenda with the adoption of the United Nations SDGs and the need to include the poorest in the energy transition framework (Daly & Walton, 2017).

To define Energy Poverty (EP), we highlight the definitions given by (Reddy, 2003; Sher et al., 2014) and (Day et al., 2016). According to (Reddy, 2003; Sher et al., 2014), EP is “a situation where there is an absence of a choice of accessing adequate, reliable, affordable, safe and environmentally suitable energy services to support economic and human development.”

Within the capability framework (Day et al., 2016) define EP as “ inability to realize essential capabilities as a direct or indirect result of insufficient access to affordable, reliable, and safe energy services, and taking into account a reliable, reasonable alternative means of realizing the capabilities.”

Several reasons justify the choice of the two definitions. First of all, the definitions do not mention a specific form of energy, which allow the inclusion of electrical and mechanical power or a better description of energy poverty in the developing world. People lack access to electricity and modern fuels for cooking and mechanical power reduces the hardship of daily activities and improves mobility (Sovacool et al., 2012).

Secondly, although affordability issues are fundamental in the developed world, see for example (Liddell et al., 2012; Papada & Kaliampakos, 2016; Sovacool, 2015), there are also issues of concern in developing countries. Energy services´ prices remain above the population´s payment capacity, excluding people who have technical access to energy but cannot afford a minimal quantity of energy to fulfill their very basic needs. Hence, defining energy poverty in developing countries deals with access issues and affordability issues (Campbell et al., 2014; Stoerring, 2017).

Finally, in many developing countries, regions with technical access to the grid, households, health clinics, and companies use unreliable and inadequate energy, which compromises the production of goods and services and losses of medicines (Sampson et al., 2013; UNEP, 2017; WHO, 2010, 2014).

Thus, speaking of energy poverty is to find ways to deal with different aspects such as lack of access, affordability, reliability, availability, sustainability, and safety of energy services provided by electrical and mechanical power taken as granted for the developed world.

2.2. Measurements of energy poverty

Given the difficulty in finding a globally accepted definition for energy poverty and the considered difference between fuel and energy poverty, one may consider two significant approaches: fuel poverty approaches and energy poverty approaches.

Fuel poverty approaches: the most recent literature on fuel poverty argues that there are three main approaches used to measure the phenomenon: the expenditure-based approach, consensual based approach, and direct measurement approach (Bollino & Botti, 2017; Gouveia et al., 2019; Herrero, 2017; Sareen et al., 2020; Thomson et al., 2017).

Energy poverty approaches: Energy poverty is measured using the access approach, based on the assumption that since the problem in the developing world is the lack of access to energy services, having access to modern, clean, reliable, safe, and affordable energy services will bring good outcomes to the population, see for example (Daly & Walton, 2017; Endoumiekumo et al., 2013; Nussbaumer et al., 2012, 2013; Practical Action, 2012).

In the access approach, (Nussbaumer et al., 2012) proposed the Multidimensional Energy poverty Index (MEPI) methodology. The authors recognize that energy poverty is a complex and multidimensional problem related to multiple deprivations on energy services for lighting, cooking, and use of appliances such as refrigerator, TV/radio for Education and entertainment, telephone for communication, mechanical power. In the same context, the non-governmental Organization Practical Action developed the Total Energy Access indicator (TEA) (Practical Action, 2012).

Even though the MEPI methodology gives a robust measure of multi deprivation of energy services in the developing world, it has essential shortcomings. (Olang et al., 2018; Pelz et al., 2018) argue that the MEPI methodology does not capture attributes such as availability, and affordability, does not consider the consumer preferences, cultural norms, differences between energy sources, and lacks indicators that capture energy access stability.

For (Ahmed & Gasparatos, 2020; Dovie et al., 2017), the MEPI does not consider cooling services in the context of hot climates. In these places, climate change has been increasing the average temperature in summers, causing weather-related diseases. However, although we recognize the importance of having access to cooling systems in hot climates, considering cooling services as an indicator of MEPI methodology in the African context of where more than 50% of the population lives in houses made of precarious local materials can lead to biased results, (The World Bank Group, 2017; Viana, 2011).

Despite all the shortcomings of the MEPI methodology, it has been widely used to measure energy poverty in the developing world and worldwide, see for example (Ahmed & Gasparatos, 2020; APERE & Karimo, 2014; Ashagidigbi et al., 2020; Bollino & Botti, 2017; Dovie et al., 2017; Endoumiekumo et al., 2013; Nussbaumer et al., 2013; Ogwumike & Ozughalu, 2016; Olawumi Israel-Akinbo et al., 2018; Papada & Kaliampakos, 2016; Sher et al., 2014; Yip et al., 2020; Zhang et al., 2019).

Another multidimensional approach is the Multi-Tier Framework (MTF) that measures energy poverty by gauging the quality of energy delivered (Bhatia & Angelou, 2015; Pelz et al., 2018). This approach has the advantage of considering more detailed dimensions, distinguishing between access and usable energy, though, is not based on an existing dataset. Therefore it implies high costs of time in data collection (Culver, 2017; Pelz et al., 2018).

Finally, we have the capabilities approach developed by (Day et al., 2016). The capabilities framework has the advantage of not mentioning specific energy services, and therefore, it can be used within Global South and Global Noth.

Energy poverty metrics frame energy poverty in terms of services and distinguish between different household services or end uses of electricity; however, there is no explicit attention paid to mechanical power for agriculture, industry, transport, commercial activities, Education, and health services) that allow the generation of goods and services and thus increasing income potential and its value. Therefore, issues and challenges remain in all metrics (Pelz et al., 2018).

The present study will use the MEPI to measure Mozambique´s energy deprivations due to its advantages of using existing datasets. However, it is recognized that energy access is essential, but not enough condition to ensure social and economic development. It is thus necessary to consider the energy impact on human welfare and income generation possibilities (Bhatia & Angelou, 2015; Cabraal et al., 2005; Daly & Walton, 2017; Kaygusuz, 2011; Kirubi et al., 2009; Mayer-Tasch et al., 2013; Practical Action, 2012; Terrapon-Pfaff et al., 2018; Winkler et al., 2011).

The productive use of energy might be related to the provision of motor power for agricultural activities, small and medium-sized enterprises, and commercial activities. Agriculture employs more than 50% of the active population in most developing countries; small and medium-sized enterprises are primary sources of job creation and income generation in the developing world. Commercial activities are one of the primary forms of self-employment and household income generation.

Therefore, we suggest the inclusion of the variable productive uses of energy as one of the leading indicators of MEPI, introducing a binary response variable where a household can say if it uses energy to generate income at least in one of the activities mentioned above. The new variable will require a new weights distribution for the different indicators/dimensions.

2.3. Energy poverty in Sub-Saharan Africa

Few studies exist on energy poverty in Sub-Saharan Africa and, in particular, for the Mozambican case. A country panel study (House et al., 2011; Nussbaumer et al., 2012, 2013) showed that, at the time, Mozambique was a country suffering from acute energy poverty, with a MEPI of 0.82 and 0.87, respectively.

(Endoumiekumo et al., 2013; Ogwumike & Ozughalu, 2016) measured energy poverty using the MEPI approach in Nigeria, finding that 83.2% and 75% of the population were energy poor in 2009-2010 and 2004, respectively. The household size, educational level, gender, and age of the household head, region of the residence, the proportion of working members in the household, and general poverty were the determinants of energy poverty (Ogwumike & Ozughalu, 2016). Three years later, (Ozughalu & Ogwumike, 2019) found that the Nigerian energy-poor population´s share had dropped to just over 50%. In 2020, Nigerian households suffered from moderate energy poverty (MEPI of 0.38) (Ashagidigbi et al., 2020).

