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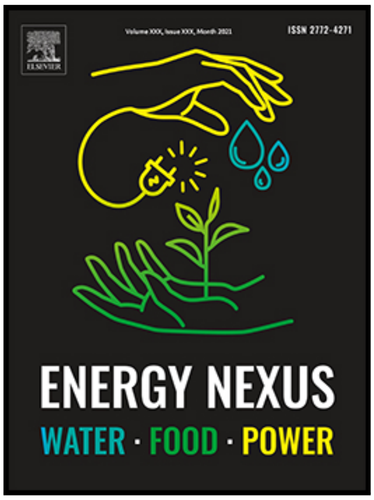

MEASURING ENERGY POVERTY IN MOZAMBIQUE: IS ENERGY POVERTY A PURELY RURAL PHENOMENON?

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Highlights

- Measures energy poverty in Mozambique using Multidimensional Energy Poverty Index approach.
- Mozambique improved from acute to moderate energy poverty.
- Inequalities accompanied the improvements in energy poverty level.
- Energy poverty is a rural and urban phenomenon.
- Need for coordinated political actions between the various economic sectors to boost the impact of the use of electricity in human development.
- Need for policies that meet the population's needs in terms of affordability of using electricity to reduce energy poverty.

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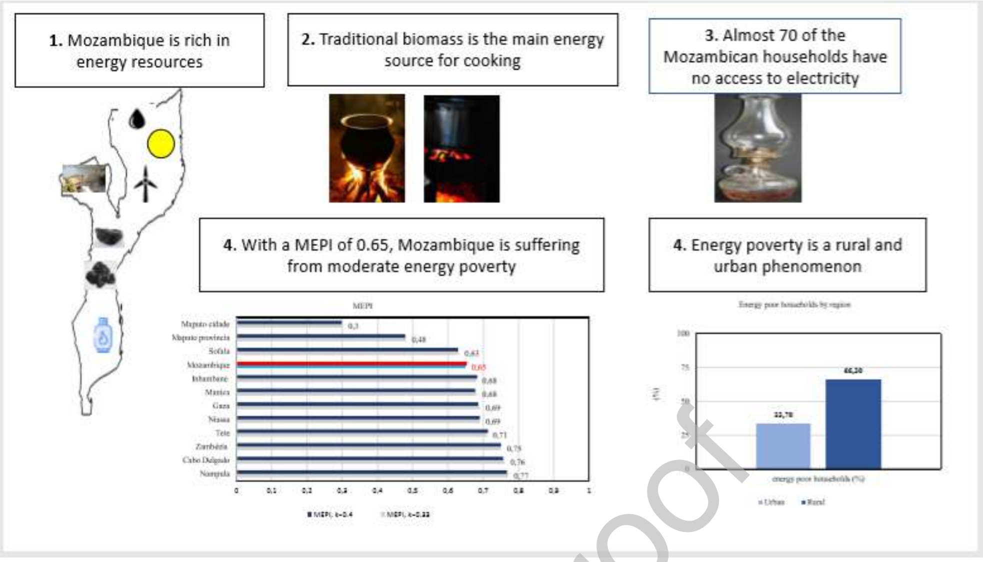
Abstract
Mozambique is one of the largest energy producers in the Southern African Development Community. Substantial efforts have been undertaken in recent years to increase energy access for poverty reduction in the country, however, most efforts seem to be concentrated to rural areas ignoring the existence of urban energy poverty, and despite all the efforts made, 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 and an urban phenomenon since 34% of urban households are energy poor, suggesting that energy poverty in the country is a problem of lack of access and a lack of capacity to afford energy services to fulfil 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 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 measures in the Multidimensional Energy Poverty Index framework to identify the causes of energy poverty.

Keywords: Energy poverty, poverty alleviation, Development, Mozambique



Graphical abstract

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Acronyms and abbreviations

ADE	Agência de Desenvolvimento Económico Local
ALER	Lusophone Renewable Energy Association
DHS	Demographic and Health Surveys
ECREE	Ecowas Centre for Renewable Energy and Energy Efficiency
EDM	Electricidade de Moçambique
EP	Energy Poverty
EPVI	Energy Poverty Vulnerability Index
FUNAE	*Fundo de Energia*
GDP	Gross Domestic Product
GW	Gigawatts
IEA	International Energy Agency
INE	Instituto Nacional de Estatística
IRENA	International Renewable Energy Agency
kWh	Kilowatt-hour
LBPL	Lower Bound Poverty Line
LIHC	Low-Income High metric
LPG	Liquefied Petroleum Gas
MEPI	Multidimensional Energy Poverty Index
MIREME	Ministry of Mineral Resources and Energy
MIS	Minimum Income Standard
MISAU	Ministério da Saúde
MITADER	Ministry of Land, Environment and Rural Development
MTF	Multi-Tier Framework
MW	Megawatts
MWh	Megawatt-hour
MZN	Mozambican Metical
NORFUND	Norwegian Investment Fund for Developing Countries
OPHI	Oxford Poverty & Human Development Initiative
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SDG	Sustainable Development Goals
SE4ALL	Sustainable Energy for All

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SNV	*Stichting Nederlandse Vrijwilligers* ("Foundation of Netherlands Volunteers)
TEA	Total Energy Access
UBPL	Upper Bound Poverty Line
UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
USAID	United States Agency for International Development
WEC	World Energy Council
WHO	World Health Organization

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List of symbols

Symbol	Description	Units of measure
c	Average deprivation scores experienced by a household	Units
i	Household in analysis	Units
k	Energy poverty line or energy poverty threshold	Units
d	Energy poverty dimensions	Units
j	Indicators of energy poverty's dimensions	Units
α	Energy poverty dimensions´ weights	Units
Σ	Mathematical symbol meaning summation	Units
H	Headcount ratio	Units
A	Intensity of energy poverty	Units
n	Total number of the sampled households	Units
q	Number of energy-poor households	Units

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1. Introduction

Mozambique is one of the largest energy producers in the Southern African Development Community – SADC, [1]–[4]. However, more than 90% of the energy sources (natural gas, coal, hydro) produced in the country are for export [2], [3].

