Energy for Sustainable Development 77 (2023) 101330

Contents lists available at ScienceDirect

Energy for Sustainable Development

journal homepage: www.journals.elsevier.com/energy-for-sustainable-development

Electricity access and unreliability in the creation of sustainable livelihoods in Mozambique

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ARTICLE INFO

Keywords:
Mozambique
Electricity unreliability
Electricity affordability
Micro, Small and medium-Sized enterprises
Sustainable livelihoods

ABSTRACT

Although Mozambique has abundant energy resources and strives to increase access to electricity as a strategy to fight poverty and to pursue the Sustainable Development Goals, the country faces a double challenge, the lack of access or affordability of electric services and their unreliability. This work assesses the level of electricity reliability in the country, surveys the perception of electricity unreliability by micro, small and medium enterprises in the provincial capitals of the central and northern regions of the country, and estimates the impact of electricity reliability and electricity expenses in the generation of sustainable livelihoods in the country. Using data from 2014 to 2018, it is shown that the studied areas experienced frequent and prolonged electricity outages, especially during working hours. Modelling of empirical results through the nonparametric Wild Bootrap estimation method shows that electricity unreliability and electricity expenses contribute negatively to the generation of sustainable livelihoods. Electricity projects that expand productive capacity in sectors employing most of the country's active population can contribute to the generation of sustainable livelihoods. Long-run policies might build resilient infrastructures and activate structural changes in the country's production system towards increased production, job creation, and generation of sustainable livelihoods.

Introduction

Universal access to electricity and other forms of modern, reliable, and affordable energy is globally and politically recognized as a key source for economic growth, human development, and poverty reduction in developing countries, and the pursuit of the Sustainable Development Goals (SDGs) (Daly & Walton, 2017; WEC, 2016). Therefore, Mozambique, which adopted the SDGs, is enhancing electricity access in urban and rural areas (World Bank, 2019a, 2019b) towards universal access to electricity by 2030 and pursuing the Sustainable Development Goals. However, access to electricity is necessary but insufficient to generate sustainable livelihoods and fight poverty in all its forms.

Expanding the economy's productive capacity and generating employment are effective ways towards economic inclusion of the poor population in the income generation process and, therefore, for the generation of sustainable livelihood and poverty reduction. Productive use of electricity through MSMEs as a source of out-employment and employment to others has the potential to contribute towards promoting the generation of sustainable livelihoods, poverty alleviation and reducing inequalities through increased revenues.

However, despite all the efforts to expand access to electricity, Mozambique still suffers from a double challenge, the low electrification rate; only 30.6 % of the country's population had access to electricity in 2020. Those with access to electricity face problems of lack of reliability of electricity supplied, and electricity supply is unaffordable despite the tariffs being set as cost-unreflective (IEA, 2019a; Salite et al., 2021).

Failures in the provision of electricity in low-income countries and Sub-Saharan Africa have been associated with 6.2 % and 5.3 % of the total losses in sales and production, respectively (World Bank, 2018a). According to IEA (2019a), 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.

In this context, the study assesses the level of reliability of electricity in the country and its empirical impact on the process of generation of sustainable livelihoods by Micro Small and Medium Enterprises (MSMEs). The study also assesses the impact of electricity expenses on generating sustainable livelihoods by the country's MSMEs.

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https://doi.org/10.1016/j.esd.2023.101330
Received 15 June 2023; Received in revised form 30 September 2023; Accepted 10 October 2023
Available online 25 November 2023

Besides the studies by IEA (2019a) and World Bank (2018a) reporting on the impact of unreliability and unaffordability of electricity supply in the country, no other studies on this subject for Mozambique were identified. Therefore, this study contributes to the literature by giving empirical evidence of the impact of electricity supply, its reliability and affordability in income generation by Mozambican MSMEs. The study provides detailed information on the frequency, duration, and distribution of power cuts over 24 h/day during the analyzed period. It compares the reliability of electricity supply between the studied regions. This information could help policymakers and energy planners design specific and effective strategies towards improving electricity reliability at the regional level and for daily needs. Furthermore, the study provides suggestions on how Mozambique could successfully use its potential in electricity resources to fight poverty and pursue the SDGs, which can help monitor the progress and effectiveness of implemented response policies towards the pursuit of the SDGs.

Literature review

Electricity access, electricity affordability and the generation of sustainable livelihoods

Ensuring access to reliable, affordable, and modern energy services is considered a critical factor in lifting people out of extreme poverty, thus with the zero-cost access policy, Mozambique is in the race for grid extension towards ensuring universal access to electricity by 2030 for poverty alleviation and sustainable development. However, most Mozambican households are still energy-poor and depend on firewood and charcoal as the main energy sources for cooking, the use of clean and modern cooking fuels is insipient and concentrated in urban areas, the households using clean cooking fuels complement them with charcoal, only 35 % of Mozambican population had access to electricity in 2020, the ownership of households, education and entertainment appliances is low, and energy poverty is both a rural and urban phenomenon in the country (Ugembe et al., 2022).

The reliance on firewood and charcoal might suggest that using clean cooking fuels (electricity, LPG, kerosene, natural gas, and biogas) is a financially unavailable option for most households. The coexistence of rural and urban energy poverty suggests that energy poverty is both a supply and demand side problem, i.e., it is not only an issue of lack of technical access to modern energy services, there are households in areas with technical access to modern energy services that cannot afford a minimum quantity of energy to fulfil their basic needs, which is indicative that the zero-cost access policy lacks economic sustainability policy for enhancing sustainable livelihoods to reduce poverty.

The productive use of electricity by small, micro, and medium enterprises has the potential to contribute to the goal of generating sustainable livelihoods and lifting people from poverty through job creation in formal and non-formal sectors, allowing the population to engage in income-generating activities, enhancing the workers' productivity, and improving agricultural productivity through irrigation.

Singh and Balachandra (2019) argue that the implementation of productive uses of energy can contribute to development through livelihood activities, microenterprises, value-added activities, and longer productive hours. Pueyo and DeMartino (2018) and Pueyo and Maestre (2019) argue that when electricity is used productively by small, and medium enterprises, it has the potential to increase productivity, generate income and sustain poverty reduction.

Expanding the population' means of living (sustainable livelihoods) is one of the effective ways to include the poor population in the production and income generation cycles, and therefore reduce poverty (EA, IRENA, UNSD, World Bank, 2022). Riva et al. (2018) state that energy projects can only fight poverty if they contribute to the improvement of the economic status of the population and influence the real formal economy (through job creation or new income-generating activities) and the informal economy as one of the main sources of employment to the majority of the active population in developing countries.

According to Bazilian et al. (2012) and Singh (2014) energy can influence income and sustainable livelihoods by making possible labour-saving mechanisms, freeing up time for income-generating activities and increasing the length of productive hours a day, however, to harness these positive impacts it is necessary that energy projects go hand in hand with additional efforts and institutional mechanisms that boost entrepreneurial activity and uses of electricity in income generating activities.

An impact evaluation study (Huq, 2018) in Bangladesh found that solar Home Systems improved all kinds of livelihoods (social, human, financial and physical) in the country. Similar results on financial livelihood were found (Mahat, 2004; Wester et al., 2019) in Nepal and Hindu Himalayan Regions, respectively. Johnstone et al. (2020), Mukisa et al. (2022), and Nhamire and Mosca (2014) found the same positive results in Tanzania, Ethiopia, and Uganda, respectively and Zaman et al. (2021) found the positive impacts of using electricity in the generation of sustainable livelihoods in Bangladesh, India, Kenia and Nigeria.

However, electricity affordability can act as a burden to the generation of sustainable livelihoods. If the electricity tariffs are high which would increase production costs, and therefore the prices of the goods and services, this in turn, will threaten the financial aspect of the generation of sustainable livelihoods. Fatona et al. (2013) consider adequate access to affordable energy as a key factor for economic development and transition from subsistence agricultural economics to a modern, diversified and service-oriented economy.

In most developing countries, agriculture is an important sector that generates livelihoods for more than half of the population, however, the lack of access to affordable energy is a barrier to agricultural and income generation activities (Nathwani & Kammen, 2019), and therefore, it is a burden to the generation of sustainable livelihoods, and the improvement of living standards in the economy.