Still, in the Nigerian context, (Jackson & Tubodenyefa, 2018) argued that although the Delta Niger´s wealth in oil and gas resources, the local population rely on unclean and unaffordable energy, the local population is energy-poor, with a Multi-Tier Energy Poverty Index of 0.29, (Akande et al., 2018).

In South Africa (Olawumi Israel-Akinbo et al., 2018) used the MEPI methodology and found moderate energy poverty among low-income households. Heating fuels is the dimension that most contributes to the energy poverty of the sampled households. (Ismail & Khembo, 2015) used a different approach (expenditure approach) to study the determinants of energy poverty in South Africa and found that the households' expenditure patterns, race, educational level, dwelling size, location of the family, and access to electricity are the factors that explain energy poverty in the country.

(Ahmed & Gasparatos, 2020; Crentsil et al., 2019) used the MEPI methodology to measure and compare energy poverty patterns around industrial crop projects. (Ahmed & Gasparatos, 2020) registered lower energy poverty levels among jatropha and oil palm plantation than in sugarcane plantations, and (Crentsil et al., 2019) found a generalized reduction in the level of multidimensional energy poverty from 2008 to 2014 in the country, accompanied by significant incidence and intensity.

In the Ethiopian context, (Bekele et al., 2015) used the MEPI approach to measure energy poverty in Addis Ababa city, finding that 57.9% of the city households were suffering from multidimensional energy poverty. (Olang et al., 2018) also used the MEPI methodology to illustrate the linkages between fuel choice and energy poverty.

In his turn (Tchereni et al., 2013), using economic approaches of measuring energy poverty in South Lunzu-Malawi, found that 90% of the sampled households were energy-poor. Expenditure on transport, income level, age and educational level of the head of the family, household size, and home size were the main factors explaining energy poverty in the region.

3. Mozambican Energy Situation

3.1. Energy sources in the country

Mozambique has significant potential for renewable and non-renewable energy resources, and it is one of the largest energy producers in the Southern African Development Community – SADC, see Table A1. Supplementary material (ALER, 2017; Cuvilas et al., 2010; IRENA, 2013; Mahumane & Mulder, 2019; WEC, 2016).

With almost 129.6 trillion m^3 of natural gas reserves in Inhambane, Sofala, and Cabo Delgado provinces, the country has the fourth natural gas reserve worldwide, more extensive than those in Angola and Nigeria (ALER, 2017; Cuvilas et al., 2010).

The installed operating capacity in natural gas production is currently 3.1 billion m^3/year, but more than 90% of this production is exported to neighbouring South Africa. Until 2014 only 3.4% of the national production was consumed within the country (ALER, 2017; Cuvilas et al., 2010).

In terms of coal, Mozambique has relatively large reserves in Tete province, estimated at 2.4 billion tonnes, with a mean production capacity installed of 14 million tons of coal per year. Most of this production is for export (Cuvilas et al., 2010).

Regarding renewables, the country has a total potential of renewable sources (hydro, solar, wind, biomass, and geothermal) estimated at 23,026 GW see (Gesto -Energia, 2014). The most exploited in Mozambique is hydropower along the Zambezi river basin[5] , which accounts for more than 50% of all electricity

[5] Where is located the largest hydroelectric dam named Cahora-Bassa and the future Mphanda N´kuwa dam

generation in the country and more than 90% of the total primary energy supply (Global Legal Insights, 2020).

Until 2015, the Zambezi river basin through the Cahora-Bassa dam had an installed capacity of 2187 MW with a generation capacity of almost 1200 GWh/ year. Around 80-90 % of the electricity generated in this production is exported to neighbouring countries such as South Africa and Zimbabwe (Mahumane & Mulder, 2019; WEC, 2016).

In addition to the sources mentioned above, Mozambique has a significant solar potential of 1.49 million GWh/year, which is more than its energy consumption. The country has an estimated average global solar radiation of 5.4 kWh/m^2/day, with a capacity for installation of 2.7 GW (UNEP, 2017).

The significant availability of energy resources (Table A1, supplementary material) enables the to satisfy its own domestic needs in terms of energy and export it to neighbouring countries (such as South Africa and Zimbabwe). More than 90% of energy production in the country is intended for export rather than national consumption (ALER, 2017; Cuvilas et al., 2010; IRENA, 2016; Mahumane & Mulder, 2019).

3.2. Electricity Market

The Mozambican power system is developed as three separate systems (northern, central, and southern). It has a weak transmission network that lacks resilience and is not sufficiently spread to allow lower voltage network expansion (The World Bank, 2018). The electricity mix consists predominantly of hydropower generation capacity (NORFUND, 2020), mostly through Cabora- Bassa dam.

The long distances covered by the transmission network and its state of degradation generates significant electricity losses during the transmission process. According to (EDM, 2018) the low population density per square kilometre, low electricity consumption in the country[6] , and the problematic geographic relief in certain areas make network expansion very costly. This situation is exacerbated by natural disasters (cyclones and floods) that have been perpetuating the degradation of the electricity network.

The Ministry of Mineral Resources and Energy (MIREME) is the governmental body responsible for energy planning, policy formulating, regulating, and supervising the energy sector in the country with *Electricidade de Moçambique, E.P.* (EDM) as the only provider of the public services of the national

[6] according to IEA[6] until 2017, Mozambican electricity consumption per capita was of 0.5MWh

electricity power production, transformation, transportation, distribution, and commercialization, (ALER, 2017).

Mozambican legislation gives importance to the private sector involvement in the country´s energy market; however, the commercial and operational context is not attractive. The Government´s vision is to reduce poverty by providing electricity to the poorest groups in remote areas using social tariffs that do not generate profit opportunities for private investors. The week attractiveness of the market is also associated with the low electricity consumption in these areas and with the fact that EDM is the only entity authorized to buy electricity from producers acting as off-taker and sell it to consumers through the national power grid.

Therefore, private sector off-grid electrifications projects in the country are few and are made through public-private partnerships with Fundo de Energia (FUNAE). FUNAE is a public entity created for sustainable management of energy resources and to promote the development, production, and exploration of various forms of energy at low cost to supply electricity to rural and urban areas inhabited by low-income population in the country (ALER, 2017; WORLD BANK, 2019).

Although the Government offers social tariffs as a strategy for poverty reduction, these tariffs remain above the payment capacity of the majority of the poorest population in the country. According to (IEA, 2019), the bottom 40% poorest Mozambican households pay more than 15% of their average income on electricity to power essential energy services such as lighting, ventilation (fan), mobile phone charging, and television. This situation is aggravated by the average increase of around 120% in electricity tariffs since 2015 (see Table A3, supplementary material).

Despite the recent increase in electricity tariffs (Ahlborg & Hammar, 2014; EDM, 2018; IEA, 2019) argue that taxes remain not cost-reflective. The cost-unreflectiveness of the tariffs is challenging to the country regarding the opportunity cost of ensuring electricity access and the electricity supply´s financial viability (Ahlborg & Hammar, 2014; EDM, 2018; Mulder & Tembe, 2008).