Despite the wealth in energy sources, Mozambique is the sixth poorest country (with a Human Development Index of 0.446 in 2018), and suffers from acute energy poverty [5], [6]. 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 [7]. Traditional solid biomass (charcoal and firewood) is the principal energy source for most Mozambicans. In 2018 total natural gas final consumption was 5360.0TJ-gross, IEA (2020)[1].

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 [8], [9]. 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 [10], 40% of rural households walk at least 30 minutes to get to the water source for drinking water. Women and girls spend hours processing cereals on manual grinding and cooking. Estimation in [8] suggests that the households relying on biomass for cooking spend around 1.4 hours/day collecting firewood and several hours cooking and exposed to indoor pollution.

Mozambique also has problems with roads network and transports. Without private vehicles, people depend on shared and overcrowded public transport (if it exists), semi-public/semi-collective and rented transport, or even walking to move from one area to another, from home to work, hospital, school, and vice-versa. 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 face traffic congestion and hike segments at the beginning or end of the journey in unsafe areas without public lighting.

According to [11], 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 on the nearest primary, secondary,

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[1] https://www.iea.org/data-and statistics?country=MOZAMBIQUE&fuel=Energy%20consumption&indicator=Natural%20gas%20final%20consumption, accessed on September 29, 2020.

tertiary, and track roads, meaning that the remaining rural population in the country walk more than 30 minutes to find the nearest road.

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[2]. i.e., poverty is related to insufficient access to affordable, reliable, sustainable, and modern energy [1]. Hence, [4], [8], [12]–[16] consider access to modern energy services as a fundamental social right and a critical element for the Development of societies and it is also considered by [17] as the first step for the Development of any country.

Therefore, knowing the importance of energy access in achieving Sustainable Development, the Mozambican Government created the Energy Fund (FUNAE)[3] 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 populations in the country [1]. The Mozambican Government also adopted the United Nations SDGs and committed itself to ensure universal access to electricity by 2030, [18].

Since then, the Mozambican Government makes significant efforts through projects carried out by the Ministry of Land, Environment and Rural Development (MITADER); FUNAE; Mozambican Government´s Five-year Plan for 2015-2019; and National Development Strategy for 2015-2053, to provide electricity access across the country, which caused the electrification rate to increase from 24% to 39%, [1], [19] .

However, all the Governments efforts in this context are mostly concentrated in rural areas see for example [1], [19] ignoring the possible existence of households in urban areas that cannot afford a minimal quantity of energy to fulfil their very basic needs in energy services.

The lack of inclusion of sustainable development strategies for rural and urban areas inhabited by low-income households is also accompanied by a lack of policies focused on access to clean, affordable, reliable, and modern energy sources for cooking.

Having said this, one can ask: is energy poverty a purely rural phenomenon? What is the magnitude and intensity of energy poverty in the country?

[2] poverty, inequalities, gender inequalities, climate changes, food security, health, unemployment, Education, transport, communication, commerce, production, and human and sustainable development.
[3] Public entity.

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Therefore, we 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.

Little has been done in the literature on energy poverty in Mozambique. Studies of [5], [20], [21] provided cross-country comparisons but did not give 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 at national, provincial, and regional levels 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, may help to monitor the progress and effectiveness of implemented response policies to SDGs allowing a possible change of actions in the formulation and implementation of policies towards achieving the United Nations SDGs. Furthermore, a detailed multidimensional analysis of energy poverty can be used to support integrated and multisectoral coordinated policies that can generate economic, social changes for those suffering from multiple energy deprivation.

The study results might also help to allocate the public budget at national, regional, and provincial levels targeting those affected by multiple deprivations in energy services. Allocating the public budget according to the needs of the different provinces and regions can help to reduce inequalities by promoting similar opportunities among the different provinces and regions. Finally, since little has been done about energy poverty in the country, both in the literature and in terms of the political agenda, the study can help to raise concerns about the problem of energy poverty in the country. This might lead to positive actions to fight energy poverty in the country, and to fill the gap in the Mozambican literature on energy poverty.

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

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2. Literature review

2.1. Defining Energy poverty

Most studies consider energy poverty (EP) as mainly fuel poverty and lack of access, however, [2] assume that they are two different concepts when considering EP related to low incomes and energy consumption of households. EP 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 [22], [23], [32], [24]–[31]. Developing countries understand EP from the perspective of the relationship between access to energy services and socio-economic development, well-being, or quality of life [12], [32]–[36].

Therefore, to define EP, we highlight the definitions given by [17], [37] and [36]. According to [17], [37], 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, [36] define EP as the " 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, the definitions do not mention a specific form of energy, which allow the inclusion of electrical and mechanical power or a better description of EP in the developing world. In developing countries, people lack access to electricity, modern and clean fuels for cooking and mechanical power to reduce the hardship of daily activities and improve mobility [38].

Secondly, although affordability issues are fundamental in the developed world, see for example [27], [39], [40], they are also issues of concern in developing countries. In these 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 fulfil their very basic needs. Hence, defining EP in developing countries is talking about access issues and affordability issues [3].

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 [41]–[44].

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Table 1. Energy poverty vs SDG7

Energy poverty Definition	Author	Relationship with SDG	Agencies and Bodies in its Measurement and Reduction process
the 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	[17], [37]	Access to modern, affordable, reliable, sustainable energy.	IEA, IRENA, UNPD, World Bank, World Health Organization, Afro barometer, SE4ALL, Practical Action
		Access to modern and clean fuels for cooking.	IEA, IRENA, UNPD, World Bank, SE4ALL, World Health Organization, Afro barometer
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	[36]	Quality of education	UNPD, World Bank
		Good health and well-being	UNPD, World Bank, World Health Organization, Afro barometer

For referring to reliability and affordability of access, sustainability and modernity of energy services, the definitions allow dealing with issues that help in achieving the SDG7 (refer to table 1), which in turn helps to achieve some other SDGs, for example, the SDG 1-5.

The access to modern and clean fuels for cooking may reduce deforestation, the exposure to indoor pollution suffered by women and girls when cooking using traditional biomass as the main cooking fuel. By reducing the hardship of the daily activities, access to mechanical power and modern and clean cooking facilities might reduce the time spent by women and girls on gathering fuelwood, and grinding cereals for cooking, and thus free-up time that could be spent in income-generating activities, education, and leisure, and thus, reducing gender inequalities and promoting women and girls´ empowerment.