Improvements in living standards, access to education, health, and human development are contingent on access to affordable energy services (electricity, particularly for its versatility) (Rahut et al., 2017). Louie (2018) and Mainali et al. (2014) go further when stating that access to electricity does little to improve the quality of life (therefore is not useful) if it is not affordable.

A study on the links between decentralized energy systems and sustainable livelihoods in the Brazilian Amazon (Mazzone, 2019) found that access to reliable and affordable energy influences individual behaviour towards the creation of new economic activities and diversified livelihoods, therefore it is essential for the implementation of new business and generation of financial livelihoods.

Mozambican electricity tariffs are not cost-reflective and electricity consumption in the country is low, which makes electricity utilities operate at a loss (EDM, 2018), however, although electricity tariffs are set too low for electricity utilities they are still above the payment capacity of the majority of the Mozambican households, making even essential energy services unaffordable to most households connected to the grid (IEA, 2019a, 2019b; UNDP, 2020). Mozambican households pay 6 % of the national GDP/year for electricity to power a refrigerator, compared to less than 1 % in South Africa and 4 % in Zimbabwe (Blimpo & Cosgrove-Davies, 2019).

Electricity ranks sixth among the top ten obstacles to doing business in Mozambique and, in particular, it is in the top three obstacles to doing business in Mozambique by medium enterprises (World Bank, 2018a). The cost of electricity as a percentage of income per capita is 3008.7 compared to 3187.5 in sub-Saharan Africa, on a scale of zero to 8, Mozambique ranks 4 for reliability of supply and transparency of tariff index.

By contributing to income generation, promoting the use of electricity to generate sustainable livelihoods is not only important for electricity customers. Still, is also important for the financial viability of the electricity supply (be it in mini-grids or the national grid) in developing countries where consumers have low purchasing power (Brew-Hammond, 2010; Kapadia, 2004; Kooijman-van Dijk, 2012; Nduhuura et al., 2021; Pueyo & DeMartino, 2018; Streatfeild, 2018; Valickova & Elms, 2021) and in Mozambique, particularly where electricity utilities operates at lose (EDM, 2018).

Therefore, unaffordable electricity supply by increasing production costs, negatively contributes to income generation, on the decision to implement new businesses, therefore, job creation, generation of sustainable livelihoods, and financial viability of electricity supply in developing countries where electricity consumption is lower due to the low purchasing power of the population.

Reliability of electricity supply and the generation of sustainable livelihoods

Energy is an important input to economic processes. For its versatility, electricity is the energy used the most in the dynamization of economies, production processes (of goods and services), and in people's daily activities (cooking, communication, security, transportation, and education). According to IEA (2017), electricity will account for more than 45 % of global final energy demand by 2040.

Electricity is also an important input for the sustainable development of the developing world; however, it is known that access to electricity is not an end on its own to generate human, social, and economic improvements, and in the context of poverty, access to electricity based on the number of households connected to the grid without productive purposes is less likely to generate poverty reduction.

Although developing countries in Sub-Saharan Africa and Asia are endowed with a wide variety of energy resources, as is in the case of Mozambique, the weakness of electricity infrastructures makes electricity supply unreliable and characterized by frequent voltage fluctuations and power cuts (Grainger & Zhang, 2019; Oseni & Pollitt, 2015).

Unreliable electricity supply constitutes one of the biggest challenges and constraints to the productive use of electricity as it contributes negatively to the development of small and medium enterprises and businesses, firm performance, production, factors' productivity, influences investment decisions and contributes to increasing companies' indirect costs (Abdisa, 2018; Falentina & Resosudarmo, 2019; Grainger & Zhang, 2019). An unreliable electricity supply also leads to losses of perishable goods and disruption in production, limiting productivity.

SMEs are one of the major sources of employment and income generation in developing countries, generating at least 60 % of employment in the manufacturing sector and accounting for almost 50 % of GDP in most developing countries (Martin et al., 2017). Moreover, SMEs are also one of the main agents for promoting productive uses of electricity in developing countries. Therefore, electricity supply failures can discourage the creation, development, and growth of SMEs, and hence, to effectively use electricity and create sustainable livelihoods to fight poverty.

For instance, according to Falentina and Resosudarmo (2019), in Nigeria, the electrification rate has reached 96 %, but only 18 % of these connections function for more than half of the time. Streatfeild (2018) points out that the electricity supply is lower in Sub-Saharan Africa than in any other region globally.

Frequent electricity outages make companies with the financial capacity to invest in backup electricity to engage in self-generated electricity by buying diesel generators (the most common strategy used) or investing in off-grid renewable energy to mitigate the costs of power interruptions (Abdisa, 2018; Falentina & Resosudarmo, 2019; Grainger & Zhang, 2019; Streatfeild, 2018).

Using diesel generators to deal with electricity outages is positively associated with productivity (Falentina & Resosudarmo, 2019). However, diesel generator for electricity production contributes to increasing indirect production costs since the electricity generated this way is more expensive than that supplied by the public grid (Oseni & Pollitt, 2015; Streatfeild, 2018). Streatfeild (2018) argues that using backup generators may increase the companies' electricity expenses up to 10-fold.

Additionally, it is argued that electricity outages and the high costs of self-generation of electricity can cause companies to operate below their full potential by forcing them to change the use of non-flexible inputs, such as labour, and can divert companies to invest in developed and modernized technologies since it implies enhanced dependence on electricity (Abdisa, 2018; Falentina & Resosudarmo, 2019). Finally, using diesel generators to produce electricity increases greenhouse gas emissions, calling into question the objectives of mitigating global warming, climate change and their effects and, thus, jeopardizing the sustainable development goals.

Besides the efficiency channel in which power outages disrupt the production process and therefore the idle of production resources, the poor quality of power causes electricity fluctuations that contribute to damage to machinery or electric equipment, making enterprises incur high costs on frequent repair or replacement of the damaged equipment and the decomposition of finished products or inventory (Ahadu, 2019; Cissokho & Seck, 2013; Gjokaj et al., 2021; Yelwa & Yusuf, 2021). Authors such as Cissokho and Seck (2013) argue that electricity unreliability also contributes to reduce the quality of the goods and services produced by enterprises due to the rush to meet deadlines due to anticipated power outages, spoiled inventories or malfunctioning machines.

All these furtherly increases the production costs that translate into high prices to the end consumers despite the reduced quality of the goods and services, however, the high prices do not necessarily imply increased profits or high production capacity of the enterprises. Therefore, the electricity unreliability also reduces the enterprises' capacity to generate employment.

The empirical literature for the African context confirms the negative impacts of the unreliability of electricity supply on its productive uses. For instance, Mensah (2016) found significant negative effects of electricity shortages on firm productivity, size, and labour employment in Sub-Saharan Africa, and Abotsi (2016) concluded that power outages have a negative impact on production efficiency.

For instance, we found studies from Nigerian, Ethiopian, Cameroonian, Ghanaian, South African, and Kenyan contexts at the country level. Analyzing the economic costs of electricity shortages in the Nigerian manufacturing sector (Adenikinju, 2003) found that firms incur huge costs on the provision of expensive backup electricity to minimize the power outage costs, even spending 20–30 % of their initial investment on the acquisition of facilities to enhance electricity supply reliability, and thus electricity supply unreliability has a significant negative impact on the cost competitiveness of the manufacturing sector.

Moyo (2012) confirmed the negative impact of power disruptions on firm productivity in the manufacturing sector, particularly in small firms in Nigeria, Amadi (2015) found that power outages reduce sustained economic growth and severely impact people's social lives in the Niger Delta, Nigeria.

Still, in the Nigerian case, Muhammed et al. (2017) found that the quality of electricity services accounts for more than 50 % of the variances in the financial and non-financial performance of manufacturing SMEs. More recently, Adanlawo and Makhosana (2021) found that electricity outages have significant effects on Nigerian SMEs, Kingsley and Tonuchi (2021) found that a 1 % increase in electricity blackouts leads to a 1.04 % decrease in productivity, and electricity price has a negative impact on productivity and similar results were found by Ogunlamİ et al. (2021) in selected semi-urban centres of Lagos and Ogun states of Nigeria.

In Ethiopia, Abdisa (2018) found that electricity supply failures negatively affected companies' productivity and costs by 15 %. Similar results were obtained by Diboma and Tamo Tatietse (2013) in Cameroon, by Maende and Alwanga (2020) and Nyangwaria and Munene (2016) in the Kenyan context.