Besides all the problems mentioned above, the Mozambican electricity system faces reliability problems causing losses in production and equipment breakdown. According to (world Bank, 2018) blackouts lead to 30% and 25% of the total losses in sales and production in low-income countries and Sub-Saharan Africa, respectively.

3.3. Electricity access and consumption

According to (REN21, 2018), in developing countries, particularly in Sub-Saharan Africa, energy access is still a significant challenge. In 2016, about 2.8 billion people lacked access to clean cooking fuels, while almost 1.06 billion people worldwide lived without electricity. According to (Daly & Walton, 2017), only 43% of the Sub-Saharan African population has access to electricity. Until 2030, the region will still represent about 89% of the people without access to electricity. About 850 million people in this region rely on solid fuels for cooking and make matters worse, and it is expected that this number will rise to 910 million by 2030. The Mozambican situation in energy access follows the standards mentioned above, despite its wealth of energy resources.

In recent years, significant efforts have been undertaken to provide electricity access in the country. The efforts lead to an increase in the electrification rate from 5.7% in 2001 to 24.2% in 2016 (Figure 2 below). When including off-grid electrification, mostly carried out by FUNAE, the electrification rate becomes 39% (REN21, 2018).

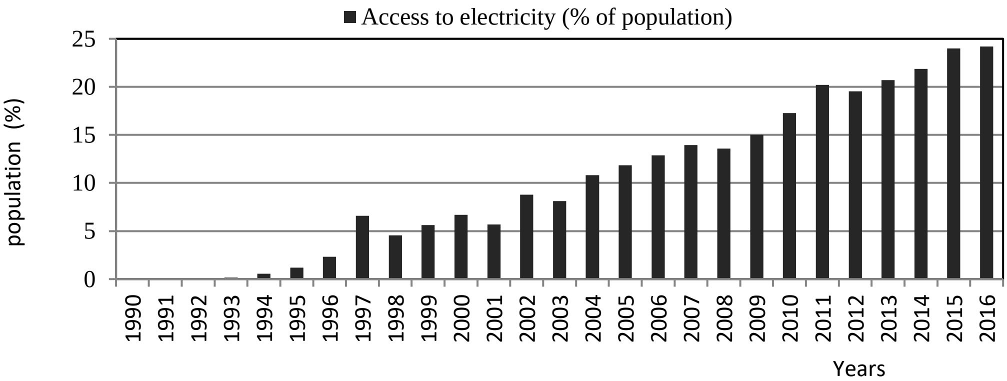

Figure 1. Evolution of access to electricity in Mozambique from 1994 to 2016
Source: Built from World Bank data

There are disparities in electricity access rates between rural and urban areas, about 27% in rural areas compared to 67% in urban areas (Ahlborg & Hammar, 2014; EDM, 2018; Mulder & Tembe, 2008; WORLD BANK, 2019). There are also disparities among the different regions. About 56% of the population in the Southern part (Inhambane, Gaza, and Maputo provinces) has access to electricity, compared to 17.5% and 17% for the northern (Cabo Delgado, Niassa, and Nampula provinces) and central region (Tete, Zambézia, Manica and Sofala provinces) regions, respectively, (WORLD BANK, 2019).

A growing trend in per capita electricity consumption accompanied the country´s increasing electricity access trend (see figure 2). The Mozambican Government´s efforts to enhance electricity access in the country during the 2000s and economic growth (8% on average) between 2001 and 2014 are the reasons for these ever-increasing trends (World Bank data 2020).

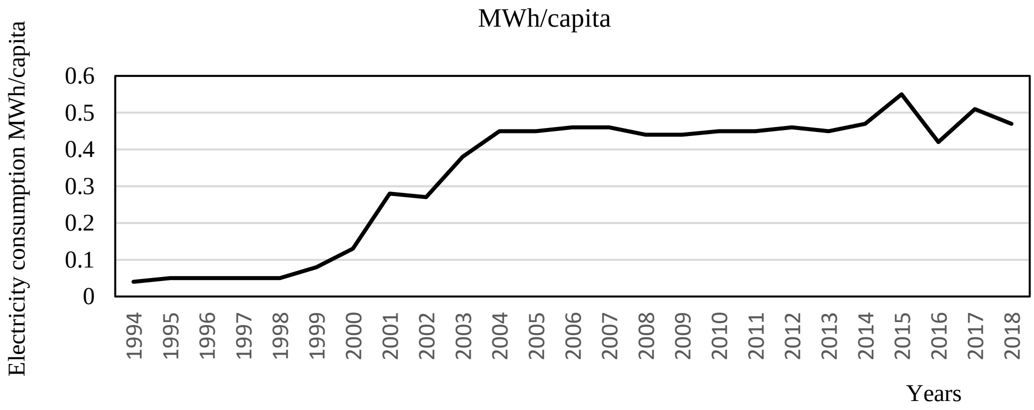

Figure 2. Per capita electricity consumption, Mozambique, 1990 – 2018
Source: Built from IEA data[7]

However, despite the growing trend in per capita electricity consumption, with an average per capita electricity consumption of 0.33 MWh, it is still below the average African per capita electricity consumption of almost 0.6 MWh (IEA 2020)[8] during the analyzed period (see figure A, supplementary material).

As in the case of energy access and electricity consumption per capita, Figure 3 shows strong growth in electricity consumption by sector of activities in the country, except for agriculture.

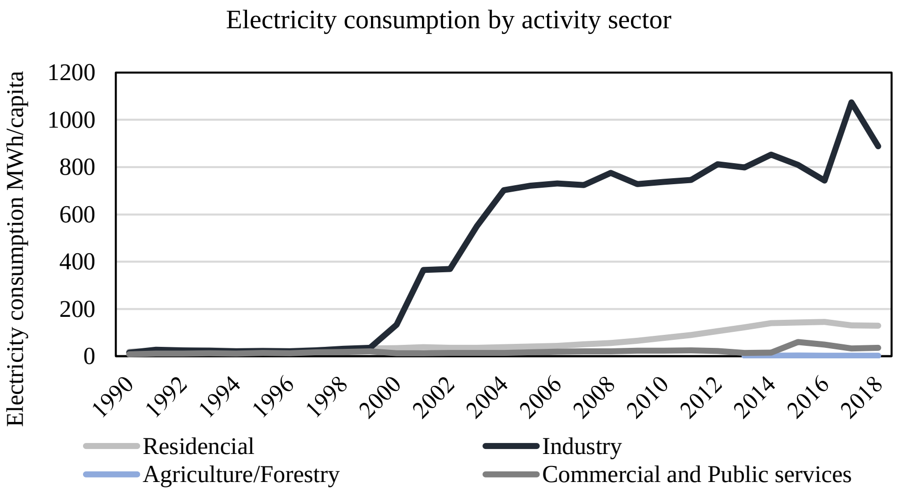

Figure 3. Electricity final consumption by sector, Mozambique, 1990 – 2018

[7] https://www.iea.org/data-and-statistics?country=MOZAMBIQUE&fuel=Electricity%20and%20heat&indicator=ElecConsPerCapita accessed on 24/10/2020.
[8] https://www.iea.org/data-and-statistics?country=WEOAFRICA&fuel=Electricity%20and%20heat&indicator=ElecConsPerCapita Accessed on 25/10/2020.