Access to modern energy services might improve the quality of education as it allows the use of computers and research engines contingent on electricity access to take place. By enabling the setting up of clinical laboratories and vaccine conservation systems, access to modern energy services allows populations in remote areas to benefit from health services that were previously only possible in district hospitals, it also allows for more safety in deliveries that occur after sunset, helping to reduce maternal and child mortality.

The affordability of energy services allows low-income households to enjoy services that they would otherwise not be able to pay for, thus, reducing poverty and inequalities among the population. Access to reliable energy services might stimulate de production of goods and services, including agriculture

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mechanization and agro-processing that may encourage the sustainable production of the food needed to fight hunger.

Defining EP in terms of access to clean, reliable, sustainable energy might encourage the use of renewable energy that can contribute to reducing the effects of climate changes that have devastated many countries such as Mozambique which has been hit by devastating floods and cyclones that have contributed for the perpetuation of poverty in the country and has witnessed an increase in drought and intensely hot summers.

Thus, speaking of EP 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 EP and the considered difference between fuel and EP, one may consider two significant approaches: fuel poverty approaches and EP 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 [45]–[48].

Energy poverty approaches: EP 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, so, having access to modern, clean, reliable, safe, and affordable energy services will bring good outcomes to the population, see for example [5], [8], [34], [49], [50].

In the access approach, [49] proposed the Multidimensional Energy poverty Index (MEPI) methodology. The authors recognize that EP is a complex and multidimensional problem related to multiple deprivations on energy services for lighting, cooking, and use of appliances such as refrigerators, 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) [34].

Even though the MEPI methodology gives a robust measure of multi deprivation of energy services in the developing world, it has essential shortcomings. [51] argue that the MEPI methodology does not capture

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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 [51], [52], 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 [53], [54], can lead to biased results.

Despite all the shortcomings of the MEPI methodology, it has been widely used to measure EP in the developing world and worldwide, see for example [5], [17], [33], [44], [51], [55]–[58].

Another multidimensional approach is the Multi-Tier Framework (MTF) that measures EP by gauging the quality of energy delivered [51], [59]. 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 [51], [60].

Finally, we have the capabilities approach developed by [36]. The capabilities framework has the advantage of not mentioning specific energy services, and therefore, it can be used within Global South and Global North.

Energy poverty metrics frame it 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 or productive uses of energy that allow the generation of goods and services and thus increasing income potential and its value. Therefore, issues and challenges remain in all metrics [51].

We 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 [8], [9], [33], [59], [61]–[65].

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

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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 EP in Sub-Saharan Africa and, particularly, for the Mozambican case. A country panel study [5], [20] showed that, at the time, Mozambique was suffering from acute EP, with a MEPI of 0.82 and 0.87, respectively.

[33], [66] measured EP 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 EP [57]. Three years later, [56] found that the Nigerian energy-poor population´s share had dropped to just over 50%. In 2020, Nigerian households suffered from moderate EP (MEPI of 0.38), [62].

Still, in the Nigerian context, [63] argued that despite the Delta Niger´s wealth in oil and gas resources, the local population rely on unclean and unaffordable energy, and [64] found that the local population is energy-poor, with a Multi-Tier Energy Poverty Index of 0.29.

In South Africa [64] used the MEPI methodology and found moderate EP among low-income households. Heating fuels is the dimension that most contributes to the EP of the sampled households. [67] used a different approach (expenditure approach) to study the determinants of EP 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 EP in the country.

[58], [68] used the MEPI methodology to measure and compare EP patterns around industrial crop projects. [58] registered lower EP levels among jatropha and oil palm plantation than in sugarcane plantations, and [68]

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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, [69] used the MEPI approach to measure EP in Addis Ababa city, finding that 57.9% of the city households were suffering from multidimensional energy poverty. [51] also used the MEPI methodology to illustrate the linkages between fuel choice and EP.

In his turn [70], using economic approaches of measuring EP 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 EP 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. It is one of the largest energy producers in the Southern African Development Community – SADC, see Table A1. Supplementary material [1]–[4], [71].

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 [1], [2]. 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 neighboring South Africa. Until 2014 only 3.4% of the national production was consumed within the country [1], [2].

In terms of coal, Mozambique has relatively large reserves in Tete province, estimated at 2.4 billion tons, with a mean production capacity installed of 14 million tons of coal per year. Most of this production is for export [2].

Regarding renewables, the country has a total potential of renewable sources (hydro, solar, wind, biomass, and geothermal) estimated at 23,026 GW see [72]. The most exploited in Mozambique is hydropower along the Zambezi river basin[5] , which accounts for more than 50% of all electricity generation in the country and more than 90% of the total primary energy supply [1].

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

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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 neighboring countries such as South Africa and Zimbabwe [3], [4].

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 [41].

The significant availability of energy resources (Table A1, supplementary material) enables the country to satisfy its own domestic needs in terms of energy and export it to neighboring countries (such as South Africa and Zimbabwe). More than 90% of energy production in the country is intended for export rather than national consumption [1]–[3], [72].

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 [73]. The electricity mix consists predominantly of hydropower generation capacity [74], 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 [75] the low population density per square kilometer, low electricity consumption in the country[6], and the problematic geographic relief in certain areas make network expansion very expensive. 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 electricity power production, transformation, transportation, distribution, and commercialization, [1].

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

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

poverty by providing electricity to the poorest groups in remote areas using social tariffs that do not generate profit opportunities for private investors.

The weak 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 FUNAE.

Although the Government offers social tariffs as a strategy for poverty reduction, these tariffs remain above the payment capacity of most of the poorest population in the country. According to [76], the bottom 40% of the 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 A2, supplementary material).

Despite the recent increase in electricity tariffs, [75]–[77] argue that taxes remain not cost-reflective, raising-challenging issues to the country as regards to the opportunity cost of ensuring electricity access and the electricity supply´s financial viability.

Besides all the problems mentioned above, the Mozambican electricity system faces reliability problems causing losses in production and equipment breakdown. According to [78] blackouts in the country 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 [19], 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 [8], 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 to make matters worse, 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.