In Ghana, power outages negatively affect the country's companies' sales growth and productivity; this negative impact is higher among manufacturing enterprises than companies in the service sector (Teye et al., 2021). Power outages reduced small business income in Johannesburg, South Africa (Schoeman & Saunders, 2018).

Therefore, electricity unreliability is a factor that, by negatively affecting production, productivity, and performance of MSMEs, can affect the process of generation of sustainable livelihood, and the use of backup electricity generation systems mostly from fossil fuels can jeopardize the pursuit of reducing greenhouse gas emission, climate changes and sustainable development.

Electricity reliability in Mozambique

Mozambique has the fourth-largest reservoir in Africa and the largest concrete dam by volume at the Cahora-Bassa Dam (Gregory & Sovacool, 2019). The country has good electricity generation potential; it can generate electricity in sufficient quantities to meet the national demand for electricity and export it to neighbouring countries such as South Africa, Zimbabwe, and other countries in the Southern African Power Pool (SAPP) (SAPP, 2020).

At the national level, Mozambique has been making efforts to increase access to electricity towards achieving SDG 7 by 2030; however, despite these efforts and the role played in the SAPP, about 65 % of the Mozambican population still lives without electricity (EDM, 2020), and many of those who have access face unreliability problems in the services provided.

The Mozambican power system is developed as three separate systems (southern, central, and northern, the latter having some mutual interconnections). With a weak financial capacity to invest in the expansion of the national electricity grid, the Mozambican power system has a vulnerable transmission network that lacks resilience and is not sufficiently spread to allow lower voltage network expansion, see Fig. A1, Supplementary materials.

According to ALER (2017), Mozambique has about 2905.45 MW of installed electricity generation capacity, 74.3 % of which comes from hydropower; of this, almost 95 % (corresponding to 2075 MW) is generated at Cahora-Bassa Hydroelectric (HCB). Only 500 MW (300 MW of firm power and 200 MW of non-firm power) of the electricity generated at HCB is available for national consumption through the national electricity utility, *Electricidade de Moçambique* (EDM).

More than 90 % of the electricity generated at HCB is exported, which was a financial requirement to finance its construction (Isaacman et al., 2015). Therefore, the national grid (electricity from HCB) does not cover the whole country; most areas are covered by other electricity sources such as natural gas electricity generation, Solar PV, small dams, and even diesel generators (Salite et al., 2021).

With 100 km of electricity transmission line per million people (Streatfeild, 2018) and an installed generation capacity for the national market of about 1044.5 MW (ALER, 2017), Mozambique does not have electricity in enough quantity to meet the growing national demand. Therefore, the country not only exports electricity to neighbouring countries but also re-imports some of the electricity exported to South Africa (some of the electricity supplied in Maputo, Gaza, and the southern part of Inhambane province is delivered from South Africa).

The transmission system is inefficient (in poor conditions) with long distances, generating a high rate of system losses. According to EDM (2020), in 2020, the national transmission network had 6298 km, and the distribution network 20,344 km; the electricity losses grew from 29 % in 2018 to 31 % in 2020. It has been estimated that for every 100kWh produced in the country, 23 % of system losses are recorded (Streatfeild, 2018).

The problems of insufficient electricity supply, the poor quality of the Mozambican electricity transmission and distribution system and the system electricity losses, make the available power to the end-users even smaller, creating overload problems and, therefore, voltage dips and more electricity outages and flickers[2] (Jufri et al., 2017; UNDP & UNCDF, 2020).

Although Mozambique has made efforts to increase its electricity generation capacity, the northern region still has a deficit of about 200 MW, and the growth in demand for electricity in the national market requires a further increase in generation capacity by at least 50 MW/year (EDM, 2019, 2020).

Electricity theft also affects the quality of infrastructure and the amount of electricity available for the end-users. According to Olaoluwa (2017) and Tehero and Aka (2020), power theft *generates* overloads of distribution networks and damages network equipment, burning cables, exploding transformers, and melting fuses, thus causing poor quality of voltage and repetitive breakdowns and electricity outages.

Additionally, the cost-effectiveness of electricity supply in the country is another factor affecting electricity reliability. Most households in rural areas cannot afford electricity to fulfil their basic needs, a situation exacerbated by the expensive nature of off-grid electrification solutions for rural areas (e.g., mini-grid Solar PV).

Therefore, to provide electricity at socially acceptable prices and reduce energy poverty, the Mozambican government regulates electricity prices for most of the national electricity utility's customers, corresponding to 63 % of EDM's total sales (EDM, 2020). However, the regulated prices are set above the payment capacity of most Mozambican households (Blimpo et al., 2020; IEA, 2019b), yet they still do not reflect the actual costs (Fig. A6 Supplementary materials) and, therefore, the electricity utility in Mozambique operates at a loss (EDM, 2018, 2020).

This makes the national market unattractive and thus, limits private and foreign direct investment that allows the transfer of technologies needed for the modernization and improvement of the quality of the country's electricity sector.

The dilemma of low electricity consumption and low competitiveness of electricity prices in the national market makes the electricity utility fall into a feedback loop of low revenues and poor financial capacity to invest in a quality electricity grid. This situation is exacerbated by the theft of electricity, which further reduces revenues from the sale of electricity, causing billing irregularities or unpaid bills (Shokoya & Raji, 2020).

The Mozambican electricity quality is also affected by climate issues/extreme weather events (floods and cyclones). According to World Bank blogs (2019), natural disasters in Mozambique lead to an annual loss of about $ 100 million, corresponding to 1 % of the country's GDP.

The natural disasters cause electricity outages and put Mozambique in an endemic situation of infrastructure recovery, lowering the quality of electricity infrastructure and exacerbating the unhealthy financial condition of the national electricity utility (EDM, 2016, 2019, 2020; Emerton et al., 2020; Governo da República de Moçambique, 2019).

To reduce unreliability in the country's electricity sector, the World Bank developed the five years Power Efficiency and Reliability Improvement Project (PERIP) running from 2018 (World Bank, 2018a, 2018b). However, power cuts are still frequent in the country and can last minutes, hours or even days (Salite et al., 2021). According to World Bank data (World Bank, 2019a, 2019b), the Mozambican Average System Interruption Duration Index (SAIDI) or the average outage duration for each customer served was about 80 h in 2018 and 2019, compared to 30.53; 20.90 and 51.22 h for South Africa, Tanzania, and Zambia respectively.

Frequent power outages and poor physical infrastructure supply (electricity, roads, water, and telecommunications) are major constraints for businesses faced by industrial sectors and SMEs in Mozambique. The country ranks 138th out of 190 countries on the annual Ease of Doing Business Index (World Bank, 2018a; World Bank, 2019a, 2019b).

[2] Rapid variations in the luminous (brightness) of lamps (Mehl, 2012).

In this section, we analyzed the EDM's data series of daily electricity outages that occurred over five years (2014–2018) in the Mozambican transmission systems of the central and northern regions. The southern region was dropped from the study because its data series had many data gaps, which would lead to a false conclusion that the electricity supply in this region is more reliable than in the other two areas.

Fig. 1 shows that during the analyzed period, the Northern Power Transmission System (DTNO) performed worse in terms of the duration of electricity outages than the Central Power Transmission System (DTCE). Similar behaviour in terms of the number of power cuts (see Fig. A2 Supplementary materials) indicates that the population with access to electricity in the northern region is more often without electricity and the power cuts in this region last longer than in the central region.

Although there have been no significant improvements in the frequency of interruptions in the electricity supply, its duration has decreased over the years. EDM (2020) reports that the improvement in the duration of the interruptions is a result of grid inspections, preventive maintenance, deforesting of easements and installation of birdwatchers.

The high interruption frequency in 2015 is explained by the flood that occurred that year in both regions that brought down the high-voltage transport towers leaving both regions (a total of 350,000 EDM connected costumers) without access to the national grid electricity and at the mercy of backup electricity supply from small dams and small diesel generation systems for one month, leaving the central distribution system unstable for 50 days (EDM, 2016; UNDP & UNCDF, 2020).