Source: Built from IEA data[9]

The agriculture, forestry, and fishery sector, whose tariffs have increased at a slower pace than the other sectors (see Table A2, supplementary material), employs more than half of the active Mozambican population and contributes the most to the country´s GDP). However, it is the sector that less consumes electricity.

The low electricity consumption in the sector reflects its subsistence character and the need for policy coordination between sectors that might stimulate electricity/energy use in the sector and thus upgrade agriculture productivity and employment.

According to (INE, 2019), Mozambique has about 27.9 million inhabitants, 66.65% of them live in rural areas (77.8% are women and children under 16 years old). 29.29% is economically active, 66% of these works in agriculture, forestry, and fishery (of which 87.8% are rural women), 12% works in commercial, finance, and public services, and 3.25% in industry, sectors that contribute with 24.24%; 16% and 19% for the country´s GDP, respectively, INE(2020)[10].

Electricity consumption is mostly concentrated in the industrial sector, which contributes to 19% of the Mozambican GDP but employs only a small fraction of the country´s active population, exacerbating social inequalities in the country and excluding most people from opportunities of participating in production activities.

4. Methods

For analysis and measurement of energy poverty in Mozambique, this study uses the Multidimensional Energy Poverty Index (MEPI) methodology proposed by (Nussbaumer et al., 2012) and created by the Oxford Poverty & Human Development Initiative (OPHI) with the association of United Nations Development Program - UNDP (Sher et al., 2014). we are using demographic and health surveys -DHS(made by USAID) data for 7169 Mozambican households (corresponding to 32557 peoples) for 2015.

The MEPI considers the set of energy deprivation that may influence an individual lifestyle. It is based on five dimensions that represent basic energy service needs with five indicators: modern cooking fuels, indoor

[9] *https://www.iea.org/data-and-statistics?country=MOZAMBIQUE&fuel=Electricity%20and%20heat&indicator=ElecConsBySector*, accessed on 24/10/2020

[10] http://www.ine.gov.mz/estatisticas/estatisticas-economicas/contas-nacionais/anuais-1/pib-na-optica-de-producao/pib-na-optica-de-producao-2020/view, accessed on 25.10.2020

pollution, electricity access, household appliances ownership, entertainment/education appliances ownership, and telecommunication means, see Table 1.

Table 1. Indicators and Weights of MEPI dimensions.

Dimension	Indicator	weight	Variable	deprivation cut-off (poor if…)
Cooking	Modern cooking fuel	0.2	Type of cooking fuel	use of any fuel besides electricity, LPG, kerosene, natural gas, or biogas
	Indoor pollution	0.2	Food cooked in the house or in a separate building using traditional solid biomass	True
Lighting	Electricity access	0.2	Has access to electricity	False
Services provided by household appliances	Household appliances ownership	0.13	Has refrigerator	False
Entertainment/ Education	Entertainment/Education appliances ownership	0.13	Has radio or television	False
Communication	Telecommunications means	0.13	Has mobile phone	False

Source: adapted from (Nussbaumer et al., 2012).

With this metric, a household is energy poor if it cannot achieve a minimum threshold of well-being in several energy dimensions and indicators; thus, the combination of the deprivation that it faces exceeds a pre-defined threshold $k = 0.33$. According to (Aguilar et al., 2019; Fisher-Vanden et al., 2015; Pelz et al., 2018; Sher et al., 2014), the threshold is arbitrarily defined according to the definition and measurement/approach used for energy poverty analysis.

Studies such as of (Ahmed & Gasparatos, 2020; Ashagidigbi et al., 2020; Bekele et al., 2015; Bersisa, 2019; Crentsil et al., 2019; Ozughalu & Ogwumike, 2019) used the energy poverty line (K=0.33%) proposed by (Nussbaumer et al., 2011). Conversely, other authors determined the poverty line according to the number of indicators considered in the study or as a percentage of the indicators, see for example,(Awan et al., 2013; Endoumiekumo et al., 2013; Ogwumike & Ozughalu, 2016; Sher et al., 2014) who determined a threshold varying from 0.2 to 0.6.

(Olawumi Israel-Akinbo et al., 2018) estimated the energy poverty threshold for the South African´s MEPI multiplying the Lower Bound Poverty Line (LBPL) and the Upper Bound Poverty Line (UBPL)[11], whose result was approximately 0.33.

There is no defined energy poverty line in Mozambique. There is no explicit criterion for the definition of the threshold for multidimensional energy poverty; therefore, similar to the studies of (Ahmed & Gasparatos, 2020; Ashagidigbi et al., 2020; Bekele et al., 2015; Bersisa, 2019; Crentsil et al., 2019; Ozughalu & Ogwumike, 2019), we adopt the energy poverty line of k=0.33 for the present study.

The MEPI dimensions are weighted according to their relative importance. Each dimension´s weights are equally divided among its indicators so that the total sum of the relative weights is equal to 1. In this scope, it is considered that access to modern, clean, safe cooking fuels is the most crucial energy need in developing countries. Therefore, it is attributed to the most significant weight of 0.4, which is equally divided between the two indicators in this dimension (modern cooking fuels and indoor pollution). The second-largest weight of 0.2 is attributed to access to electricity for lighting, and the remaining 0.4 is equally divided among the dimensions of household appliance ownership, entertainment/education, and communication, (Nussbaumer et al., 2012).

Let $d = 1,2,\dots,5$ be the five dimensions, $j = 1,2,\dots,6$ the considered indicators within the five dimensions, and α_j the associated weights attributed to the different indicators, such that $\sum_{j=1}^{6} \alpha_j = 1$.

If $c_{i(k)}$ is a deprivation score or the average deprivation score experienced by the household i, obtained by adding the weighted indicators,

$$c_{i(k)} = \alpha_1 I_{ji1} + \alpha_2 I_{ji2} + \cdots + \alpha_j I_{ji5} \quad \text{Eq. 1}$$

with $I_{ij} = 1$ if the household i is deprived in the indicator j and $I_{ij} = 0$ otherwise.

q is the number of energy-poor households, i.e., the number of families whose combination of the deprivation that it faces exceeds k, then

$$q = \sum_{i=1}^{n} c_i\,(k)\ if\ c_i(k) > 0.33 \quad \text{Eq. 2}$$

The metric allows computing a headcount ratio ($H = q/n$) which is the fraction of people known as energy-poor and the average of the intensity of deprivations of the energy-poor ($A = \sum_{i=1}^{n} \frac{c_i(k)}{q}$), i.e., the percentage of

[11] The LBPL and UBPL represente the allowance necessary for the consumption of non-food basic necessities by an average household composed by 3.8 peoples.

the dimensions in which energy-poor households have deprivations. The product between H and A gives the MEPI. $MEPI = H \times A$

Eq. 3

For the current study, the total sample of 7169 households was calculated using probabilistic sampling theory. The number of surveyed households in each province was determined considering the notion of the sample´s representativeness, and the effect of the number of inhabitants, i.e., the sample for each province is the share of its inhabitants (USAID DHS, 2012).

We recognize the importance of mechanical power for mobility as a component of energy poverty; however, finding data on this dimension limit the consideration to the theoretical scope.

All variables/indicators that compose the MEPI are defined here as in (Nussbaumer et al., 2012) except for indoor pollution. We assume that the household i is exposed to indoor pollution cooks food using any fuel besides modern cooking fuels in the house or a separate building. The present study considers the mobile phone as the single variable 'telecommunication.' This is justified by the fact that most families have a mobile phone, and only a tiny fraction (<2%) of families have access to phone landlines. Thus the simultaneous consideration of the two variables would lead to an overvaluation of the indicator.