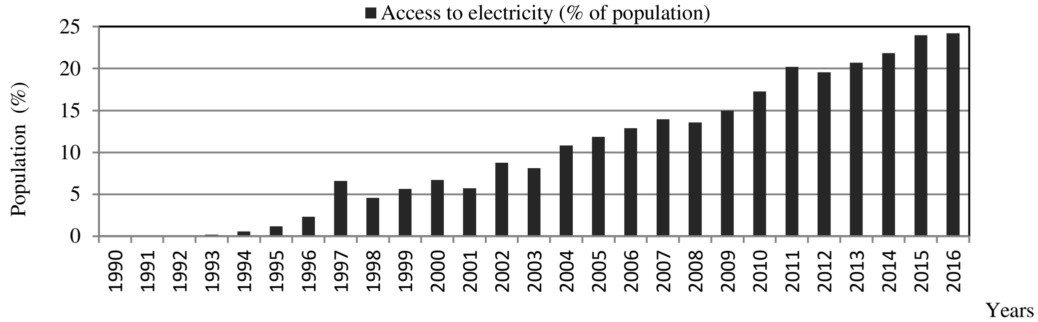

Figure 1. Evolution of access to electricity in Mozambique from 1994 to 2016
Source: Built from World Bank data.

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 1). When including off-grid electrification, mostly carried out by FUNAE, the electrification rate becomes 39% [19].

There are disparities in electricity access rates between rural and urban areas, about 27% in rural areas compared to 67% in urban areas [76], [78]–[80]. 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, [80].

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).

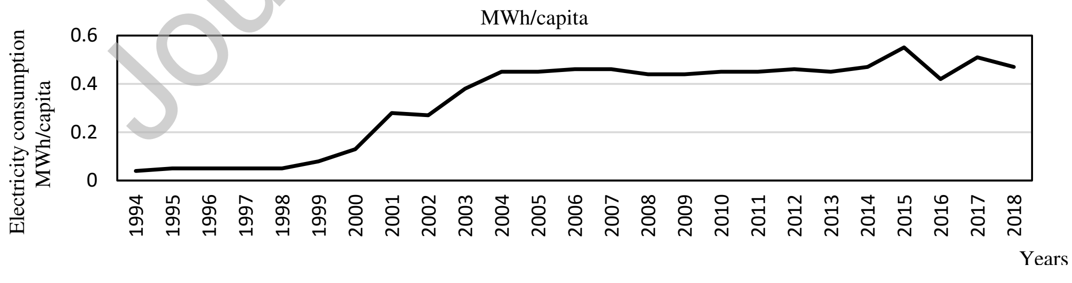

Figure 2. Per capita electricity consumption, Mozambique, 1990 – 2018
Source: Built from IEA data[7]

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

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] .

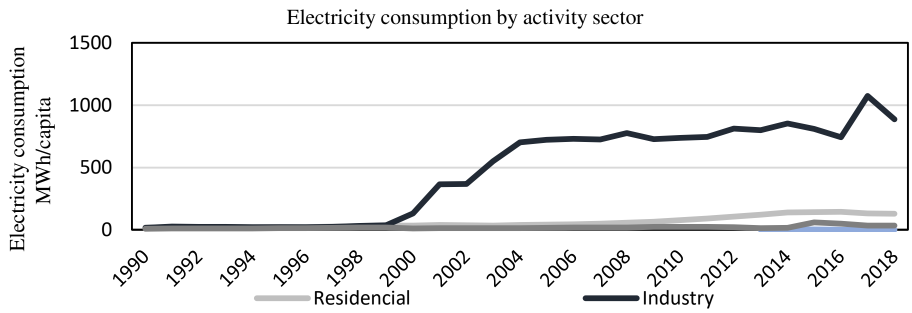

Figure 3. Electricity final consumption by sector, Mozambique, 1990 – 2018
Source: Built from IEA data[9].

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.

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 [7], Mozambique has about 27.9 million inhabitants, of which 29.29% is economically active, 66% of these works in agriculture, forestry, and fishery, 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[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

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

[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

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inequalities in the country and excluding most people from opportunities of participating in production activities.

4. Methods

For analysis and measurement of EP in Mozambique, this study uses the Multidimensional Energy Poverty Index (MEPI) methodology proposed by [20] and created by the Oxford Poverty & Human Development Initiative (OPHI) with the association of United Nations Development Program - UNDP [17], and the demographic and health surveys -DHS (made by USAID) data for 7169 Mozambican households (corresponding to almost 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 six indicators: modern cooking fuels, indoor pollution, electricity access, household appliances ownership, entertainment/education appliances ownership, and telecommunication means, see Table 2.

Table 2. 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 [20].

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 $k = 0.33\ or\ K = 0.4$. According to [17], [18], [51], [79], [81], the threshold is arbitrarily defined according to the definition and measurement/approach used for EP analysis.

Studies such as of [51], [56], [68], [69] used the EP line (K=0.33%) proposed by [20]. 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, [17], [33], [57], [82] who determined a threshold varying from 0.2 to 0.6.

[83] estimated the EP 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 EP line in Mozambique and there is no explicit criterion for the definition of the threshold for multidimensional EP; therefore, similar to the studies of [44], [52], [56], [68], [69], [80], we adopted the EP line of $k = 0.33$ for the present study. We also considered a threshold $k = 0.4$, meaning that a household deprived of at least two out of fife dimensions is treated as energy poor.

Given that the earlier assessment on EP [5], [20] found that more than 98% of the country´s sampled households were suffering from acute EP and was deprived in 84% of the five dimensions in analysis, we consider that setting the EP threshold at a value higher than 0.4 can lead to biased results by selecting a small number of severely deprived households.

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, [20].

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,

$$c_{i(k)} = \alpha_1 j_{i1} + \alpha_2 j_{i2} + \cdots + \alpha_6 j_{i5} \qquad \text{Eq. 1}$$

with $j_i = 1$ if the household i is deprived in the indicator j and $j_i = 0$ 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, therefore,

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

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

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 the dimensions in which energy-poor households have deprivations. The product between H and A gives the MEPI:

$$MEPI = H \times A \qquad \text{Eq. 3}$$

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 [57].