The distribution of the electricity outages throughout the day was assessed, registering the occurrence of power outages every 10 min during the five years under analysis. Fig. 2 shows a concentration of electricity outages during the normal working period (between 8:00 a.m. and 4:00 p.m.), reaching the maximum frequency of power outages during peak hours (between 6:00 and 8:00 p.m.) until 2016. Since then, the electricity outages have been concentrated and smoothly distributed between 8:00 a.m. and 9:00 p.m.

Additionally, Fig. 2 also shows that the DTCE had its situation worsened between 2015 and 2016, during which the region had the maximum frequency of power outages at peak hours. This behaviour can be explained by the problems caused by the region's 2015 floods, whose impacts might have lasted until the following year.

Finally, it also shows an improving trend in the electricity outage distribution during the period in analysis with increasingly smoother and flat distributions in both distribution systems and electricity outages that are concentrated in normal working hours (09:00 a.m. and 3:00 p.m.), those that may be more negatively influencing the country's production.

The EDM annual report reported three reliability indexes for the years 2018 to 2020: The System Average Interruption Frequency Index (SAIFI), the System Average Interruption Duration Index (SAIDI), and the System Average Restoration Index (SARI) for the years 2019 and 2020 (EDM, 2019, 2020), see Figs. A3–A5 Supplementary materials.

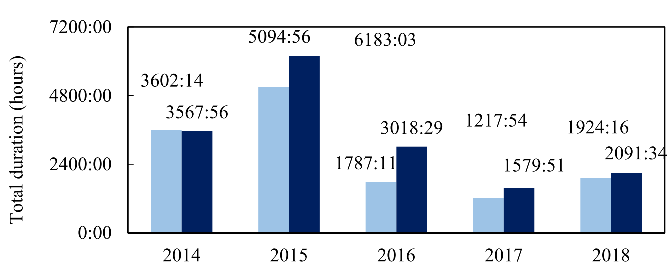

Fig. 1. Total annual duration of the power cuts in the Northern Power Transmission System (DTNO, dark blue line) and Central Transmission System (DTCE, light blue line).
Source: Built from EDM data.

With an average of 54 and 56 electricity interruptions in 2019 and 2020, respectively, the DTNO is leading in the average number of electricity interruptions experienced by customers (SAIFI), as the average number of electricity outages experienced in this area increased from one year to the next (see Fig. A3 Supplementary materials).

The Southern Power Transmission System (DTSU) has the lowest SAIFI among the three regions, suggesting that the electricity supply in this region is more reliable than in the other two regions. Despite the increased SAIFI for the central region in 2019 due to Cyclone Idai, which destroyed the electricity infrastructures in this area, the national electricity utility managed to rebuild the system and improve its performance since the average electricity outages experienced by a typical electricity customer reduced by 9 units in 2020, and 3 electricity outages less than in 2018 compared to 4 and 8 in the southern region, respectively.

At the national level, the National Power Transmission System (RNT) results show that the country performed well, with a reduction of 4 in the average number of electricity outages experienced by a typical customer from 2019 to 2020, A3 Supplementary materials. The DTNO had the worst performance in 2020 compared to the same period in 2019 and 2018, suggesting that, despite the improvements in the national grid, the DTNO still needs investment to reduce the number of interruptions in the electricity supply.

Regarding SAIDI, Fig. A4 (Supplementary materials) shows that a typical electricity interruption can leave the customer without electricity for over 70 h/year, on average. It also shows that the three regions managed to reduce their SAIDI, which is reflected in a 41.5 % reduction of this index at the national level. The Central region performed better, having reduced the average interruption duration index to 54:15 h, an almost 45 % decrease from 2019 to 2020. Once again, the negative impacts of Cyclone Idai are shown in 2019's SAIDI for the central region.

Regarding SARI, Fig. A5 (Supplementary materials) shows improvements: in the event of an electricity outage, the national electricity utility EDM took an average of 2:14 h to restore the electricity in the system in 2019, but the following year, the time was reduced by about 32.8 %. The central region also performed better in this indicator than the other regions.

Although the southern region has better reliability indicators regarding SAIFI and SAIDI, it has the worst performance in terms of SARI. In the event of electricity interruption, the national electricity utility takes longer to restore electricity to the system in the southern region than in the rest of the country.

Looking at the five years under analysis (2014–2018) and the two years (2019 and 2020) published by the EDM's reports, one can conclude that, while there is still a long way to go, the country is achieving significant progress improving electricity reliability, which has been shown by the reduction in the frequency and duration of the electricity outages over the years as well as in the improvements in the three-reliability electricity index presented above. The DTNO is still showing negative performance, which means that more efforts are needed to improve the electricity reliability in this region.

Methods and model specification

To access the empirical impact of electricity reliability in the generation of sustainable livelihoods by MSMEs in the country, the perceptions of electricity unreliability by Mozambican MSMEs[3] operating in the cities of provincial capitals in the central and northern regions of the country are surveyed using the non-probabilistic convenience sampling in which the participants are selected because are ready and readily available (Taherdoost, 2016) and simple model in which the

[3] These are companies whose number of workers does not exceed 99 and whose annual business volume varies from less than 1,200,000.00 and more than 29,900,000.00 MZN (Ministério da Indústria e Comércio, 2016).

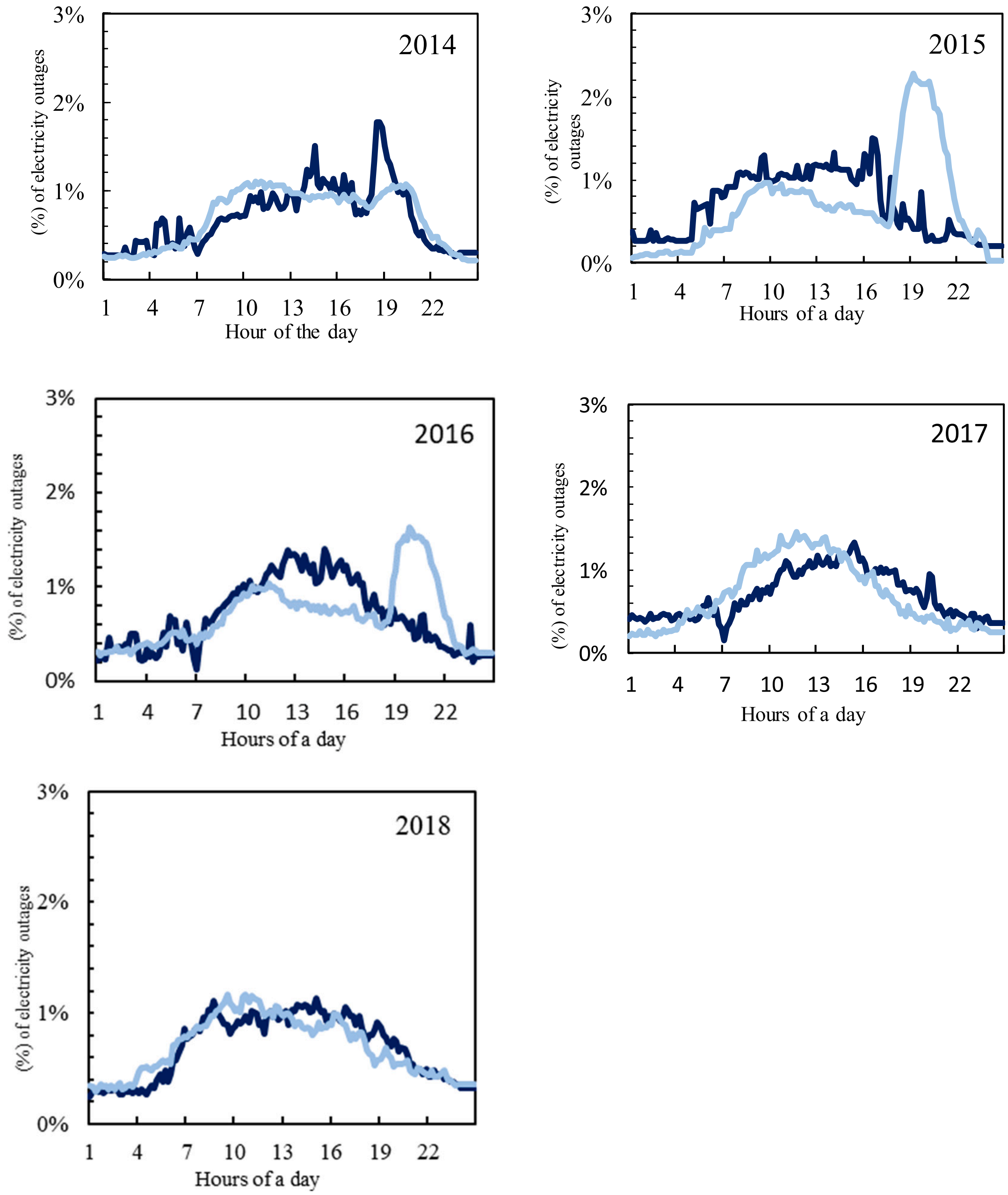

Fig. 2. Distribution function of power outages/hour for the analyzed period, in the DTNO, dark blue line and DTCE, light blue line.
Source: Built from EDM data.