Recognizing the relative importance of the different indicators on MEPI, the study assumes the relative weights considered in (Nussbaumer et al., 2012).

5. Results

This section presents the results of the MEPI and the different dimensions of energy poverty at the national and provincial level and a comparative analysis between provinces, and a sensitivity analysis of the other values obtained in the various areas as mentioned in Section one.

5.1. Overview

Before the presentation of the main results of the study, it is crucial to present an overview of the different variables that characterize the MEPI´s dimensions (the type of cooking fuels, indoor pollution, access to electricity; appliance ownership, telecommunications) for a better understanding of the results obtained for the MEPI.

Regarding the variable type of cooking fuel, the results show that 92% of the sampled households use biomass (wood and charcoal) for cooking (see figure 4), the use of modern cooking fuels (natural gas, electricity, coal/lignite, and biogas) is incipient. It is all concentrated in urban areas.

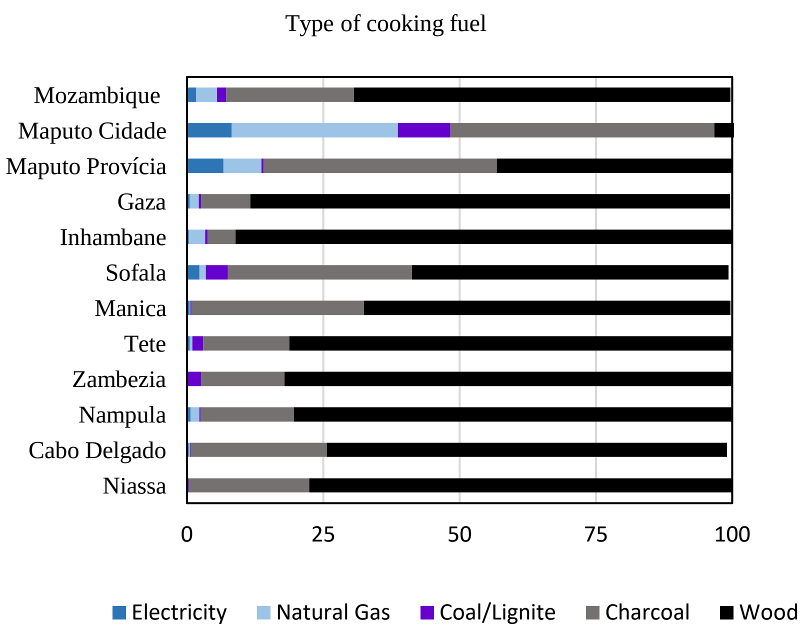

Figure 4. Type of cooking fuels in the percentage of households
Source: Built from DHS survey data

Almost 50% of households deprived of modern cooking fuels are exposed to indoor pollution; the other 50% also use traditional biomass but cook food outdoors (Figure 5).

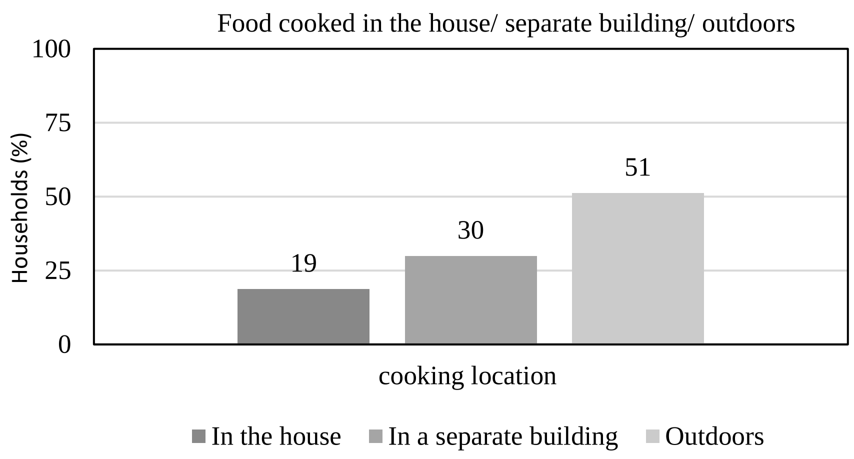

Figure 5. Indoor pollution
Source: Built from DHS survey data.

Although the use of traditional biomass is not considered as the primary source of environmental degradation, it contributes to deforestation, changes in land use, greenhouse gas emission, and health hazards see for example, (Akande et al., 2018; Crentsil et al., 2019; Daly & Walton, 2017; Day et al., 2016; González-Eguino, 2015; Nalule, 2019; Obeng et al., 2008; Ogwumike & Ozughalu, 2016; Sovacool, 2012; Ugboma, 2015).

The results also show that 66% of the sampled households were living deprived of electricity access in 2015, 53% lived in rural areas, and the other 47% living in urban areas, suggesting the coexistence of rural and urban energy poverty, see figure 6.

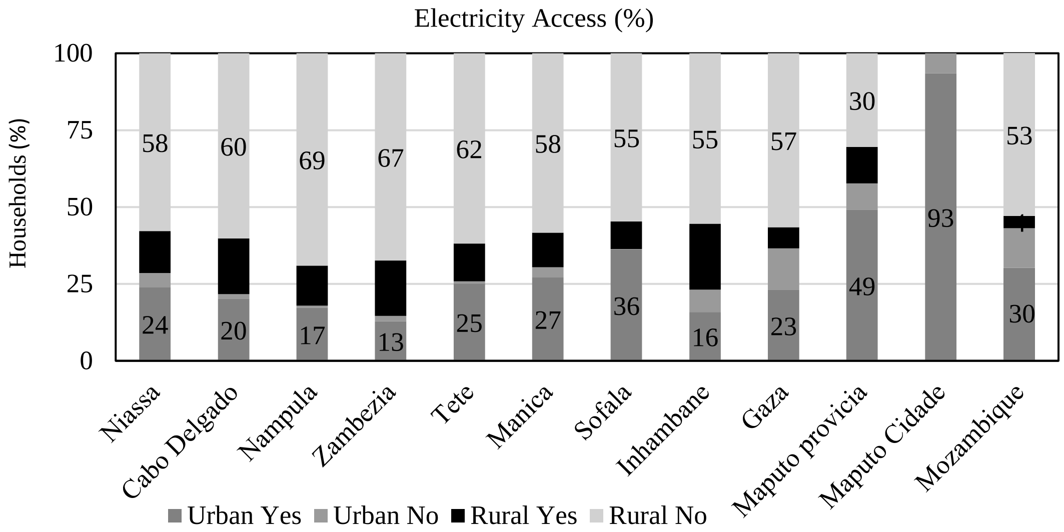

Figure 6. Electricity access at the national and provincial levels in the percentage of households
Source: Built from DHS survey data.

We also found that almost 80% of the sampled households did not have a refrigerator. At least 60% and 50% of households were deprived of entertainment/education appliance ownership such as television and radio in 2015, respectively (Refer to Figure A2 in the Appendix). Families deprived of entertainment means, such as radio and television, have restrictions on accessing information and are excluded from participation in the governance process; thus, energy poverty also coincides with income poverty.