We recognize the importance of mechanical power for mobility as a component of EP; 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 [20] except for indoor pollution. We assume that the household i is exposed to indoor pollution if it cooks food using any fuel besides modern cooking fuels in the house or a separate building. We consider 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 [20].

5. Results

This section presents the results of the MEPI and the different dimensions of EP 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

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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, and is all concentrated in urban areas.

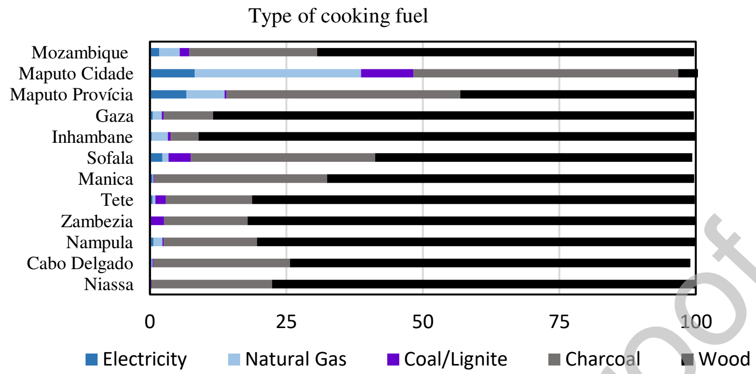


Figure 4. Type of cooking fuels in the percentage of households.
Source: Built from DHS survey data.

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).

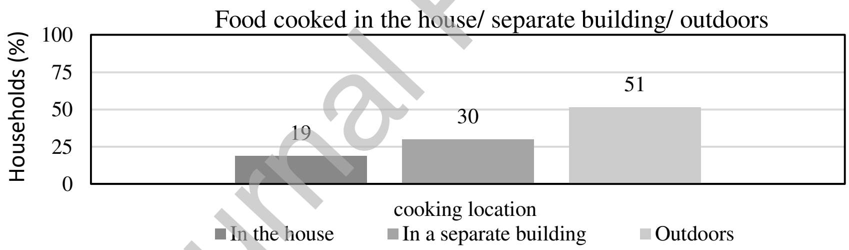
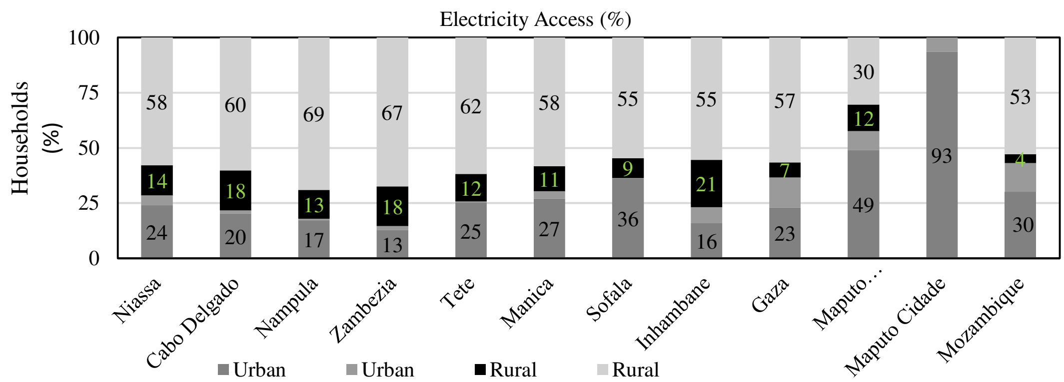


Figure 5. Indoor pollution
Source: Built from DHS survey data.

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, [8], [36], [39], [57], [68], [84]–[88].

The results also show that 66% of the sampled households were living deprived of electricity access in 2015, of which 53% lived in rural areas, and the other 13% living in urban areas, suggesting the coexistence of rural



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and urban EP, 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). In average, at least 15% of appliances' deprivations may result from affordability issues, see Figure A3 in Appendix, suggesting that introducing energy affordability measures in the MEPI framework could help identifying the causes of EP.

Households deprived of entertainment means, such as radio and television, have restrictions on accessing information and are excluded from participation in the governance process; thus, EP 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 A4 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 EP 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 fulfil basic.

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 most households with access to the grid. Therefore, affordability of electricity access is not only about connecting a family to the grid but also focusing on the affordability of using electricity.

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5.2. 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 and 0.4, we classified the different regions according to the degree of EP they face. A region is considered as suffering from acute EP if $MEPI > 0.9$ or moderate EP if $MEPI < 0.6$.

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

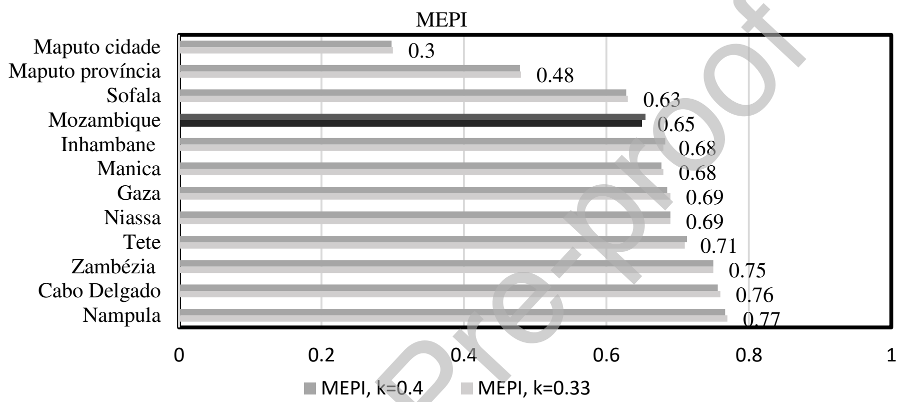

Figure 7. MEPI results at the national and provincial level, for the different cutoffs.
Source: Built from DHS survey data.

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 EP is linked to a greater level of inequalities among the population, as 84% (for k=0.33) of the sampled households suffer from multidimensional energy poverty. The survey revealed that approximately five people live in each family on average, therefore, 84% of the sampled households correspond to 30110 people suffering from multidimensional energy poverty. The level of inequalities reduces to 77% when we set the EP threshold to 0.4.