enterprise's revenues (Rev_i) are expressed as a function of $Labour_i$, $Electruse_i$, Rel_i, $Elecxp_i$:

$$Rev_i = f(Labour_i; Electruse_i; Rel_i; Elecxp_i) + \mu_i \tag{1}$$

where i represents the $i = 1, 2, 3, \ldots, n$ surveyed enterprises, $F()$ is unknown function describing the empirical relationship between the dependent variable (Rev_i) and the independent variables ($Labour_i; Electruse_i; Rel_i; Elecxp_i$), Rev_i represents the enterprise i revenues, which represents the sustainable livelihoods; $Labour_i$ is the number of employees in the enterprise i; $Electruse_i$ is a dummy variable that takes 1 if the enterprise i uses electricity in its production process and zero otherwise; Rel_i; $Elecxp_i$ measure the electricity expenses as a percentage of revenues in enterprise i; and μ_i the error term represents other factors that can explain the enterprises' revenues than the four used insofar.

Due to the informal nature of most micro, small and medium-sized enterprises in the country, it was not possible to find historical records of the enterprises 'information for the period (2014–2020) analyzed in the previous section, therefore, the variable $\mathrm{Rel_i}$ used in the model represents the reliability of the electricity accessed by the enterprise i measured as the enterprise's perception of the average duration of power outages (in hours).

The choice of this population is explained by the fact that the country's business sector is mainly composed of MSMEs (97.6 % of the 61,579 registered enterprises) (INE, 2017). The MSMEs and developing countries are labour-intensive, and labour is a factor contributing positively to the enterprises' production and income in the developing countries' MSMEs (Ariesa et al., 2021; Noor Salim et al., 2020; Suhaili & Sugiharsono, 2019), therefore a positive impact is expected from labour ($log(Labour_i)$) to enterprises' revenues ($log(Rev_i)$).

Electricity outages generate forced production stops, translating into reduced revenues (Adanlawo & Makhosana, 2021; Doe & Asamoah, 2014; Falentina & Resosudarmo, 2019). Consequently, a negative relationship is expected between enterprises' revenues and electricity unreliability. Electricity costs negatively impact African SMEs' profitability (Esselaar et al., 2006). Thus, a negative relationship between electricity expenses and enterprises' revenues is expected.

However, the success of MSMEs depends on other factors or complementary factors, such as access to other infrastructures (roads and markets), access to finance, and investment in electrical equipment (Pueyo & DeMartino, 2018; Terrapon-Pfaff et al., 2018). Then, the following model, including the complimentary variables, will be estimated:

$$Rev_i = F(Labour_i; Electruse_i; Rel_i; Elecxp_i; Inv_i; Finance_i; Market_i; Region_i) + \mu_i \quad (2)$$

where Inv_i is the monetary value of the investment in electrical machinery by enterprise *i*; $Finance_i$ is a dummy variable assuming one if the enterprise *i* has access to credit and zero otherwise; and $Market_i$ a dummy variable that takes one if the enterprise *i* sells its products in other markets than the local one. Electricity access enables enterprises to use electrical equipment that improves production and human productivity (Terrapon-Pfaff et al., 2018). Therefore, a positive influence is expected from the variable (Inv_i) to the enterprises' revenues.

Studying the impact of constraints to access to finance on the performance of African firms, Fowowe (2017) found that firms that are not credit-constrained experience faster growth than those which are credit-constrained. Mbuva and Wachira (2019) found a positive correlation between access to finance and the financial performance of processing SMEs in Kitui County, Kenya, hence, a positive signal is expected for the coefficient of the variable $Finance_i$.

Access to infrastructures such as roads and markets is also an important factor for the acquisition of raw material production flow and therefore making the productive uses of electricity successful Terrapon-Pfaff et al. (2018), thus, a dummy variable denoted as ($Market_i$) is introduced in the model expecting a positive relationship between access to the market and enterprises' revenues.

Empirical results

Descriptive results

Most of the interviewed enterprises (corresponding to 72 %) fall into the micro-enterprises whose annual revenues are less than 1,200,000.00, according to the Ministry of Industry and Commerce classification, see (Ministério da Indústria e Comércio, 2016).

Almost all (95 %) of the surveyed enterprises stated they use electricity in their production process, that the National grid is the source of electricity they use and reported facing unreliable electricity supply (Table 1), with electricity outages occurring daily, weekly, and monthly for 13.94 %, 58.17 %, and 28.85 % of respondents, respectively.

When the enterprises were asked what they would do in the event of a power outage, all enterprises using electricity in the production process without a backup generation system stated that they stop producing until the power was restored. Therefore, electricity outages generate forced stops in the production process, threatening the fulfilment of order deadlines. It was reported that the production also stops in cases of under-voltage situations.[4] In addition to the abovementioned cases, enterprises also face spikes, voltage swells, and overvoltage[5] that cause equipment breakdowns.

Table 1
Electricity outages.

	Electricity outages (%)	Daily (%)	Weekly (%)	Monthly (%)
Yes	95.0	13.94	58.17	28.85
No	5.0			

For enterprises such as bakeries, poultry farms, and cement block factories, electricity unreliability also implies the loss of raw material. Bakeries, for example, use machines that depend on the availability of electricity to knead the wheat. Thus, a power outage during the kneading process or before the bread is fully baked can generate considerable losses of raw materials. To avoid these losses and reduce electricity costs, some bakeries (10.05 % of the interviewees) reported using diesel generators as backup electricity and others (3.35 %) use wood-fired ovens, see Table A1 Supplementary materials.

More than half (68 %) of the interviewed enterprises use between 0.3 % and 14.7 % of their revenues to pay for electricity. The remaining 32 % use from 14.7 % up to almost 39 % of their incomes on electricity expenses; see Fig. 3. These expenses are especially high for micro-enterprises, which are less likely to afford a backup electricity generation system. Therefore, when there is an electricity outage, these enterprises stop their production and lose revenues that would be earned from continuous production. Some carpentry shops choose to do manual work during power cuts as a way of not delaying production.

Electricity use in income generation depends on other factors, such as access to finance and public infrastructures, such as roads and markets. The survey showed that only 17.6 % of the surveyed enterprises have access to finance, and the overwhelming majority (82.4 %) do not have access; of these, 13.7 % have never asked for funding despite being aware of the existence of this possibility to leverage their enterprises; 2.7 % claim to have already applied for funding and been denied due to lack of collateral and high bureaucracy during the process. The remaining argued that they did not know they could apply for funding. Others claim that only state employees have access to funding, reaffirming the need for collateral for finance access. Almost 80 % of the interviewed enterprises sell their products only in the local markets, which can be explained by their stage of development, as they are primarily micro-enterprises, see Table A2 Supplementary materials.

Before estimating the model, we accessed the descriptive statistics to check the Normality of the data series through the Kolmogorov-Smirnov

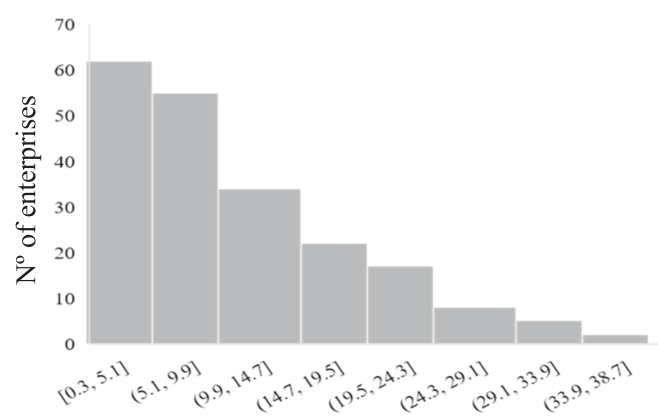

Fig. 3. Electricity expenses as a percentage of revenues.