Figure 6 shows that more than 50% of the sampled households lack access to electricity. However, more than 63.24% of the sampled households have a mobile phone (see figure A3 in supplementary material), which might be showing the importance of off-grid electricity access. One of the criticisms made to the MEPI stems from the fact that its methodology does not consider the different energy sources that allow access to electricity, reflected in the telecommunication variable. Thus, we suggest that access to telecommunications can no longer be used as a criterion to assess energy poverty since it is now widespread across the population. However, there is still an apparent condition of poverty in terms of access to on-grid electricity.

The low access to electricity in urban areas might suggest that households are in regions with physical access to the grid that cannot afford a minimum quantity of electricity to fulfill basic needs although living in areas with physical access to the grid.

The use of traditional biomass as the primary energy source for cooking suggests that electricity consumption is limited to more basic energy needs (lighting, mobile phone charging, and entertainment) reflecting affordability problems. i.e., using electricity for cooking might be a financially unviable option for the majority of households with access to the grid. Therefore, affordability of electricity access is about connecting a family to the grid and focusing on the affordability of using electricity.

6.2. MEPI, Headcount ratio, and intensity of energy poverty

Using the USAID database for Mozambican DHS survey data for household Record phase seven, version one for 2015,[12] we calculated the MEPI at national and provincial levels.

Setting the multidimensional energy cut-off k to 0.3, we classified the different regions according to the degree of energy poverty they face. A region is considered as suffering from acute energy poverty if $MEPI > 0.9$ or moderate energy poverty if $MEPI < 0.6$.

Comparing to the earlier assessment (2009), one may observe that Mozambique is no longer suffering from acute energy poverty but now features, at the national level, a Multidimensional Energy poverty Index ($MEPI$) of 0.65 (figure 7).

[12] year of the most recent DHS survey

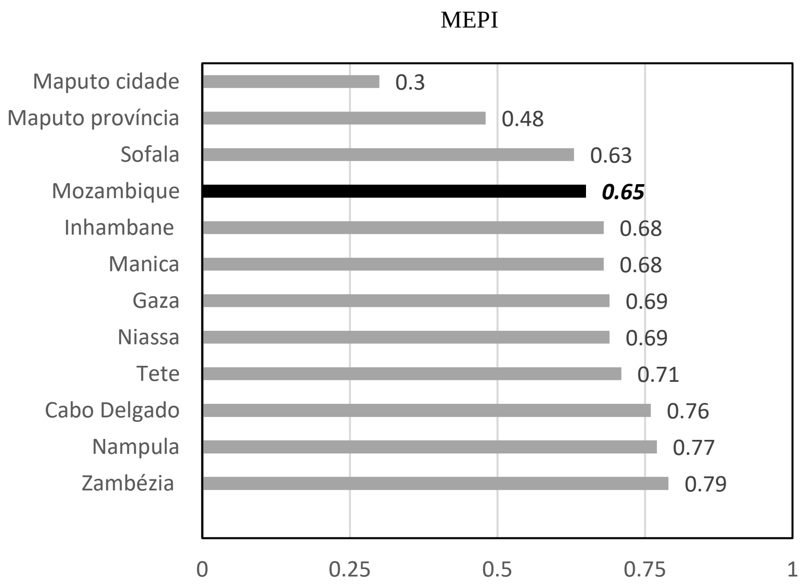

Figure 7. MEPI results at the national and provincial level
Source: Built from DHS survey data.

A MEPI of 0.65 shows that in 6 years, the country has improved by about 20% compared to the results obtained from the earlier assessment (2009), resulting from the efforts to enhance electrification rates and expansion of telecommunications networks. Figure 8 shows that the upgrading on energy poverty is linked to a greater level of inequalities among the population, as 84% of the sampled households suffer from multidimensional energy poverty. The survey Frevealed that approximately five people live in each family on average. 84% of the sampled households correspond to 30110 peoples suffering from multidimensional energy poverty.

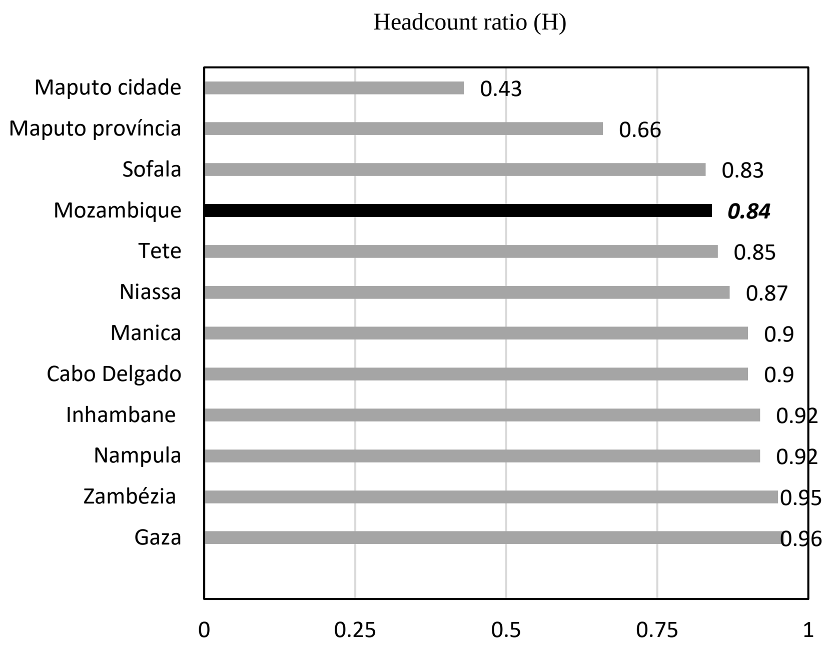

Figure 8. Headcount ratio (H) at the national and provincial levels, representing the fraction of energy-poor households.
Source: Built from DHS survey data

The level of inequalities mentioned above is also accompanied by 0.78 of deprivations (Intensity of energy poverty - A), i.e., the 84% of Mozambican households living below the energy poverty line are deprived form 78% of the considered essential energy services that characterize the MEPI (see figure 9).

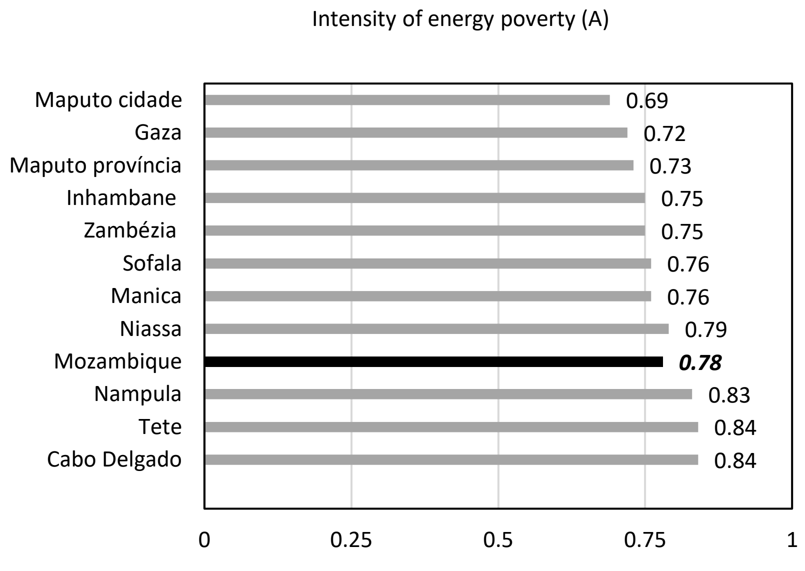

Figure 9. The intensity of energy poverty (A) at the national and provincial level
Source: Built from DHS survey data.