[12] year of the most recent DHS survey

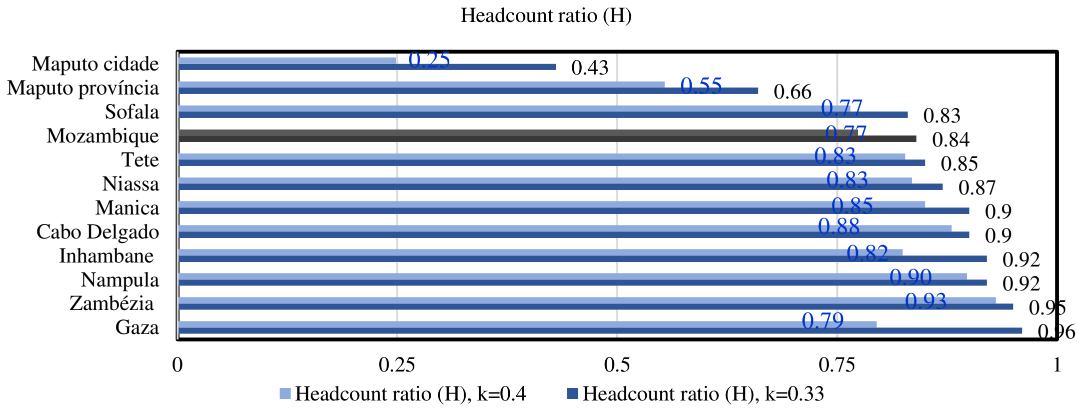

Figure 8. Headcount ratio (H) at the national and provincial levels, representing the fraction of energy-poor households.
Source: Built from DHS survey data.

The level of inequalities mentioned above is also accompanied by a high level of deprivation (0.78- Intensity of energy poverty – A, for k=0.33), i.e., 84% of Mozambican households living below the EP line are deprived form 78% of the considered essential energy services that characterize the MEPI (see figure 9). The situation gets worse when the EP line is fixed at 0.4 to which the energy-poor households are deprived in 85% of the five dimensions in analysis.

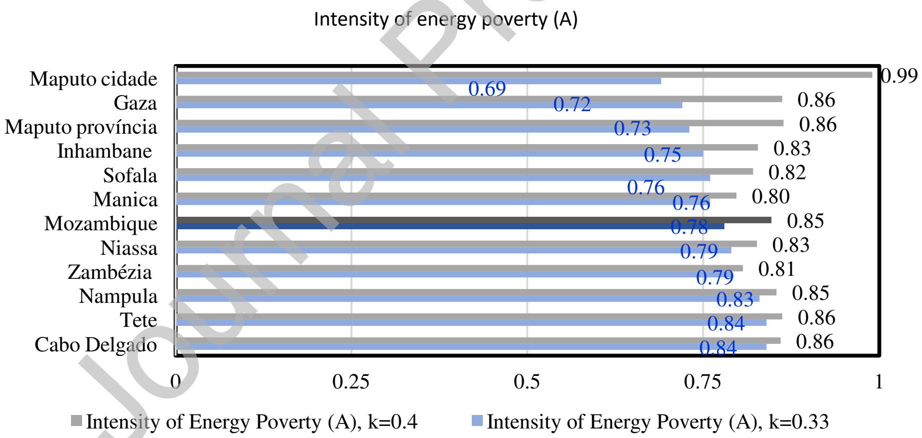

Figure 9. The intensity of energy poverty (A) at the national and provincial level
Source: Built from DHS survey data.

At the provincial level, Nampula is the energy poorest province followed by Cabo Delgado and Zambezia, with MEPI scores of 0.77, 0.76, and 0.75, respectively, and intensity of EP 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, Zambezia, respectively, (Figure A5. Supplementary material).

Gaza and Tete are the provinces showing great inequalities among their population, given that, with the MEPI of 0.69 and 0.71 respectively, the intensity of EP and score are 0.76 and 0.84 respectively and about 96% and 85% of the sampled households in these provinces are energy poor.

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).

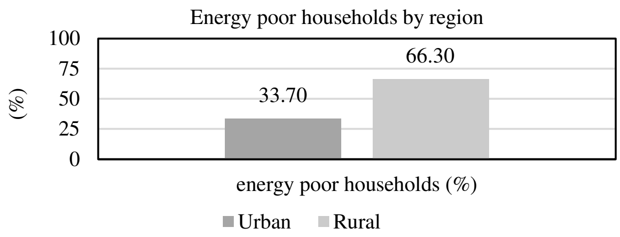

Figure 10. Energy poor households by region (%)
Source: built from DHS survey data.

There is a coexistence of a tremendous significant concentration of rural EP and a small but not negligible percentage (34%) of urban EP. The coexistence of urban and rural EP 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, EP 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 EP is a rural feature and an urban phenomenon, a fact that has been generally ignored in previous studies on EP. Considering the two different thresholds for EP does not affect the general results in terms of the MEPI, however, it affects the level of inequalities among the population and the intensity of energy poverty. The results show that the level of inequalities is lower, and the intensity of energy poverty is greater when considering the EP line k=0.4 compared to the results obtained for k=0.33.

Given that EP 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, EP in the country is both a lack of access and a lack of capacity to afford energy services necessary to fulfil basic needs; consequently, it coincides with income poverty.

5.3. Discussion

The economic and political agenda worldwide links access to clean, reliable, affordable, and modern energy services to human development and the achievement of the United Nations SDGs. The common belief is that

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once poor people have technical access to modern energy services the social welfare will be automatically generated for them. In this scope, there are ongoing efforts through programs and projects whose main purpose is to increase access to modern forms of energy.

Mozambique while being one of the countries that adopted the United Nations SDGs, is in the race together with the World Bank and other international partners (the main source of investment in electricity expansion), seeking to achieve universal access to electricity by 2030 in the belief that this will bring good outcomes in the fight against poverty, unemployment, hunger, gender inequalities, climate changes, health, and education problems.

Therefore, taking advantage of the country´s vast wealth in energy resources to produce electricity, we currently witnessing a growing number of villages connected to an electricity network, either by the expansion of the national grid or by mini-grids such as solar PV and natural gas-driven electricity, which along with the expansion of telecommunication network, contributed for the improvement of the level of EP from acute in 2009 to moderate EP in 2015, although with greater inequalities among the country´s population.