[4] When voltage levels are below the minimum voltage required to power the equipment used in the production process.

[5] Voltage swells are disturbances in the supply of electricity characterized by the increase in the supply voltage above the normal limit, according to relevant technical standards whose duration do not exceed 2 s. They are called spikes when the disturbances occur in an extremely short period (micro or milliseconds) and are called overvoltage when the duration exceed 2 s.

and Shapiro-Wilk normality tests (Hanusz & Tarasińska, 2015; Lilliefors, 1967; Royston, 1992; Srivastava & Hui, 1987). Table 2, shows that the significance level for all variables is less than 5 %, which indicates that the data series of all the variables under analysis are not normally distributed.

One of the solutions to correct the problem of nonnormality of the data consists of transforming the variables into logarithms (Wooldridge, 2002, 2016), however, given the nature of most of the variables considered in the model, some retruncated or binary, therefore are not normally distributed (Noreen, 1988) and other such as Inv_i can take zero value for the enterprises that did not make any new investment in the period from 2020 to 2022. Therefore, only the variables Rev_i and $labor_i$ can be transformed into logarithms. However, even with the transformation, the data series of the variables Rev_i and $labor_i$ are still not normally distributed.

The nonnormality of the data series violates one of the most important assumptions of parametric analysis to describe the relationship between the dependent variable Rev_i and the independent variables (Wooldridge, 2002, 2016).

For producing biased estimators and invalidating the t and F tests of the parametric analysis, the nonnormality of the data series can lead to misleading results of the relationship between dependent and independent variables (Jacquez et al., 1968; Wooldridge, 2002, 2016). In this case, studies by (Dhekale et al. (2017), Mahmoud et al. (2016), and Rajarathinam and Parmar (2011) suggest the use of nonparametric and semi-parametric analysis to estimate the relationship between the dependent variable and the independent variables.

According to Grosser et al. (1984), Lin and Ying (2001), and Yatchew (1998) the nonparametric and semi-parametric analysis relaxes the assumptions (the assumption of normality of the residual series and prior knowledge of the functional form describing the relationship between the dependent and independent variables) needed by parametric models to generate accurate estimates of the model's parameters.

Within the nonparametric framework, authors such as Bollen and Stine (1990), Horowitz (2019), and Ron (1995) suggest the bootstrap methodology proposed by Efron (1979). By resampling the data series, the bootstrap methodology consistently estimates the asymptotic distribution of econometric and test statistics without requiring the normality assumption and provides a way to reduce or eliminate finite sample errors in the rejection probabilities of statistical tests (Horowitz, 2019). In the bootstrap framework there are several estimation approaches, for details, see Horowitz (2019), for this study, we use the Wild bootstrap approach as it can deal with the heteroskedastic and nonnormality of the data series (Horowitz, 2019).

To explain the bootstrap methodology, consider a random variable Y that includes in its components the dependent and independent variables used in the model and the data denoted by $\{Y_i : i = 1, 2, \dots n\}$ as the iid[6] observations of the sample from an unknown probability distribution function $F()$ and $F_n()$ the empirical distribution function of the sample.

The empirical distribution function of the sample is defined for any vector z whose dimension is equal to that of Y as follows:

$$F_n(z) = \frac{1}{n}\sum_{i=1}^{n} I(Y_i \leq z) \tag{3}$$

where $F_n(z)$ is the nonparametric maximum likelihood estimate of $F_n()$, $I()$ is the indicator function whose inequality holds component by component.

The main purpose of the bootstrap methodology is to estimate the distribution $T_n(Y_1, Y_2, \dots, Y_n)$ (a statistic that estimates the parameter θ of the unknown $F_n()$) by pretending that the empirical distribution of the data was drawn from the population whose distribution function is $F_n()$ Instead of $F()$ (Horowitz, 2019).

Therefore, the methodology pretends that the empirical distribution of the data for Y is known, and the exact finite sample distribution of T_n can be computed with accuracy by simulation, thus first step is to resample the original data randomly with replacement to generate a bootstrap sample $Y_i^* : i = 1, 2, \dots, n$, then compute $T_n^* = T_n(Y_1^*, Y_2^*, \dots, Y_n^*)$ and use the results of many repetitions of the first and the second steps to compute the empirical probability of the event $T_n^* \leq \gamma$ or the proportion of repetition in which the event $T_n^* \leq \gamma$ occurs.

In this context, the wild bootstrap combines the data with random variables drawn from a known distribution to generate the bootstrap sample, and it is implemented as follows:

1. We estimate a parametric linear regression model $Y_i = \beta' X_i + \mu_i$ using the Ordinary Least Squares (OLS) methodology and generate the residual series $\widehat{\mu}_i = Y - \widehat{\beta}' X_i$;

   Being Y_i the enterprise's i revenues and X_i the vector of the explanatory variables in Eqs. (1) and (2).

   Generate the bootstrap sample $\{Y_i^*, X_i : 1, 2, \dots n\}$ from

$$Y_i^* = \beta' X_i + \mu_i^* \tag{4}$$

   and compute the resulting bootstrap t statistic, t_n^* by using a heteroskedasticity consistent covariance matrix;
2. Obtain the empirical distribution of t_n^* by repeating step 2 many times (for this study the repetitions were 10,000 times) and the critical values of t_n^*. These critical values are used with the t statistic from the original data to test the hypothesis and construct confidence intervals for the components of β.

Model estimation and results

In Table 3, we present the results of the model estimation of the model parameters, standard errors, and confidence intervals assessed at a confidence level of 95 % or a margin of error/significance level of 5 %, using the Wild Bootstrap methodology with 10,000 resampling repetitions. The coefficients represent the average impact of the independent variables on the dependent variable.

Note that the results above are not parametric, therefore, they should be interpreted with caution since they do not represent marginal impacts as it is in parametric models, but they give us the average impact through which we can confirm the theoretical positive or negative impacts of the independent variables in the dependent one.

Regarding electricity-related variables, Ugembe et al. (2022) argued that the productive uses of electricity can generate income that can leverage the impact of electricity access on poverty alleviation. The model's estimation confirms that enterprises use electricity in their production process (expressed by the dummy variable $Electruse_i$) have on average greater revenues than those of those that do not use electricity in their production process, however, the electricity expenses (measured by the variable $Elecxp_i$) contributes negatively to the enterprises' revenues or the generation of sustainable livelihoods.

The model estimation also confirms electricity unreliability or outages (represented by the variable). Rel_i) in a certain geographical area negatively contributes to the generation of sustainable livelihoods (measured by the enterprises' revenues) in that area.

Besides electricity, the MSMEs' revenues are also explained by the number of workers, as was expected from the model specification theoretical framework, if the enterprises increase their number of workers (measured by the variable $labour_i$) by 1 %, their average annual revenues are expected to increase by about 0.8 %.

The theoretical framework argues that the economic impact of the use of electricity in the production process depends on other factors such as access to infrastructures (roads and markets), access to credit and investment in electrical equipment to boost production and productivity

6 Independent and identically distributed.

Table 2
Normality test.

Normality tests						
Variables	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	Degrees of freedom	Significance	Statistic	Degrees of freedom	Significance
Log(revenues)	0.124	219	0.000	0.951	219	0.000
Log(labour)	0.094	219	0.000	0.941	219	0.000
Electruse	0.541	219	0.000	0.211	219	0.000
Elecexp	0.198	219	0.000	0.552	219	0.000
Rel	0.350	219	0.000	0.439	219	0.000
Investment	0.371	219	0.000	0.346	219	0.000
Finance	0.415	219	0.000	0.639	219	0.000
Region	0.380	219	0.000	0.628	219	0.000
Market	0.489	219	0.000	0.496	219	0.000

Table 3
Model estimation results.