At the provincial level, Zambézia is the energy poorest province followed by Nampula and Cabo Delgado, with MEPI scores of 0.79, 0.77, and 0.76, respectively, and intensity of energy poverty of 0.83, 0.84, and 0.79, respectively. The energy poorest provinces are also the most populous ones, with 19.6%, 18.7%, and 8.7% of the population for Nampula, Zambézia, respectively, (Figure A6. Supplementary material).

At the regional level, the majority (66%) of the energetically poor households, live in rural areas and are deprived of 80% (average intensity of energy poverty $A = 0.80$) of essential energy services (see fig.10).

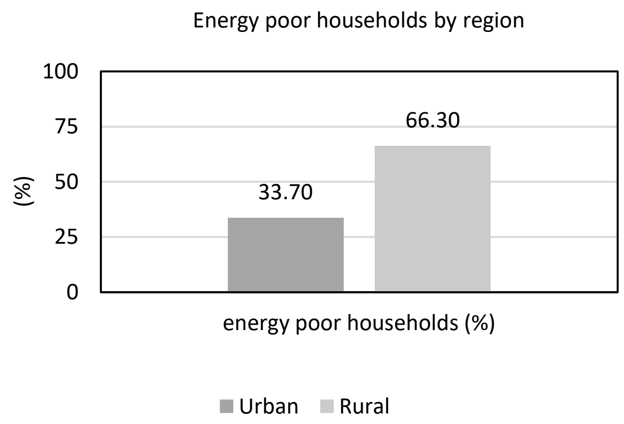

Figure 10. Energy poor households by region (%)
Source: built from DHS survey data.

There is a coexistence of a tremendous significant concentration of rural energy poverty and a small but not a negligible percentage (34%) of urban energy poverty. The coexistence of urban and rural energy poverty indicates that people live in areas with physical access to electricity and modern cooking fuels but cannot afford the minimum quantity of essential energy services. Therefore, energy poverty is a challenging issue affecting rural and urban populations; hence, additional efforts and studies are necessary to ensure that aimed strategies are designed and implemented.

From this, we conclude that significant inequalities have accompanied the improvement in MEPI and energy poverty a rural feature and an urban phenomenon, a fact that has been generally ignored in previous studies on energy poverty.

Given that energy poverty in the country affects rural and urban households, the Government must consider the difference between the affordability of access and affordability of using energy services. Therefore, energy poverty in the country is both a lack of access and a lack of capacity to afford energy services necessary to fulfill basic needs; consequently, it coincides with income poverty.

6. Conclusion and policy implications

Mozambique has significant renewable and non-renewable energy resources, and it is one of the largest energy producers in the Southern African Development Community – SADC. However, despite the wealth in energy sources, Mozambique is the sixth poorest country more than 90% of the energy sources (natural gas, coal, hydro) produced in the country are for export and about 70% of the Mozambican population live without clean, affordable, reliable, and modern energy services.

This work assessed the magnitude and intensity of energy poverty in Mozambique determining the multidimensional energy poverty index (MEPI) at the national and provincial levels using demographic and health surveys -DHS (made by USAID) data for household Record phase seven for the year 2015.

Results show that Mozambique is no longer suffering from acute energy poverty, having improved the energy poverty index from 0.9 in 2009 to 0.65 in 2015. This improvement is not uniform across the country. At the provincial level, Zambézia is the poorest province, followed by Nampula and Cabo Delgado, with MEPI scores of 0.79, 0.77, and 0.76, respectively, and intensity of energy poverty scores of 0.83, 0.84, and 0.79, respectively. Zambézia province is the one that suffers from higher deprivations for all indicators.

Despite all efforts to increase electricity access, around 70% of Mozambican households lack access to electricity. The other 30% of electricity consumption is mostly limited to more basic energy needs such as lighting, mobile phone charging, and entertainment rather than productive uses. Almost 90% of households, both in rural and urban areas, use traditional biomass (wood and charcoal) as cooking fuel. The use of modern fuels for cooking is still incipient and restricted to urban areas, suggesting that using electricity or natural gas for cooking might be a financially unviable option for most households. Therefore, affordability of access is about connecting a home to the grid and focus on meeting the population´s basic needs, on technical and financial issues that may enable income generation, and upgrade the use of electricity and its impacts on human development, (Winkler et al., 2011).

Agriculture, forestry, and fishery is the sector that employs the majority of the country´s active and most vulnerable (women) population; it is also the sector that contributes the most to the GDP and the one with the lowest electricity consumption. Thus, mechanization and electrification projects might increase the sector´s productivity, employment, target the most vulnerable population, and reduce social inequalities.

Furthermore, these findings portray a diverse landscape of energy poverty across Mozambique provinces, suggesting that public policies should be defined at the provincial level and not via one umbrella policy to address energy poverty. Therefore, coordinated policy actions between the electricity and other economic sectors (financial, agricultural, and infrastructural), might help fight against energy poverty and inequalities among the population.

Although energy-poor households live mostly in rural areas, 34% of urban households are energy poor, which suggests that energy poverty in the country is a rural and urban phenomenon. The coexistence of urban and rural energy poverty suggests that the problem might be both lack of access and lack of capacity to afford energy services necessary to fulfil basic needs.

Therefore, the improvement in MEPI is accompanied by more significant inequalities that pose challenges to the country. Ensuring universal access to electricity (number of households connected to the grid) with lighting-based consumption is not enough to generate social Development and reduce inequalities. Since energy consumption based on lighting services does not create wealth for poverty alleviation, it is necessary to ensure the energy available for productive uses to generate income promoting economic and social development and reduce the inequalities.

Finally, the MEPI approach does not consider the use of energy for income generation, therefore, we suggest the inclusion of a new variable related to productive uses of energy, e.g., the electrification of agriculture might be a good indicator of constructing an index for energy poverty that can capture the use of power to generate income and poverty alleviation. Furthermore, the MEPI methodology does not explain why a household is energy poor, i.e., if it is because of the lack of access to energy services or cannot afford energy services, thus, it would be interesting to introduce a measure of energy affordability in energy poverty metrics. The measure of energy affordability would help identify households that while living in areas with access to energy cannot afford a minimum quantity of energy services to fulfill their basic needs.

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Supplementary material

Table A1. Mozambican energy resources by source.

Type	Localization	Reserves	Reserves potential	Installed capacity
Non-Renewables	Tete	Coal	2.4 billion tones	14 million toe/year
	Inhambane, Sofala, and Cabo Delgado	Natural gas	129.6 trillion m^3	3.1 billion m^3/year
	Cabo Delgado	Oil	2 Mt*	-
Renewables	All country	Hydro	2187MW/year	1200 MW/year
		Wind	5GW	1.145MW
		Solar	5.4kWh/m2/day	599MW
		Biomass	2GW	-

*Confirmed reserves

Sources: (Cuvilas et al. 2010; IRENA 2013; WEC 2016; World Bank Group 2015; ALER 2017; WEC 2016; Mahumane and Mulder 2019).