The electricity network expansion is combined with a zero-cost access policy in which households do not incur any cost to connect their homes to the electricity network- the affordability of electricity access. However, unlocking the economic and social benefits of electricity access in human development is not automatic nor an easy task as it is believed.

Despite the zero-cost electricity access policy adopted by the Mozambican government, and the role the country plays in the Southern African Power Pool (SAPP) exporting electricity to neighbouring countries such as South Africa and Zimbabwe, the country remains one of the 20 countries with the lowest electricity access rate in Sub-Saharan African region, [89]. The proportion of the population with electricity access in the country is no more than 5% in the period 2015 to 2019 [90]. Households´ electricity uptake is still relatively low, varying between 50% and 60% (at least five in ten households under the grid choose to connect their houses to the grid) compared to 75% and 98% in Zimbabwe and South Africa, respectively [91], [92], only 29% of the rural households had access to electricity in 2018, compared to 84% in urban areas.

As we can see in section 3.3, with an average per capita electricity consumption of 0.33MWh, the residential sector is the second largest electricity consumer (based on lighting, cell phone charging, including small

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carpentries, drinks refrigeration, small barbershops, and hair salons) after industrial sector in the country. However, the industrial sector employs only 3.25% of the Mozambican active population.

The United Nations SDGs emphasize the importance of having access to a reliable and affordable energy source to unlock the potential benefits of human development. However, the electricity supply in the country is low, unreliable and with high costs.

In terms of reliability, the country has one of the highest rates of losses due to the poor electricity transmission system, ranking second after Malawi among the neighbouring countries. In every 100KWh of electricity produced, the country loses 23% in system losses along the transmission line, compared to 15% and 10% for Zimbabwe and South Africa, respectively, [93]. About 55% of the Mozambican households connected to the grid reported having electricity at least most of the time, 35% and 20% reported never having electricity or having electricity half of the time, respectively, [91]. According to [94], the level of electricity reliability in Mozambican households is about 61% compared to 81% in South Africa.

The 2018 Mozambican Enterprise Survey shows that the country represents 30% and 25% of the total losses in sales and production resulting from failures in the provision of electricity in the low-income countries and Sub-Saharan Africa, respectively, [81].

Therefore, the expansion of the electricity network in the country is being done ignoring reliability issues which may somehow be negatively contributing to the electricity uptake and for the impact of electricity access on the social and economic aspects of the population welfare and thus to EP.

In 2020 the country had an installed electricity generation capacity of 2915 MW of which 2313 MW are from renewable energies (hydro, solar and geothermal), [95], [96], and 100km of the transmission line per million people in 2017, compared to 250km and 550km for Zimbabwe and South Africa respectively, [93]. Electricity utilities in Mozambique operate at loss due to the low purchasing power and low electricity consumption among the Mozambican population, [76].

Although the electricity tariffs in Mozambique are too low for electricity utilities compromising the financial viability of electricity supply in the country, they remain above the payment capacity of the majority of the Mozambican households, making even basic energy services unaffordable for most households connected to the grid, [96], [97]. In annual terms, Mozambican households pay 6% of the national per capita GDP for electricity to power a refrigerator, compared to less than 1% in South Africa and 4% in zimbabwe, [92].

According to [77], the bottom 40% of the poorest Mozambican households pay more than 15% of their average income in electricity to power a few basic energy services such as lighting, ventilation (fan), mobile phone charging and television.

Mozambique is also one of the 20 countries with the lowest rate of access to clean cooking fuels, [89], only 13% and 5% of the urban and rural households had access to clean cooking fuels respectively, [90]. According to [98] until 2017, less than 5% of the Mozambican population had primary reliance on clean cooking fuels, there were 0.7 doctors for every 10000 people. Along with this, it was estimated that the rate of mortality attributed to air pollution in Mozambique was around 110 per 100 000 population in 2016, indicating that about 32 636 Mozambican peoples died in 2016 due to air pollution. When the issue is addressed in terms of gender, the study shows that the mortality rate for women is around 113.8 per 100000 women corresponding to about 17274 women and 106.4 per 100000 men corresponding to around 15417 men deaths due to air pollution.

Even so, little has been done about the issue. The Energy and Sustainable Development Forum of Mozambique (FEDESMO) has been developing through its partners'[13] strategies for the promotion and production of efficient and improved cookstoves at the national level, [1]. The first attempt at promoting the use of clean fuels from cooking was made in 2015 by FUNAE in partnership with SNV[14] when they introduced "the ethanol kitchen" with the so-called Ndzilo stove for women in low-income households living in Maputo. More recently there is a pilot program in progress that introduces technological and clean stoves to the Changalane women farmers association (Maputo outskirts).

Promoting the efficient use of traditional biomass does not improve the energy transition from the use of charcoal and firewood to clean fuels for cooking but it is a way to reduce deforestation and the exposure to indoor pollution since efficient stoves burn the traditional biomass more efficiently and require fewer fuels than the traditional ones to cook and heat food.

The expensive nature of clean and modern fuels along with the low purchasing power of most households in developing countries, see [99], [100], and the poor investment in this area, [90] undermine the governmental and international agencies to streamline the transition from the use of traditional fuels to modern and clean

[13] ADEL Sofala; ADEL Cabo Delgado; ADEL Nampula; Razende; Kulima; Livaningo; FUNAE, and Kawedzi.

[14] *Stichting Nederlandse Vrijwilligers* ("Foundation of Netherlands Volunteers")

fuels for lighting and cooking. Therefore, access to clean cooking fuels is one of the dimensions contributing the most to the level of EP in the country.

From all this rise the following questions: Is the strategy based on increasing the number of households connected to an electricity grid enough to generate the expected social and economic benefits for human well-being, and reduce the effects of climate changes, ensuring long-term sustainability and security of electricity supply?

The adopted strategies to achieve the United Nations SDGs 7 in the country suffer from the lack of connection between social, economic, and technical issues as they address EP as only a problem of access to electricity, not as a complex problem that coexists socially, economically and technologically requiring multidimensional solutions to fight it, as it is argued in [101].