Dependent variable log(revenues)
Method: Wild bootstrap
Original data observations: 219
Resampling repetitions: 10,000

Independent variables	Coefficient	Bias	Standard errors	Significance	Confidence interval (95 %)	
					Lower bound	Upper bound
Constant	11.821	−0.014	0.492	0.000	10.975	12.638
Log(labour)	0.791	0.004	0.093	0.000	0.609	0.990
Electruse	0.483	0.004	0.447	0.359	−0.300	1.274
Elecexp	−1.340	0.019	0.422	0.001	−2.159	−0.490
Rel	−0.004	3.484E−5	0.003	0.177	−0.010	0.002
Investment	6.533E−7	1.476E−10	1.693E−7	0.000	3.512E−7	9544E−7
Finance	−0.029	−0.001	0.070	0.693	−0.164	0.105
Region	0.266	0.003	0.141	0.069	−0.016	0.550
Market	0.229	−0.016	0.164	0.183	−0.077	0.498

(Pueyo and DeMartino, 2018; Terrapon-Pfaff et al., 2018).

The impact of investment in the creation of sustainable livelihoods (measured by enterprises' revenues) is positive and statistically significant at 5 % of the significance level. However, although negative, the impact of access to credit (finance) is statistically non-significant. This might be showing that access to credit to finance investment in Micro, small and medium enterprises through commercial banks can be a burden to the generation of sustainable livelihoods by micro and small enterprises as the interest rates are high (Alfazema, 2021; Filosofia, 2014; Osano & Languitone, 2016) and therefore threatening production expansion and the process of generation of sustainable livelihoods.

When it comes to access to other markets (measured by the variable $Market_i$) to dispose of the additional production (e.g. the production that increases due to the use of electricity in the production process), the model estimation shows that with a 5 % significance level, the average revenues of the enterprises with access to other markets are higher than of those who sell their products only in the local markets.

Discussion and policy implications

The study provided evidence that electricity is used productively by MSMEs and has a positive impact on the enterprises' revenues, demonstrating that if electricity is used productively, it can contribute to the generation of sustainable livelihoods. Such improvement can be made through increased revenues, yet, no evidence was found of a specific program supporting the productive use of electricity in the studied areas, which shows the existence of abilities for the business initiative among the population.

However, electricity expenses and unreliability negatively affect their performance, generating a counter-productive effect. This supports the idea that unreliable and unaffordable electricity supply is a factor that can threaten the generation of sustainable livelihoods.

Access to the market and finance are also factors that were proven to contribute positively to the upgrade of the performance of MSMEs. However, the small size of most enterprises in the country, utmost of the interviewed enterprises are informal and family-owned, employing up to 4 workers (members of the same household), with low production and income, which makes access to other markets and finance, challenging issues as they are unable to provide the necessary collateral to be eligible for financing to invest in more efficient production instruments and expand their business.

Expanding the economy's productive capacity and generating employment are effective ways towards economic inclusion of the poor population in the income generation process and for developing sustainable livelihood. The productive use of electricity through MSMEs as a source of out-employment and employment to others has the potential to promote poverty alleviation and reduce inequalities through the generation of sustainable livelihoods.

For most developing countries like Mozambique, the MSMEs and agriculture are some of the most critical sectors of the economy, often the only opportunity for self-employment and job creation for others (Mukhoti, 2019). The agricultural sector contributes an average of 20.2 %[7] to the GDP in the SADC countries, and it is an important livelihood source for about 70 %[8] of the population in this region. In the Mozambican case, agriculture, and forestry account for 24.4 % of the national GDP and employ 66 % of the country's active population (INE, 2019); however, their activities are highly dispersed with significantly reduced productive capacity, i.e., they produce for subsistence.

From this, how could Mozambique successfully use its potential in

[7] See https://www.sadc.int/about-sadc/overview/sadc-facts-figures/, accessed on 06/21/2022.

[8] See https://www.sadc.int/themes/agriculture-food-security/, accessed on 06/21/2022.

electricity resources to fight poverty and pursue the SDGs?

Developing electricity infrastructures that aim to build productive capacities in the sectors contributing the most to the national GDP and employing most Mozambican population

In our case, addressing the factors limiting the uptake and development of productive use of electricity in the performance of MSMEs for generating sustainable livelihoods by developing electricity infrastructures that aim to build productive capacities in the sectors contributing the most to the national GDP and employ most Mozambican population could be a way to activate structural changes in the economy that would lead to diversification of the production system and its development away from subsistence agriculture. However, the long distances separating the semi-urban areas from rural areas, the relatively low population density, low purchasing power, low electricity consumption, and the weak development of the almost non-existent enterprise sector in rural areas make the expansion costs of the electricity network to these areas prohibitive.

In this scope, off-grid solutions, especially from renewable sources (e.g., solar-PV systems), could generate environmental benefits towards the pursuit of Sustainable development goals while allowing the development of rural non-agricultural activities and, therefore, the diversification of the economy.

For this purpose, the Mozambican Government has designed the Energy For All project to be funded by the Ministry of Mineral Resources and Energy (MIREME) and the Ministry of Economy and Finance with Banco Mundial Group founding, Implemented by EDM and Fundo Nacional de Energia (FUNAE-National Energy Found) in which the government recognizes the importance of productive uses of electricity for income and sustainable livelihoods generation (FUNAE & EDM, 2019).

In this context, many projects (private and public) are developed, focusing on improving agricultural, apicultural, and fishery farming sectors to ensure productivity, food security, household income, employment, and social inclusion, such as the Sustenta project (or support project) that benefits 22,600 individuals in Niassa and Zambezia provinces, the ExxonMobil as its social responsibility in Cabo Delgado, JAM (Joint Aid Management) in Inhambane province, Mozland, MozNorte (Northern Mozambique rural resilience project), and the Governmental Program for Sustainable Rural economy giving support to 431,500 households in the central and northern regions of the country.

All these projects act in coordination with the Ministry of Agriculture and Rural Development (MADER), Ministry of Land and Environment (MTA), Ministry of Sea, Inland Waters and Fisheries (MIMAIP), and the National Fund for Sustainable Development (FNDS) without involving the MIREME which means that the efforts to develop a sustainable agricultural do not involve access to electricity.

Therefore, although it is recognized the importance of giving support to productive uses of electricity initiatives in the generation of sustainable livelihoods, the projects developed are short-term projects, scattered and concentrated in the same geographical area (central and northern regions) without apparent coordination among them so some overlap in their actuation and objectives.

Removing the access and affordability gap for electrical equipment

Off-grid solutions prove to be economically more effective when coupled with programs that support financing for farmers and micro enterprises in other areas (financing packages) for the acquisition of irrigation systems (to reduce the seasonality of production and employment in the agricultural sector in the country), agro-processing systems, and refrigeration systems (to avoid the deterioration of the perishable goods and allow the negotiation of better prices) (Arora, 2015; Borgstein et al., 2020; UOMA, 2019).

Since rural and remote areas are characterized by less developed infrastructures, less developed public services and business linkages, lack of access to markets and most rural entrepreneurs do not have financial resources to pay for the electrical equipment (e.g. mills, grinders, fridges, and water pumps) the financing packages should include a clear policy of subsidies for equipment purchasing as well as agreements with companies that can provide high-quality equipment.

In most cases, banking finance is a solution for entrepreneurs that can provide collateral, a requirement that most rural smallholders may not be able to meet, so an effective way to ensure that this part of entrepreneurs gets funding for their business is to make concessional funding and grants funding available.

In this context, the above-mentioned projects help small farmers to purchase seed and agricultural inputs through a line of credit at interest rates ranging from 0 % to 5 %, however, except for Exxonmobil, the other projects do not support the development of climate-neutral agriculture, which means that in years when the climate is not favourable to agriculture, farmers are unable to ensure their own food, much less to repay the credit contracted for the purchase of seeds and agricultural inputs even with the low-interest rates. This also, means that the seasonality of agricultural production is still an issue of concern in the country.

Electricity projects should influence the creation of sustainable livelihoods in other informal activities such as agro-processing, refrigeration systems, and retail as one of the main sources of employment for the youth (Colombo et al., 2018) that might complement agricultural productivity in the creation of sustainable livelihoods. In this context, a credit line was opened to support the youth's local initiatives, however, the line was closed due to a lack of payments, which brings up issues of training and building management skills to the young people engaged in the process of creating sustainable livelihoods.