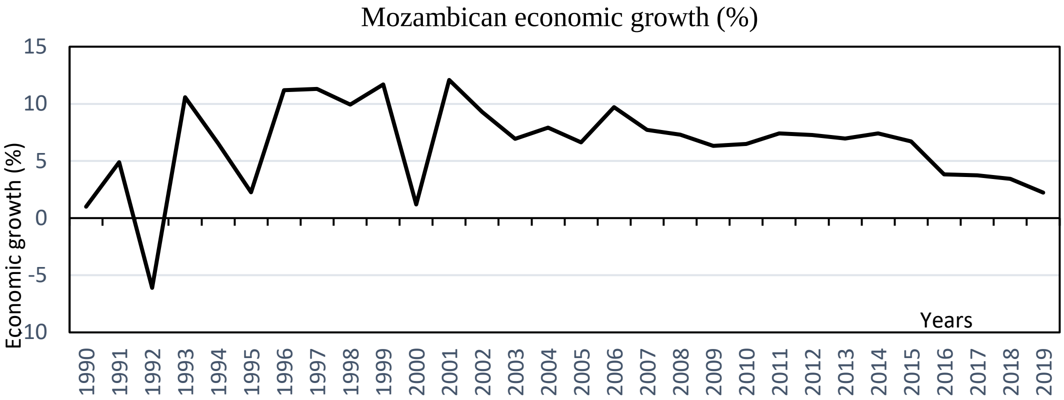
Table A2. Evolution of electricity tariffs per kWh between 2015 - 2020

Recorded consumption (kWh)	Social tariff (MZN/kWh)		Household tariff (MZN/kWh)			Farming tariff (MZN/kWh)			General tariff (MZN/kWh)		
	2015	2020	2015	2020	Growth (%)	2015	2020	Growth (%)	2015	2020	Growth (%)
From 0 to 100	1.07	1.07									
From 0 to 200			2.95	6.63	124.75	2.68	4.08	52.24	4.16	10.30	147.60
From 201 to 500			4.17	9.39	125.18	3.81	5.81	52.49	5.94	14.71	147.64
Above 5000			4.38	9.85	124.89	4.17	6.39	53.24	6.50	16.10	147.69
Pre- payment	1.07	1.07	3.75	8.44	125.07	3.75	5.65	50.67	5.96	14.75	147.48

Source: EDM Annual Statistical report 2015, and https://www.edm.co.mz/en/website/page/electricity-tariffs[13]

Figure A1. Mozambican economic growth from 1990 to 2019.

[13] Accessed on 24/ 05/2020.

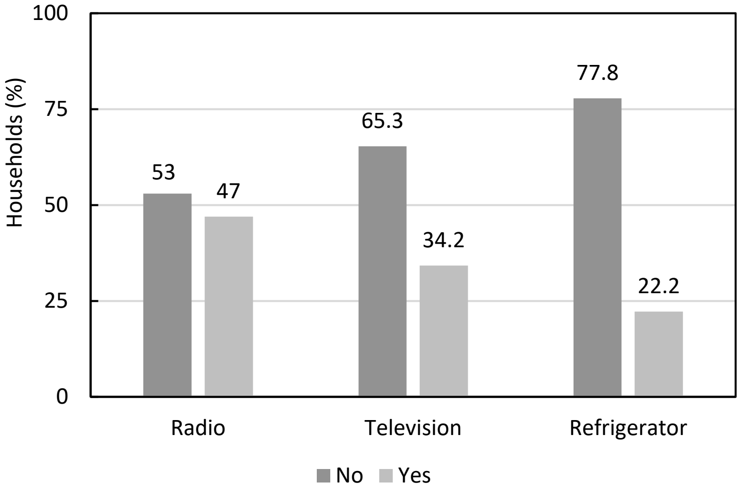


Source: Built from World bank data[14]

[14] https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=MZ Accessed on 25/10/2020.

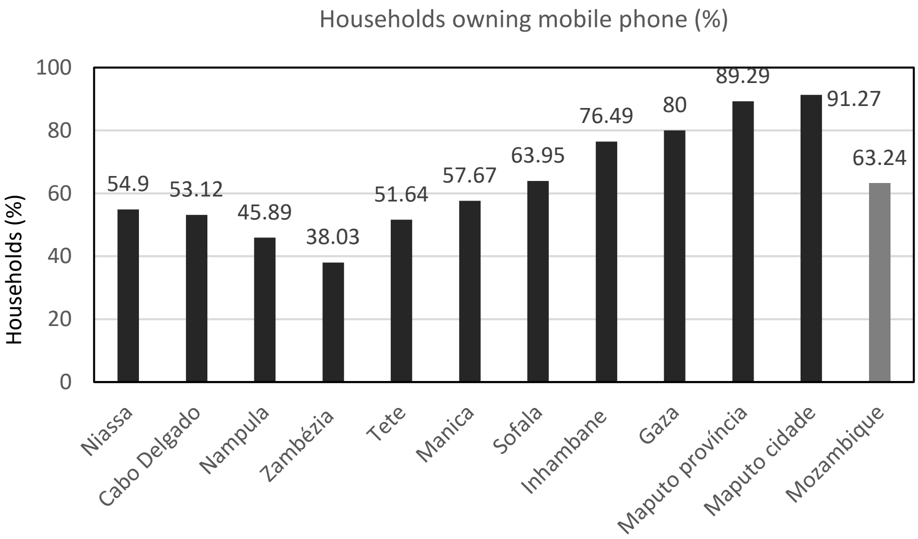
Detailed results of MEPI´s indicators at national, provincial and regional levels.

Figure A2. Entertainment/Education and household appliance ownership in the percentage of households.



Source: Built from DHS survey data.

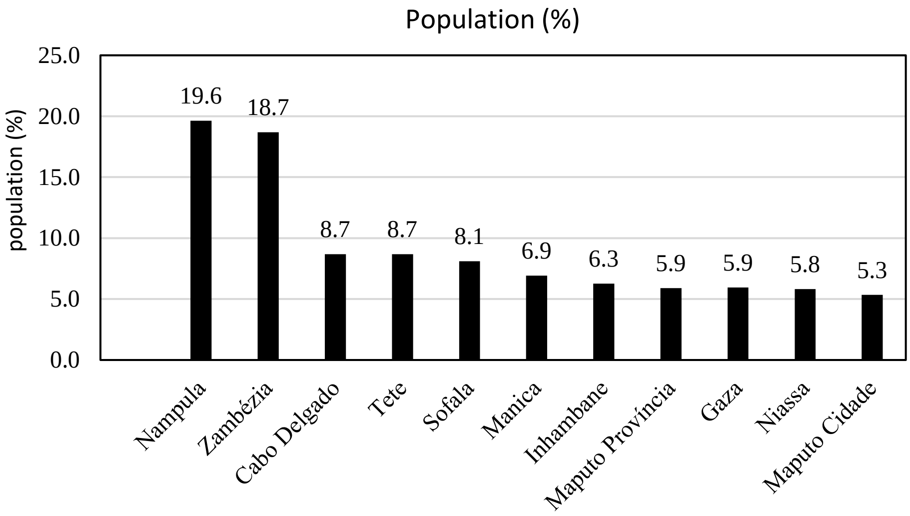
Figure A3. Mobile phone ownership in the percentage of households.



20

Source: Built from DHS survey data.

Figure A4. Population by province (%).



Source: Built from INE- Mozambican data[15] (census 2007).

[15] http://www.ine.gov.mz/iv-rgph-2017/mocambique/censo-2017-brochura-dos-resultados-definitivos-do-iv-rgph-nacional.pdf/view