The provided solutions to reduce EP not only address it as only a problem of access to electricity as well as it is seen as a supply-side issue without any link with the reliability of supply and the demand side of the problem, and also without the private sector involvement. [91] argued that electricity sectors must focus on creating economic and financial capabilities at the community level to generate a fast sustainable development without neglecting the electricity reliability and affordability to ensure the financial viability of the electricity utilities and equitable provision between rural and urban areas.

Inefficient energy policies can be counterproductive, increasing EP or taking the country to the so-called "electrification trap" or a crowding-out effect, [102]. Since EP affects households almost unable to eliminate the factors causing the problem, [103], setting energy policies based on increasing the number of villages and households connected to the electricity grid without any connection to income production nor policies for affordability on using electricity can make the country fall into a vicious cycle of low uptake, insufficient recovery of investment costs and thus, scarcity of private investments in the sector, reducing employment levels, rising prices, and revenue stagnation.

Having access to electricity for lighting without any prospect of income in the context of low purchasing power and consumption may jeopardize the continuity and security of the supplied services as the consumption will not be able to cover the costs of electricity production and distribution undermining private investments in the electricity sector (it cannot help the households to eliminate the factors causing EP). This will put electricity utilities and the country in a vicious of low electricity supply, unreliability (due to lack of financial capacity to invest in a reliable grid expansion) low demand (due to unaffordability of access and of using electricity services) undermining the expected positive effect on human development towards achieving the United Nations SDGs.

[92] suggest that the inequalities in the electricity uptake between countries may be explained by the differences in the levels of development (measured by total GDP and per capita GDP) among the different countries, and the fact that electricity supply programs do not include income-generating projects (productive uses of electricity), polices of affordability of using electricity and other infrastructures (Public) that may upgrade the impact of electricity access in the human livelihoods.

In the same study, the authors concluded that although the level of income is the first factor for electricity uptake, having a regular income is also an important factor. i.e. the households are likely to connect their houses to an electricity network when they have a regular source of income, households associate electrification primarily with economic activities. [103] also, emphasize the importance of the productive energy supply to unlock its potential benefits to human development.

However, productive uses of electricity do not take place automatically, the country must invest in social infrastructures (publics such as roads, schools, hospitals) and ensure financial inclusion as a way for access to investment for income-generating activities (coordinated policy action between different sectors). [100] demonstrated the importance of financial inclusion to improve households' income, reduce inequalities and poverty alleviation in Ghana.

The productive uses of energy may create a financial environment for the transition from the use of traditional biomass to clean fuels for cooking. [104]–[106] concluded that income is one of the factors that influence households on choosing to use clean fuels for cooking, as well as the reliable supply of clean cooking fuels. Female labour participation is also an important issue in choosing clean fuels for cooking, [107], [108].

Thus, economic, and social policies that encourage the use of clean cooking fuels are likely to help to reduce the levels of EP in the country towards achieving the United Nations SDGs. Energy policies on clean cooking fuels should not neglect households that even with the financial ability to pay for the use of cooking fuels may still rely on traditional biomass as the primary cooking fuels or still combine traditional and modern fuels for cooking. Therefore, the development of public policies based on subsidies in the use of clean cooking fuels may stimulate the uptake in this area.

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The existing gap in the programs focused on fighting EP in the social, financial, and economic sphere and the actual pace of action undermines the progress on achieving the United Nations SDGs, see [92], [100], [101], [109], [110] and fight climate changes.

Therefore, coordinated efforts in which the financial, social, and economic issues are considered in the different economic sectors may upgrade the country´s performance towards achieving the United Nations SDGs. However, even if there are serious changes in the country´s policies, and therefore manage to eliminate the existing gap between energy policies and social, economic, and technical aspects the result will be a positive change in the expected scenario for the year 2030 without reaching the goal of universal access by then.

6. Conclusion

This work assessed the magnitude and intensity of EP 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 EP, having improved the MEPI from 0.9 in 2009 to 0.65 in 2015. This improvement is not uniform across the country. At the provincial level, Nampula is the poorest province, followed by Cabo Delgado, and Zambezia with MEPI scores of 0.77, 0.76, and 0.75, respectively, being Zambezia province the one suffering from higher deprivations for all indicators. Gaza and Tete are the provinces showing great inequalities among their population.

Considering the two different thresholds for EP does not affect the general results in terms of the MEPI, however, it affects the level of inequalities among the population and the intensity of EP. The results show that the level of inequalities is lower, and the intensity of EP is greater when considering the EP line $k = 0.4$ compared to the results obtained for $k = 0.33$.

Around 70% of Mozambican households lack access to electricity. Electricity consumption is mostly limited to more basic energy needs such as lighting, mobile phone charging, and entertainment rather than productive uses. Access to electricity along with telecommunication means are the dimensions that contributed the most to the improvement on the level of EP in the country.

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Traditional biomass (wood and charcoal) is the main 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 financially unviable option for most households. This is the indicator contributing the most to EP in the country. Therefore, policies encouraging the use of clean fuels for cooking are likely to contribute to EP reduction toward the achievement of the United Nations SDGs.

Agriculture, forestry, and fishery is the sector that employs most 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 EP across Mozambique provinces, suggesting that public policies should be defined at the provincial level and not via one umbrella policy to address EP. Therefore, coordinated policy actions between the electricity and other economic sectors (financial, agricultural, and infrastructural), might help fight against EP and inequalities among the population.

Although energy-poor households live mostly in rural areas, 34% of urban households are energy poor, which suggests that EP in the country is a rural and urban phenomenon. The coexistence of urban and rural EP 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 that does not create wealth for poverty alleviation is not enough to generate social Development and reduce 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 EP 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 EP 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 fulfil their basic needs.

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7. Getting DHS survey datasets

We used the 2015 Mozambican demographic and health surveys data for households to measure the multidimensional energy poverty index.

Datasets are publicly available and can be downloaded free of charge for legitimate research purposes. To get the datasets, you must register as a DHS data user at the DHS Program website at www.dhsprogram.com. You can find the registration link by going to icon Data then registering for dataset access. The registration is made for a specific country´s datasets. In our case, you must request the 2015 Mozambican DHS survey dataset.

Conflict of interest statement

There is no conflict of interest concerning this work to decelerate.

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