Therefore, in addition to access to finance, more help may be needed in building entrepreneurial behavioural/personal initiative, confidence to take action on productive uses of electricity and management skills. A study made in West Africa (Campos et al., 2017) found that personal initiative training increased firm profits by 30 % and statistically nonsignificant impact of traditional training on firm's profits, suggesting that psychology-based personal training initiatives focused on entrepreneurial behaviour is more effective than those focusing on traditional training.

Ensuring market linkages and building demand

Rural areas are very isolated from main markets and main roads, so smallholder farmers face challenges in getting their products to markets, a factor that along with the need for money to buy other goods and services for the households' needs (e.g. transport means such as a motorcycle), they end up selling their products locally right after harvest at un-competitiveness prices (Bachke, 2019; Mango et al., 2018).

Projects such as Sutenta create a market by being a buyer of the products produced by the farmers covered by the project, however, in this case, the producers act as price takers and therefore, without power to negotiate better prices. While this measure has its disadvantages in the negotiation of prices, it helps the farmers to eliminate the transportation costs from the production site to markets on deplorable roads and overcrowded transports.

Encouraging the organization of smallholders in associations can be an easy way to enhance production, productivity, and revenues, improve access to markets and finance, and promote the negotiation of more competitive prices (Bachke, 2019). However, all this requires that investment in road infrastructures and transport is made to allow the easy flow of goods from the production sites to the main markets, which may contribute to the reduction of transportation costs and stimulate the productivity of the economy (World Bank Group, 2021).

Affordability of electricity supply

The affordability of electricity supply is a double-edged sword in the country. The Mozambican Government regulates the electricity tariffs (ALER, 2017; UNDP & UNCDF, 2020), most recently the government approved a policy that standardizes on-grid and off-grid electricity tariffs (UNDP & UNCDF, 2020). As a strategy to fight poverty, the electricity tariffs are set below the production costs, however, while the tariffs are not cost-reflective, they are above the payment capacity of most households, therefore, building financial capacity through activities that contribute to the generation of sustainable livelihoods can improve the population purchasing power, and increase electricity consumption while insuring the financial viability of electricity supply in the country.

Therefore, creating packages of electricity supply for productive purposes through subsidized tariffs would ease the burden of electricity bills for these companies, which would contribute to leveraging the micro-enterprises and increasing the demand for electricity on the other side.

However, it is necessary to coordinate and integrate efforts between the different actors (public and private) with the Ministry of Mineral Resources and Energy, so that energy policies are linked to the efforts of improving production, productivity, job creation and therefore sustainable livelihoods. This would also encourage the practice of climate-neutral agriculture through irrigation systems to eliminate (even if not totally) the seasonality of agricultural production.

Building electricity reliability

Mozambique ranks 114th out of 137 countries in terms of the quality of grid-supplied electricity (UNDP & UNCDF, 2020) therefore, the future of energy should address the factors affecting electricity reliability in the country, incorporating grid resilience to natural disasters as an essential item for electricity security and reliability as well as investing in a backup electricity supply system and including a facility management program with mechanisms for regular maintenance and effective fault repair. Promoting predictable and transparent management to encourage the participation of private investment in the electricity sector and generate competitiveness that would contribute to a reliable electricity supply in the country.

Mozambican government recognizes the challenge of electricity unreliability in the country, so, with the World Bank's help it developed the five-year Power Efficiency and Reliability Improvement Project (PERIP) that ran from 2018 to 2022 (World Bank, 2018a, 2018b). The project allowed the country to start elaborating on the reliability indexes seen in the Electricity reliability in Mozambique section.

However, it was a short-term project for a vast territory such as the Mozambican, therefore, it ended before creating a resilient electricity infrastructure in the country, thus, electricity outages still are a reality in the country. The project also did not solve the deficit of electricity supply that has been creating voltage dips, flickers, and load shedding in the northern region of the country (UNDP & UNCDF, 2020). Through the Energy For All project, EDM intends to outsource network operation and maintenance to qualified private providers so that service quality meets applicable standards.

This shows the need for long-term policies and long-term projects that would help the country build resilient infrastructures and activate structural changes in the production system so that sustainable development is achieved at social, and economic levels.

Electricity projects for entrepreneurship should be gender and socially inclusive

Not least of all, electricity projects for entrepreneurship should be gender and socially inclusive (Osunmuyiwa & Ahlborg, 2022), i.e., electricity projects must be inclusive to avoid the existing socioeconomic and power imbalance perpetuating gender-based social inequalities and affecting entrepreneurial outcomes in rural areas.

Mozambique is a country where social norms are important determinants of labour and resource allocation (Arora & Rada, 2017), where in addition to domestic tasks, women are also relegated to the task of producing food and therefore, there is a feminization of smallholder farming and poverty (Porsani et al., 2019), i.e., 66 % of the 87.8 % active population working in agriculture and forestry sector are women (INE, 2019). Female-headed households have a relatively high probability of being poor (Salvucci & Tarp, 2021).

Therefore, gender and socially-inclusive electricity projects can help the country to act directly in the focus of the problem, ensuring that electrification projects target those (the face of poverty) affected by multiple deprivation and poverty and include them in the income generation process and livelihood generation.

As seen above, it is not enough to provide electricity access to the poor and expect living standards to improve automatically without addressing the factors limiting the income generation process. Addressing the barriers to income generation activities requires that electrification projects also cover the human component of the issue, and promoting access to electricity to meet the producers' needs can contribute to accelerating production, productivity, and the generation of sustainable livelihoods which requires joint efforts between the public and private sectors of the economy as well as long-run policies that might build resilient infrastructures and activate structural changes in the country's production system.

Conclusion

Although Mozambique has abundant energy resources and strives to increase access to electricity as a strategy to fight poverty, the country faces a double challenge, the lack of access to electricity and, for those who have access, the lack of reliability and unaffordability of electricity supply, therefore, in this work, we accessed the impact of electricity unreliability and electricity expenses in the generation of sustainable livelihoods in the country.

Analyzing electricity outages in the central and northern regions of the country from 2014 to 2018, we found that most electricity outages occur during the normal working period hours from 08:00 a.m. to 03:00 p.m., which may negatively influence the country's production and productive uses of electricity by micro, small and medium enterprises, often without means to finance backup electricity systems.

Additionally, having in mind the important role that electricity plays in the country's economic and political agenda as a strategy for poverty alleviation towards the pursuit of the SDGs and the challenges of access to electricity and reliability of electricity supply in the country, we survived the perception of electricity reliability by 219 MSMEs in the provincial capitals of the central and northern regions of the country, and a nonparametric model was estimated through the Wild Bootstrap econometric methodology to access the empirical impact of electricity unreliability and electricity expenses (electricity affordability) in the process of generation of sustainable livelihoods measured by the enterprises' revenues.

The survey showed that electricity is used productively in the regions under analysis. The model estimation disclosed that the average revenues of enterprises using electricity in their production process are higher than those that do not use electricity for production purposes, a positive and statistically significant impact, which suggests that if electricity is used productively, it contributes to income generation through increased production and revenues. However, the electricity bills and unreliability of the electricity used in the production process are counter-productive, having negative and statistically significant impacts.

Notwithstanding electricity unreliability and affordability acting as counter-productive, electricity access might generate the expected positive impacts on sustainable livelihoods if the productive uses of electricity are linked to other factors such as access to public infrastructures (markets and roads) and access to finance.

However, although the model estimation has proven the expected impacts of access to markets and access to finance in the enterprises' revenues, access to finance is statistically non-significant, and it was not possible to test the effect of access to roads infrastructures in the enterprises' revenues, which might be subject for future studies.

Providing electricity access to the poorer expecting the living standards to improve automatically without addressing the factors limiting the income generation process (such as reliability, affordability, access to markets, access to finance, individual entrepreneurial skills, and gender inequalities) will not help the country to harness its potential in energy resources to fight poverty.

Addressing the barriers to income generation activities requires that electrification projects also cover the human component of the issue, which in turn requires joined efforts between public and private sectors of the economy with coordinated and integrated approaches to unlock the potential of access to electricity in generating sustainable livelihoods and sustainable development, as well as long-run policies that might build resilient infrastructures and activate structural changes in the country's production system towards increased production, job creation, and generation of sustainable livelihoods.

Declaration of competing interest

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

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.esd.2023.101330.

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